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# Towards Event-Related Potential Predictions in Short-Term Responses of Physiological Measures

**Fatima Isiaka**
*Department of Computer Science, Nasarawa State University, Keffi, Nigeria.*

**Zainab Adamu**
*Department of Computer , Ahmadu Bello University, Zaria, Nigeria.*

**Sophia Al Sharji**
*Department of Computing, Sheffield Hallam University, United Kingdom.*

**Abstract**

Event-related potential (ERP) is mostly used in electroencephalography (EEG) readings as a neutral response that is associated with certain sensory, and motor events normally called stimulus and cognitive responses. This is often recorded using scalp EEG and notes the average changes in the current-voltage over some time with the initial time as an onset of the stimulus over several event trials. This paper access the phenomenon behind the ERP for brain process and tends to emulate this with the concept of Electrodermal activities (SCR) in synchronous to other physiological processes like pupil dilation (PupilC), skin temperature (SkinT) and Fixation duration (FixD) using four different filters (Savisky Golar filter (SVGfilter), Moving Average filter (MovAFilter), Peak find filter (FindPeak) and Least mean square (LMS)), to predict the short term time frame for the responses. The performance of each filter is compared to determine which best suits the predictions of synchronous events from physiological responses.

**Keywords:** Event-related potential, EEG, Physiological response, Information acquisition, human conditions, Synchronous events

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**Corresponding Author: Fatima Isiaka**
Correspondent Email:
fatima.isiaka@outlook.com



## 1 Introduction

The event-related potential is used to gain information and used to evaluate the brain and other physiological functioning of the human body by looking at how the brain and neurons process information and also to view how this processing affects and differ from other physiological process. ERP can be recorded by evoking stimuli and measured at the scalp with EEG. The events from the brain activities are recorded in response to the discrete and inaccessible events.

The stimulus is presented multiple times and allows the physiological process to be averaged after filtering out low-quality or noisy trials, in this way, the ERP signals are clear and the response event can be detected accurately (Figure 1 ).

## 2 Literature Review

ERP sensory recordings were first performed by [1] by Pauline and Hallowell in the early 1935-36, then by [2] [Walter] and his colleagues, this made a major advancement in the discovery of the first cognitive ERP components, that commenced the modern-day state of the art ERP research. Combined with further advancement and developments in technology and computer graphics, the research in ERP became more well-known. Now, ERPs are known to be one of the most widely utilised methods in cognitive neuroscience and imaging that studies the physiological correlates between the presented stimuli and the data processed from the events generated. One of the applications of this is to identify the similarities and differences in the responses of a normal individual compared to a person with a potentiality for the negative effect of the response.

The question that is most paramount in ERP is how the events are triggered and what triggers the events. The sensory-motor and cognitive stimulus can affect ERP. A lot of cognitive ERP experiments use auditory and visual stimuli. And there have been experiments with its somatosensory and gustatory responses. American Electroencephalographic Society (AES) has provided guidelines for the different stimuli and how their responses can be described in their research [3].

To perform an ERP experiment, the stimuli are typically separated in different ways from each other by a lengthy and variable inter-stimulus interval. This interval is mostly short-term and allows the brain processes to relay a baseline state of response before the next stimulus is presented. One of its important topics is the "OddBall Paradigm", which is most frequent [4, 5, 6, 7, 8]. A subject is shown a train of standard stimuli in the form of an image as a cat interjected with random deviant stimuli like a tree. The participant responds to a deviant target stimulus rather than the frequent standard stimulus since the subject is conscious of the present stimulus and provides a paradigm that contains useful information about the brain processes and probability response.

One of the major characteristics of an ERP is that it consists of a sequence of peaks and waveform configuration that is characterised by amplitude latency and the interval between different peak responses [9, 10, 11, 12, 13, 14]. The time frame between responses provides a measure of the brain communication latency and information processing speed. The constant waves and peaks of the ERP are termed to be different in neuronal processes [15, 16, 17, 18, 19]. In most studies, they are differentiated from each other by labels with letters indicating positive and negative potential effects from the waveforms [20, 21], which are followed by numbers for grouped strategic latencies in milliseconds. The ERP are more informative and is widely used in the user interface face design and cognitive level analysis for descriptive ergonomic provision in different research areas. The concept is simple and can be applied in other similar physiological response experiments. The novel approach applied here is to use the concept to analyse and predict ERP in other synchronous physiological responses as a contribution to the brain-computer interface and cognitive processes [22, 23]. The peaks and amplitudes are treated with different descriptive parameters that represent the labels used in analysing ERP in brain processes.

