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Synchronizing EEG, User-Triggered Events and Audio-Visual-Tactile Stimuli for Interactive Event-Related Potentials Experiments

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ABSTRACT: The Electroencephalography (EEG) is a technique for brain imaging and analysis very accurate in time. However, no commercial software is available to warrant synchronization between stimuli and the EEG registry. This problem is worse when prototypes are involved. In this letter, it is presented a system to perform complex EEG, behaviour and multi-sensorial stimuli experiments under laboratory conditions. The system is described and the results regarding registered data and error measurements are provided.
It has been concluded that the brain has different reaction time speed regarding on the type of stimulus (visual, audio or touch). This has to be taken into consideration while stimulating the brain, as a correct synchronization between the issued stimulus and the time in which the brain would have perceived it is essential to guarantee a correct experience. Thus, and added to the inexistence of any system for this issue, a system has been developed and implemented, whose results, demonstrates that the system is valid for accurate measures of the mentioned experiments.

KEYWORDS: EEG, ERP, Synchronization, Stimuli, Tactile.

I.INTRODUCTION

Electroencephalography (EEG) is a widely established technique to measure rapid cerebral activity, which has yield to an impressive increase of knowledge of the brain during the last decade [1]. As the signals measured can achieve time resolutions of ms, it is crucial to have a proper synchronization between stimuli, user reactions and the EEG signals records, to accurately detect the Event-Related Potentials (ERPs) [2].
However, there are very few commercial software to perform such tests, and specific software (SW) to trigger complex stimuli (audio, images, video and/or other physical stimuli) is not available at all [3]. In the scientific software market we can find some solutions that cover specific areas of this research field (see [5-7] for some examples), although none providing support for the whole experiment.
Thus, a new SW has been designed along with a hardware (HW) setup to perform accurate (resolution below the ms), behaviour and EEG measurements with complex stimuli.
This manuscript describes both, the SW and the HW setup, and presents the results that demonstrate the proper functioning of the whole system under laboratory conditions.

II.HARDWARE AND SOFTWARE DESCRIPTION

The HW needed is composed of:

- The EEG register computer: a general purpose computer connected via USB to the EEG amplifier focused on the EEG signals recording and further analysis.
- The stimuli manager computer: another general purpose computer which launches the stimuli. This computer is connected to the screen that presents the visual stimuli to the participant, to a couple of speakers for the

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auditory stimuli, via USB with a button pushed by the participant when needed, via Serial port with the tactile display to produce the tactile and through another Serial port to the EEG amplifier.

- The EEG amplifier: A high-density (128 channel) ATI EEG system (Advantek SRL) with a custom-designed electrode Neuroscan cap.
- The tactile display: Prototype of 28x28 polymer actuators matrix.
- The button: an ATTiny85 microcontroller based button acting as USB keyboard.

The main contribution of this experiment lays on the algorithm and software design and its implementation in a specific commercial HW. As written in previous paragraphs, the synchronization of stimuli, user-triggered events and EEG recordings is mandatory to get accurate and significant results when performing complex tests with this technique. Moreover, if some prototypes are involved, it becomes impossible to find commercial software to manage the system.

The designed SW is divided in different blocks and independent programs:

- Button: The ATTiny85 microcontroller (embedded in the Digispark board [8]) can be programmed to act as an USB keyboard, so it is a very cheap, light and functional (up to six inputs) digital input device that can be implemented with this hardware. The firmware is available at[1].
- Stimuli manager: Core of the system, this program is written in JAVA and uses a multi-thread implementation to achieve the following tasks:
    - Manage the stimuli files (images, sounds, videos or tactile "images") and the protocol files (which define the experiment, times and stimuli launched).
    - Manage the connections with the tactile display, the EEG amplifier and the USB button.
    - Manage the synchronization of the previous elements when the experiment starts.
    - Generate the appropriate "marks" (sent to the EEG amplifier) whenever an event in the protocol or a user event appears. These marks will appear in the EEG registry to ease the analysis of the data.
- EEG register: A commercial SW from Advantek was used to record both EEG signals and marks generated by the stimuli manager computer.

