

# Cognitive Response Classification From Physiological Recordings Based on Data Segregation

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## Abstract

The cognitive response is a range of mental processes relating to the acquisition, manipulation, storage, and retrieval of information. It helps to underpin a lot of daily life activities both health, age span, and diseases. The main ability to test and monitor cognitive performance across the lifespan opens up the chance for both patients and users to be identified and access certain treatments faster and stay healthy and also increase cognitive perception by helping to optimise a given process. The paper addresses concepts in cognitive response by data marginalisation using aggregate residuals of the user to understand their cognitive response based on five main classes of user cognition to solve a particular problem. Forty participants were recruited to test the level of cognition on a complex mathematical problem, they were asked to solve these problems using the shortest means to arrive at the solution. The result shows that the complex mood is usually related to these forms of problem while the user is relaxed and complexity in a problem doesn't necessarily mean a high optimal response at peak level but rather a decrease in amplitude of the person's response to task performance..

**Keywords** : Cognitive response, Complex mathematical problem, Peak response, Residual output, Cognitive analytics, Task performance

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## 1 Introduction

The basics of user cognition indicate that the mental action or process of acquiring knowledge and understanding is through the thought process, experience, and the senses. The Cambridge concept of cognition is the mental processes relating to the input and storage of information and how this information is used to guide user behaviour. In essence, it is the ability to perceive certain reactions and processes and also retrieve information by decision-making and producing appropriate responses The Cambridge cognition concept refers to the mental processes relating to the input and storage of information and how that information is then used to guide your behaviour.

It is in essence, the ability to perceive react, and process information that helps with cognitive functioning which is critical to everyday life and governs actions and thought, this is needed to distill all the information to its essentials. Cognitive and the data attributed to cognitive processes can be accessed in many ways through cognitive and behaviour analytics. Recent research on cognition shows that the cognitive process has a physical basis concerning the brain process with over a hundred million nerves in sensory organs [Adam [1], Baars and Gage [3], Berthoz [5], Hugdahl [12], John and Schwartz [16], Mesulam [18], Mountcastle [20], O'Shea [21], Swanson [25], Tucker [26]]. Each of these cells can possess up to twenty thousand connections with different other nerve cells called the neurons [Shepard and Podgorny [23], Turk and Salovey [27], Van Gog et al. [28], Wang and Chiew [29]].

## 2 Literature Review

This is where physiological processes can be monitored. To understand the sensory organs, we rely on simplified scientific models that have been developed based on other groups of mammals. The fundamentals in cognitions control the thought and behaviour processes which are regulated by discrete sensory circuits which are underpinned by several motor control dynamics [Anson et al. [2], Garratt et al. [9], Grillner and El Manira [11], Makino et al. [17], St Clair Gibson et al. [24]]. There are also a lot of sensory cells that play a great role in regulating the cognitive processes including serotonin. These are measured with biometric tools and applications to understand the cognitive processes of the body and brain to make clear certain aspects as to what governs and drives certain behaviour patterns. The distinct cognitive functions arise from the process of subconscious awareness [Barua [4], Borsook et al. [6], Imam and Akhouri [13], Iseli [14, 15]].

Research [Adam [1], Mountcastle [20]], has shown that cognition is not a unitary concept and different cognitive functions and domains are responsible for the regulation of certain behaviour or actions that are identified in a person. These functions are both convoluted and unconscious and also operate synergistically by making it a challenge to measure distinct cognitive processes. Other testing models such as CANTAB can be able to different cognitive functions that have been known to be dependent on different neural integrated phases, the phases are correlated with the physiological response that is used to interpret the motor controls [Coles [7], Collet et al. [8], Goodlich et al. [10], Miall and Wolpert [19], Reis et al. [22], Winter [30]].

The work in this paper describes a method based on the application of Electrodermal activity (EDA), Skin temperature (ST), Pupillary response, and Baseline of users to generate data from an experimental setup that involves selected participants. The residuals from their physiological response data based on the motor control dynamics are used to determine the class of cognitive response. The proceeding sections discuss some of the results and procedures in data collection.

## 3 Method

The initial stage of the study started by conducting an experiment that involved Fifty participants (thirty males and twenty females) who were asked to sit in front of an eye tracker used to collect eye movement and EDA and ST sensor pad used to collect their physiological response data (Figure 1). The task they were given was to place their first two fingers on the sensor pad while they solve some complex mathematical problem which is set to induce some predetermined cognitive response from the participants. The basic class of responses is grouped as

“Complex”, “Stress”, “Relaxed”, “Average” and “Neutral”. The average response is placed at a constant state between “Neutral” and “Complex” moods depending on the response correlates detected from the physiological readings, each of these moods is used to automatically annotate the physiological response, and the main aim is to identify response peak and what occurs at a given point and to give a definition to optimal response correlates to the different cognitive response. The data generated was simulated to increase the number of instances and serve as an input for classified outlier detection. Figure 2 shows the categorical data set on the different cognitive states based on supervised learning. This part of data analysis is done to understand the nature of the data and physiological correlates to perception.