## 2.1 The Skin Conductance Response

The Skin conductance response (SCR) [24, 25] a.k.a. Electrodermal activity $E_a$ is the reaction to changes in the skin as a result of sweat, usually when a person is involved with a certain activity that requires some cognitive load and human perception. The reaction is modelled in Equation 1, a, c, and b are external and constant reactions to outer events like a distraction.

$$Y = \int \int_{1=1}^{n} a\frac{d^2E_a}{dy^2} + b\frac{dE_a}{dy} + c. \tag{1}$$

$Y$ is the result response as viewed from data visualisation in synchronous to other responses. Each peak and amplitude represent a significant response to stimuli from stimulus onset (latency), a time delay between the rise of stimulus reaction to a peak point in amplitude with an adaptive similar concept from ERP.

## 2.2 The Skin Temperature (ST)

The skin temperature[26, 27] is the hotness or coldness of the skin, and this is equivalent to the heat in SCR. Most physiological measuring tools use SCR electrodes and measure the ST which is derived from its response readings as the amount generated in the body during a visual activity like a reactant stimulus.

$$R = \int \int_{1=1}^{n} a\frac{d^2ST}{dy^2} + b\frac{dST}{dy} + c. \tag{2}$$

The reaction $R$ is measured in a similar conception to the SCR, the difference is that it maintains a constant measure of normality in a person.

## 2.3 Pupil Changes

The Pupil changes [29, 29, 30] are the measure of the reactions in pupil diameter, and this relatively old method for inferring different types of activity in the brain processes. The pupil changes can be subjected to both dilation and constriction depending on what the person is reacting to. It is mostly an automatic nervous response that provides indices of attention, emotion, or interest that correlate to mental and cognitive processes. It not only tells of changes in light intensity but also the response to subtle and underlying mental workload. It can be described as:

$$\frac{dP_d}{dy} = 2\int_{i=1}^{n} \frac{dP_d}{dy} + c. \tag{3}$$

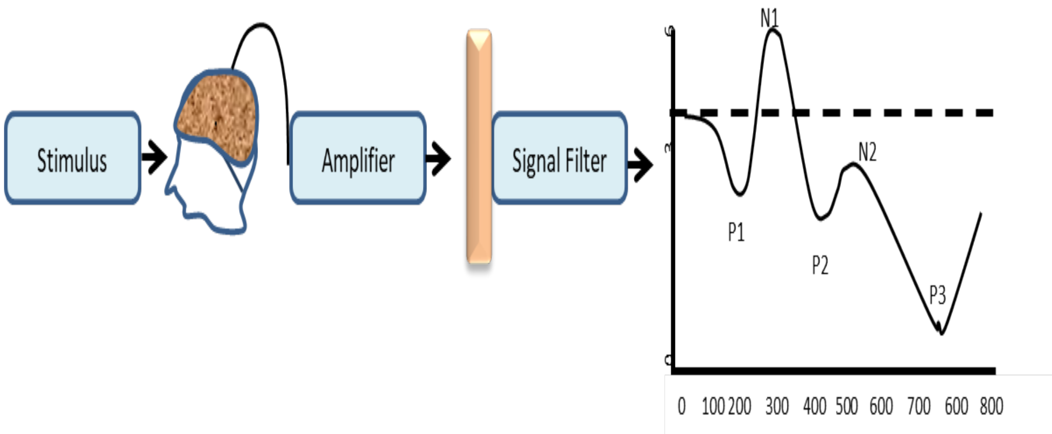



Figure 1: Model for Event related mapping in EEG.

Where $P_d$ is the Pupil dilation and Pc is the constriction which is twice the amount of constriction in intense visual concentration.

The initial physiological readings are usually noisy and computational filters are often used to analyse and produce clear peaks. One of these filters is the Savitsky Golay filter (SVGfilter) which is defined by:

$$Y_j = \sum_{i=\frac{1-m}{2}}^{\frac{m-1}{2}} C_i Y_{j+1}, \frac{m+1}{2} \leq j \leq n - \frac{m-1}{2}. \qquad (4)$$

Where each signal marker is data consisting of a set of points $(x_j, y_j), j = 1, .., n$, where $x_j$ is an independent variable and $y_j$ is an observed value treated with a set of $m$ convolutional coefficients $C_j$. The filter is also used to predict the ERP events and correlates to order physiological response. The resultant response is used to compare with other standard techniques such as the Moving Average filter (MovAveFilter), Find-Peak function, and the Least mean square (LMS) measure. The following section discusses the method used and the results obtained for the comparisons of these filters.

## 3 Methods

To measure ERP responses, data needs to be generated; this data should be concessive with a high cognitive workload that requires reactions from a complex visual stimulus with dynamic contents. The webpage interface was used in this case, with uneven aesthetics and complex design controls where users will have to be very attentive to be able to locate a desired user interphase icon. Two groups of participants were selected from mixed gender, where the data generated can serve as a test and training set. Each group consists of fifty and seventy participants. Each set is simulated to a hundred and fifty instances. The participants (Figure 2 ) sit in front of a visual stimulus in form of a complex business product webpage with both hands placed on a wireless touchpad that records the SCR and ST. The pupil changes are recorded from the PC with an embedded webcam and modules that record their eye movement.