Figure 1 shows the block diagram of the system described.

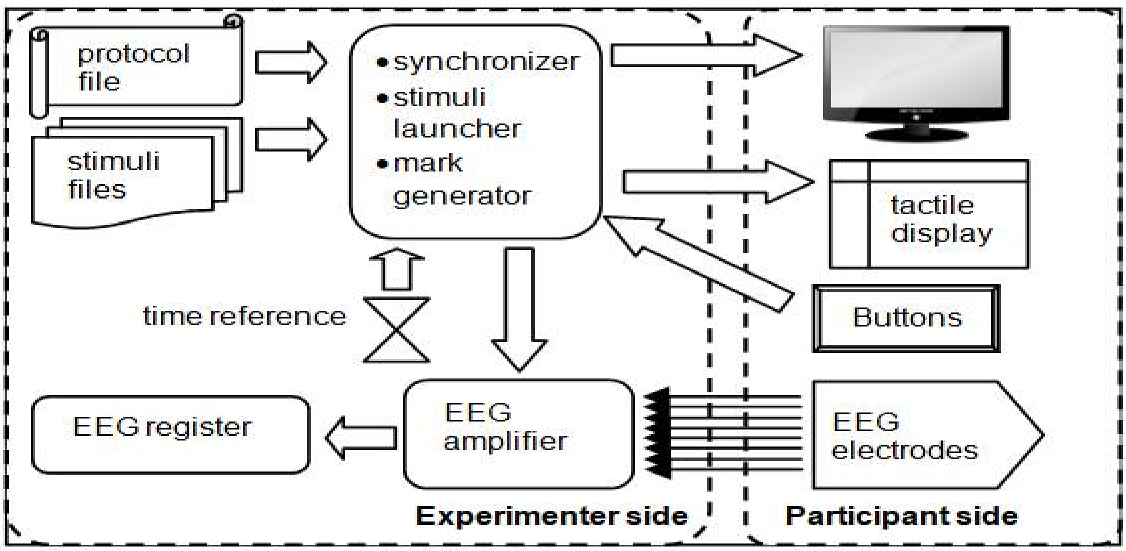

Fig 1 Block diagram of the system.

1 http://www.cesya.es/insubs/baseline/code/keyboard.ino

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III.RESULTS

The stimuli were a random mix of auditory and tactile sparks along with videos. The desired synchronization between marks (produced by the participant or by the stimuli) and EEG waves was achieved. This is shown in figure 2: a capture of the EEG signals with the synchronized marks generated from the protocol or the user's responses.

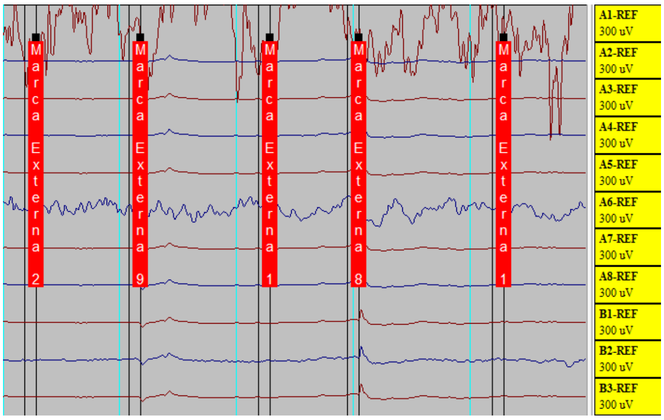

Fig 2 EEG signals and three marks: "Marca Externa 1" and "2" representing stimuli and "8" and "9" two different user responses.

VI.CONCLUSION

Synchronizing EEG signals with stimuli and user-generated events is crucial for proper brain analysis and there is no commercial solution in this field. This proposal solves this situation by providing an integrated multiplatform system generating time-coherent marks (from stimuli and user responses) embedded in the EEG data. This system can be used for, besides visual, audio and touch stimuli, and with the implementation of other sensors, for thermal or pressure stimuli if needed.

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