The figure shows that all cognitive states from the data generated are clustered and would require a dynamic motor control to predict the correlates to the physiological readings. The clustering effects show the similarity among the cognitive states and user attributes, the data points are closely related and can be structured and analysed to understand the nature of the data and correlates, such mapped the right instances to the exact optimal point. A good inference engine can be used to understand the pattern of the data and be able to detect and predict the response that correlates to each peak and spike observed in the physiological readings.

## 4 Result

The motor control dynamics used to predict the cognitive correlates to the spikes used a third-order state-space model, that sets the response parameters as input and the resultant variables and the residual output for both testing and training data. The vector matrix is mapped to each class group and determines the correlates of each physiological response. The initial response readings appear noisy due to environmental factors (Figure 3) and the moving average filter is applied for a smooth and aggregate response detected for each phase. Figure 3b shows the resultant response readings for a particular participant. The baseline in the dashed cyan color is used to determine the response peaks and map the cognitive response to the spikes while the user is involved with the given tasks.

For this result, there were different optimal responses detected for a 60 seconds time interval, each correlating to a different cognitive response. Normally, an increase in physiological reading signifies a high point of awareness or arousal, but the above Figure 4b shows a “Relaxed” mood detected for a high amplitude. These are reflected as based on a computational model and could only be termed feasible when compared to other standard models. The baseline also signifies that the cognitive response is at the optimal stage since it is greater than the baseline level and therefore it is deemed authentic.

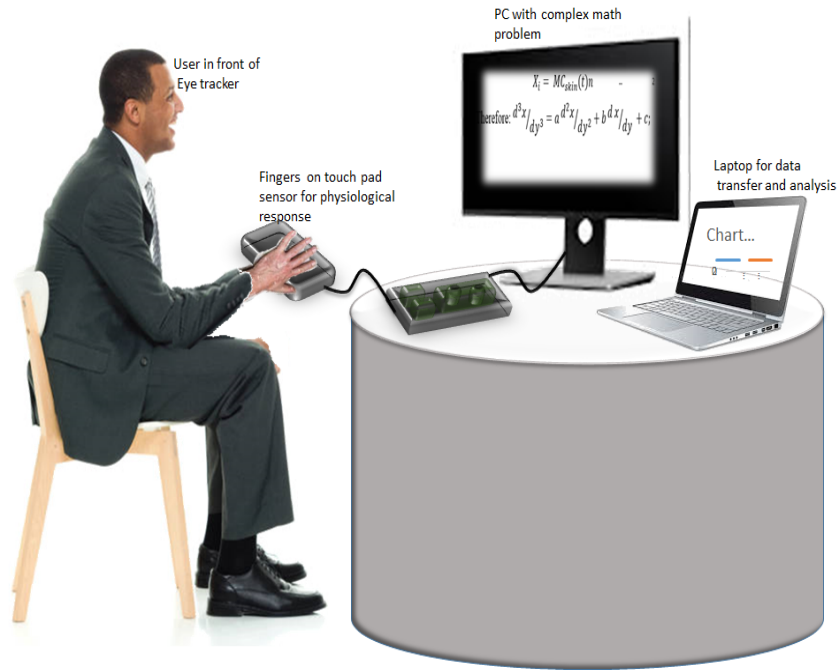


FIGURE 1 – User sitting in front of eye tracker with task allocated index page.