The data generated is sent to another laptop for data analysis and synchronisation. Comparison of the filters to other standard techniques depends on the time interval for each short-term interval (fifteen seconds) using a minimum distance of five seconds. The parameters used in labeling the peak and baseline response are based on the randomisation of the data sequences, for example, temperature and fixation duration have a larger number of inputs than the response of the response signal and they are measured as:

$$ST = \frac{ST_{original}}{N}. \qquad (5)$$

$$FixD = \frac{FixD_{original}}{M}. \qquad (6)$$

Where $N$ and $M$ represent the minimum entries for both skin temperature and fixation duration in each short-term interval.

## 4 Results

Figure 3 shows the raw physiological response from the two groups of participants, and Figure 3b shows more active events than the first even if both groups used the same visual stimulus. The event process can be difficult to detect in this process and hence a short-term interval of fifteen seconds was filtered out for both groups. Noisy data could seem spurious but very useful in terms of human behaviour processes. In such a case outliers are very significant to compare with original data for detecting significant differences. Sometimes, the short-term response can be ambiguous since it takes more than three

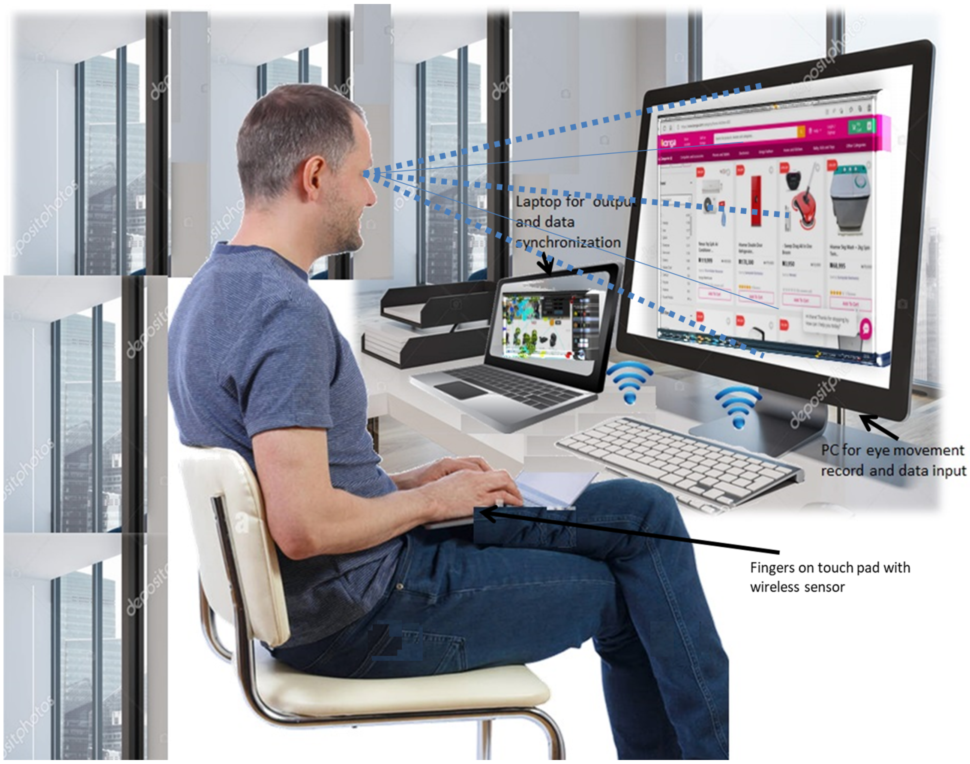
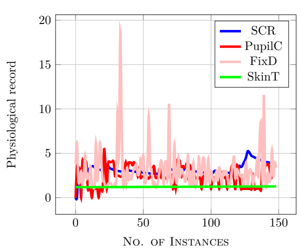
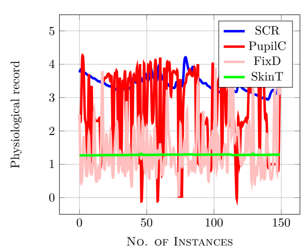



Figure 2: Participants interacting with visual contents with hands-on wireless touchpad sensor for data generation.

seconds to detect any significant response in a person, hence the interval is limited to fifteen seconds for this case.




(a) Raw physiological response from first group




(b) Raw physiological response from second group

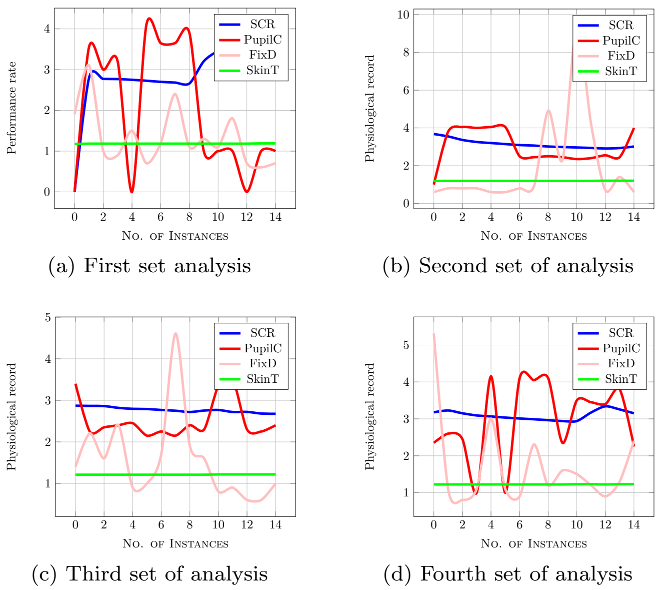
Figure 3: Sychronised physiological response from two groups

From the four different short-term responses used, the Pupil response (PupilC) seems to have more response peaks than SCR and Fixation duration (FixD) and Skin temperature remains at a constant state. Studies have also shown that the pupil constricts and dilates more in visual attention i.e. they are very responsive to visual screen if the stimulus contains complex contents that the brain has to process within a short time interval. A significant synchronous event is recorded for all responses in Figure 4a, within 10 secs of the interaction. This depicts a similar response in Figure 4d.

Different performance rate was compared for the filters used, SVGfilter can predict ERP with a ten-second minimum distance and can still serve as a filter for the smooth response reading. The other filters were used as form additional response measure to level the reliability of the SVGFiler in ERP prediction. Figure 5 shows the different performance rates of all filters for the different training sets. The SVGFilter performs better in all runs and shows the model's capability for detecting ERP events in physiological response.

# 5 Conclusion

This paper attempts to analyse and predict ERP on Physiological responses using the concept from readings in EEG that helps derive information from the experimental setup. In EEG, the information derived can be used to evaluate brain functions by viewing the brain's normal process speed in terms of information acquisition, as well as determining the amount of time it takes to end the process and its difference in neurological human conditions. This paper accesses the phenomenon and tends to emulate this with the concept of Electrodermal activities (SCR) in synchronous to other physiological processes like pupil dilation (PupilC), skin temperature (SkinT), and Fixation duration (FixD) using four different filters (Savisky Golar filter (SVGfilter), Moving Average filter (MovAFilter), Peak find filter (FindPeak) and Least mean square (LMS)), to predict the short term time frame for the responses. The perfor-



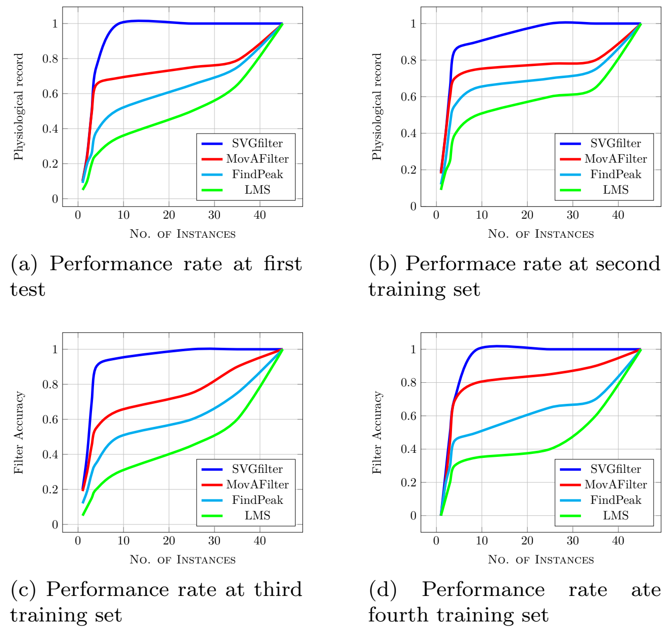

(a) First set analysis

(b) Second set of analysis

(c) Third set of analysis

(d) Fourth set of analysis

Figure 4: Short terms responses for different sets at fiften seconds interval




(a) Performance rate at first test

(b) Performace rate at second training set

(c) Performance rate at third training set

(d) Performance rate ate fourth training set

Figure 5: Different performance rate of training and test set of data

mance of each filter is compared to determine which best suits the predictions of synchronous events from physiological responses. The future perceptive of the research would be to conduct a pilot EEG reading and compare it with synchronous Electromal activity to determine the difference for both event-related potentials by comparing the physical parameters in response to multifaceted visual stimuli

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