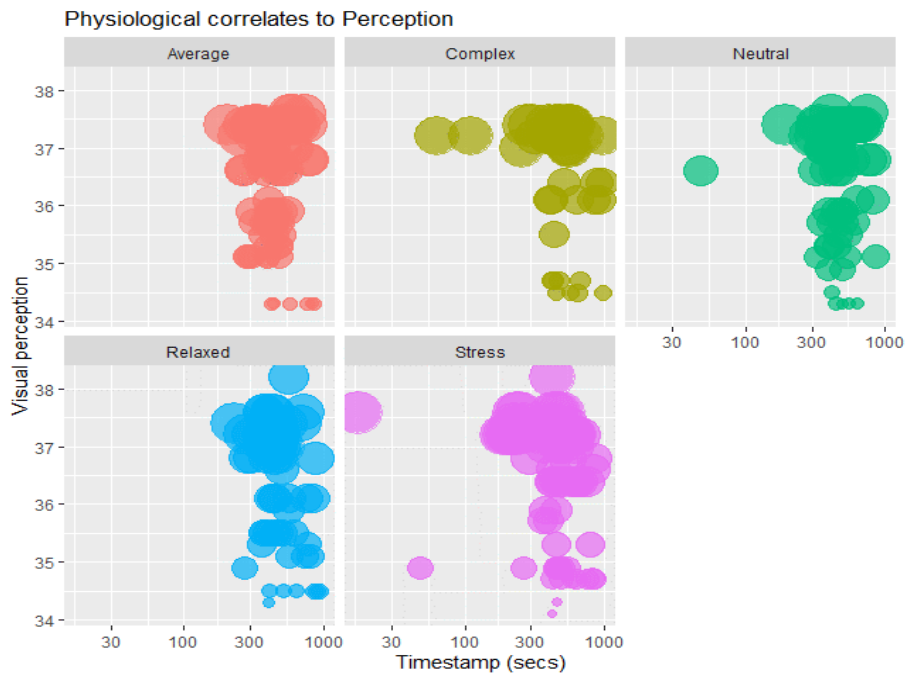
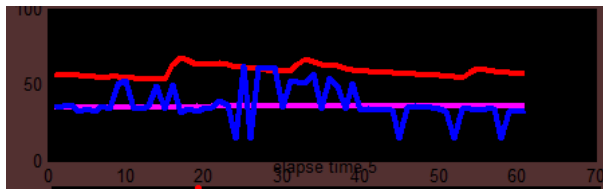


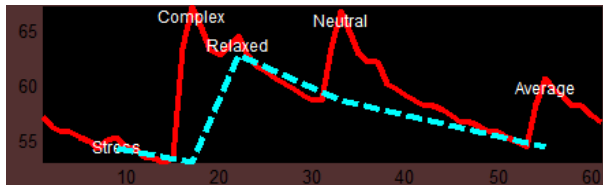
FIGURE 2 – Classified cognitive state of users to different cognitive data and state spatial distinct attributes.

Figure ?? shows another noisy response reading, that indicates low peaks and low skin conductance level, this doesn't mean that no response is detected, the correlates show a stress point detected for that coordinate which is different from the cognitive response related to a complex mood at a point greater than the baseline estimate. There is a significant correlation between the complex

task at an optimal level and stress cognitive response (Figure ??). The amplitude of the positive peak declined to about 50% to half recovery time with a repetitive stimulation from the task. The time constant for this declined adaptively to a concentrated level and was dependent on variation to 30 – 60 secs time interval as the task gets more reduced in concentration.

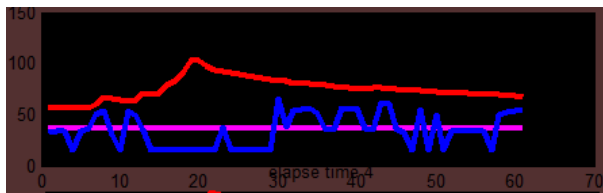


(a) Noisy physiological response data at initial stage of the experiment

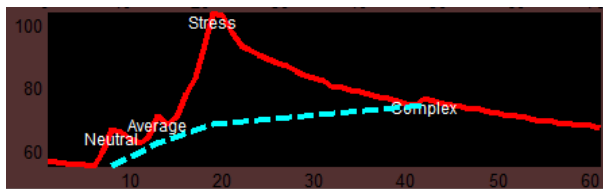


(b) Smooth EDA response data after applying moving average filter

FIGURE 3 – The noisy and smooth version of the physiological reading of a participant measured with time



(a) Participant's noisy physiological response data in synchrony with other physiological response.



(b) The participant's smooth response reading correlates to cognitive states

FIGURE 4 – The noisy and smooth physiological response of a participant's reaction to task performance.

The error in detection rate was computed for both inner EDA and outer EDA at the lens point, Figure 6 shows the Error in EDA measure was conducted for both inner and outer EDA signal on the lens, and Figure 5 shows the aggregate of error in measurement to the EDA data, the main and standard (SD) of the contact area under the finger are higher at start point while the fingers were placed on the lens, and this seems to be performed under stress versus the relaxed mood (mean area :  $p = 0.029$ , effect size = 0.75; SD area :  $P = 0.12$ , effect size = 0.56). The result shows that a little touch contact on the lens can also be used to detect binary levels of EDA i.e. for skin with a lack of conductivity and low moisture content.

Figure 6 also shows the EDA for an outer signal on the lens and the mean and SD of the contact area for ou-

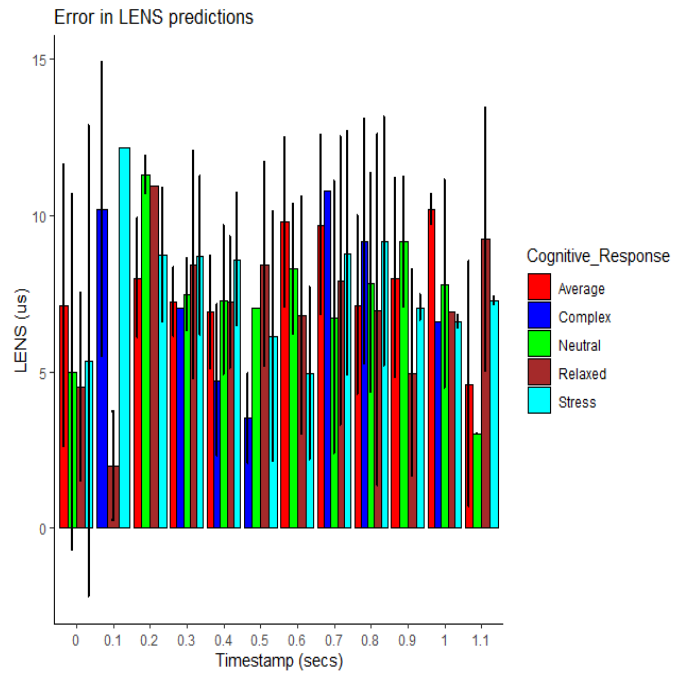


FIGURE 5 – Error in standard deviation (SD) detected for inner EDA at lens point.

ter EDA from finger-tip contact to the lens are higher at the initial touchpoint as was performed under stress and relaxed mood similar to the result above which is (mean area :  $p = 0.018$ , effect size= 0.88; SD area :  $P = 0.04$ , effect size = 0.68). The results show that subtle motion on the touchpad can also be used to detect logical levels of stress mood whether it is present or not present at all. The results that the negatively toned cognitive response related to relaxing mood provoked increases in EDA response and also declines for the other physiological response. The physiological outcomes depend on the particular task complexity and personality and user perception.

## 5 Conclusion

This paper demonstrated cognitive response data marginalisation based on aggregate residuals, the main ability to test and monitor cognitive performance across different stages in a complex task opens up the chance for users to be identified and access certain cognitive processes that also increase cognitive perception by helping to optimise the given process. The paper addresses in concept of cognitive response by data marginalisation using aggregate residuals of the user to understand their cognitive response based on five main classes of user cognition to solve a particular problem. The Forty participants recruited were tested on the level of cognition they put in the complex mathematical problem, they were asked to solve these problems using the shortest means to

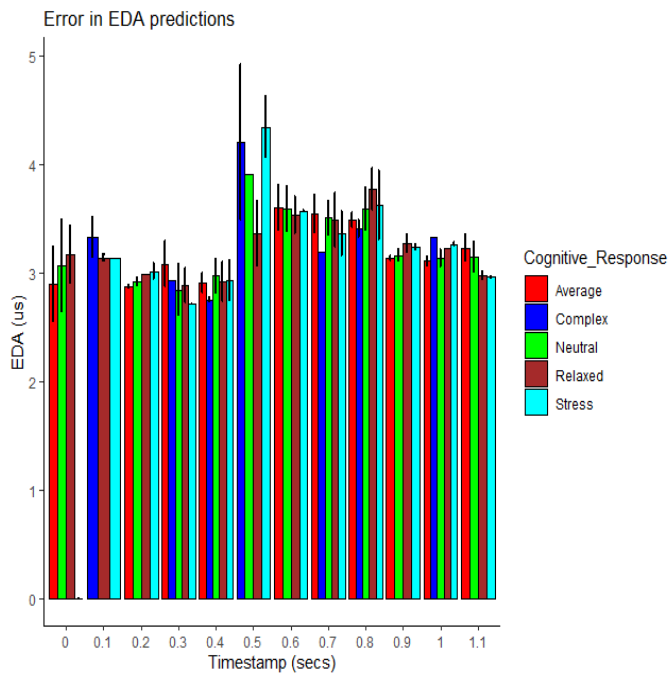


FIGURE 6 – Aggregate Error in performance of cognitive response to task for outer EDA..

arrive at the solution. The result shows that the complex mood is usually related to these forms of problem while the user is relaxed and complexity in a problem doesn't necessarily mean a high optimal response at peak level but rather a decrease in amplitude of the person's response to task performance. These findings also give room to the future perspective where standard methods like AI and AI analytics will be used to determine correlates in real-time, this would save computational speed and variations in user behaviour data.

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