An EEG Based Novel Approach for Understanding the Processing Bias of Different Colour Temperatures in Human Brain During Professional Chess Playing (An Indoor Game with Cognitive Load)

A THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF

THE REQUIREMENT FOR A DEGREE OF

MASTER OF ENGINEERING

IN

ILLUMINATION ENGINEERING

SUBMITTED BY

RONI JANA

EXAMINATION ROLL NO:- M4ILN24002

REGISTRATION NO:- 163495 of 2022-23

UNDER THE SUPERVISION OF

Dr. SUDDHASATWA CHAKRABORTY

Associate Professor, Jadavpur University

ELECTRICAL ENGINEERING DEPARTMENT

JADAVPUR UNIVERSITY

KOLKATA- 700032

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FACULTY OF ENGINEERING AND TECHNOLOGY

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RECOMMENDATION CERTIFICATE

This is to verify that the thesis entitled **"An EEG based novel approach for understanding the processing bias of different colour temperatures in human brain during professional chess playing (An indoor game with cognitive load)**" submitted by **RONI JANA**, (Examination Roll No. **M4ILN24002**, Registration No. **163495 of 2022-23**) of this University in partial fulfilment of requirements for the award of the degree of Master of Engineering in Illumination Engineering, Department of Electrical Engineering, is a bonafide record of the work carried out by him under my guidance and supervision.

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CERTIFICATE OF APPROVAL

This foregoing thesis is hereby approved as a creditable study in the area of Illumination Engineering, carried out and presented by **RONI JANA**, in a manner of satisfactory warrant its acceptance as a pre-requisite to the degree for which it has been submitted. It is notified to understood that by this approval, the undersigned does not necessarily endorse or approved the thesis only for the purpose for which it has been submitted.

FINAL EXAMINATION FOR EVALUATION OF THESIS

BOARD OF EXAMINERS

……………………………………………..

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(Signature of Examiners)

JADAVUR UNIVERSITY

DECLARATION OF ORIGINALITY AND COMPLIANCE OF ACADEMIC ETHICS

I hereby declare that this thesis contains a literature survey and original research work by the undersigned candidate, as part of my Master of Engineering in Illumination Engineering studies.

All information in this document has been obtained and presented in accordance with academic rules and ethical conduct.

I also declare that, as required by thesis rules and conduct, I have fully cited and referenced all material and results which are not original to this work.

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EXAMINATION ROLL NO.	**:**	**M4ILN24002**
REGISTRATION NO.	**:**	**163495 of 2022-23**
THESIS TITLE	**:**	**"An EEG based novel approach for understanding the processing bias of different colour temperatures in human brain during professional chess playing (An indoor game with cognitive load)"**

SIGNATURE WITH DATE **:**

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Date:

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CHAPTER- 1

1.1 Abstract:

In the present situation, different studies are being conducted around the world on the effect of lighting conditions in different tasks. Development of modern technologies and integration of them with the lighting parameters produce crucial outcomes for further research and study. Human-centric lighting is now becoming an interesting topic for researchers. Light is not only necessary for vision but also responsible for maintaining circadian rhythm and it also affects individuals' mood, attention and reactions.

Area lighting, road lighting, facade lighting and sports lighting are basically parts of outdoor lighting. Like in every field, lighting also plays a very important role in sports lighting, both in indoor and outdoor sports. Several studies throughout the times suggest that mind games like Sudoku, puzzles, chess, etc., have an effect on individuals' cognitive behaviour.

The aim of this thesis is to investigate the effect of different correlated colour temperatures of a light source on the mood, attention, and reaction time of chess players, and to analyse their brain response through Electroencephalograph (EEG) analysis. Through experimentation, the study aims to examine how these lighting conditions influence cognitive performance, as well as how they affect the decision-making process and concentration required in a chess game. Using both game analysis and EEG analysis, this study creates a link between lighting and cognitive study.

1.2 Introduction:

Presently, sports lighting is a important aspect of lighting world. Different brands produce various types of floodlights with different specifications to fulfil the requirement for sports lighting design. Proper sports lighting design should serve the needs of clear glare free vision for the players, officials, spectators and telecasting cameras. Two different types of sports are there, indoor and outdoor. Based on lighting requirement it can be divided as aerial and ground level sports. Different sports required different lighting standards as per guided and suggested by the CIE and other sports authority boards. NLC 2010 (SP 72:2010) suggests values for different parameters for both televised and non-televised sports events. CIE 083:2019 guides for the lighting of sports events for colour televisions and film systems, also before this CIE published other documents related to sports lighting.

Horizontal illuminance, Vertical illuminance, Uniformity, Glare rating these are the some of the parameters required for proper sports lighting. Horizontal illuminance represents required lux value in the working plane, it can be different for different classes. For example, FIFA suggests average horizontal illuminance >2500 lux and uniformity 0.5 for U1, 0.7 for U2 for standard A matches (World cup matches). FIFA guides different values for various standards of matches. As per NLC 2010 (SP 72:2010), for badminton, tennis games 750 lux, 500 lux and 200-300 lux illuminance is required for class I, II, III matches respectively. Uniformity required 0.7 for both class I and II matches but 0.5 for class III matches. Classes are basically based on national or local events.

This thesis studies effect of different lighting conditions, mainly varies the correlated colour temperature (CCT) of a LED light source on mood, attention and reaction times of chess players and analyse of their brain responses using electroencephalographic (EEG) analysis through EEG lab. Basically CCT define as the temperature of a blackbody radiator whose colour appearance most closely resembles that of the particular light source.

Indoor games like chess, sudoku, puzzle requires sharp memory throughout time to play the games. Previous studies showed that mind games like these had a positive impact on the cognitive part of an individual. Chess is a complex strategic mind game, it requires high level of attention and proper concentration throughout the match time. Previously, Singh S mentioned in his review paper named 'Chess and the human brain- Demystifying the therapeutic value of a board game' that chess activates various brain circuits that leads to the improvement of attention and problem-solving skills. Other studies had also mentioned that chess plays an important role for cognitive purposes. Different schools across the different European countries already added the chess game as a part of school syllabus for the memory development of children. Recently in India, All India Chess Federation (AICF) pointed several initiatives that needs to address in the field of chess in India, like introduction of chess in school curriculum, strengthening grassroot academies throughout the country etc. As per FIDE, lighting should not cast shadows and try to avoid direct sunlight during the game. Lighting of a standard similar to that used for examinations should be about 800 lux.

In recent years, there has been a growing interest in understanding the impact of lighting conditions on human behaviour and cognitive functions. Electroencephalogram (EEG) measures electrical activity of the brain responses using the electrodes attached to the headset. EEG data analysis using EEG lab produces cognitive details of an individual while the person doing a particular task under specified lighting condition.

Next chapters represent the background of this thesis work, design setup for the experimentation, obtained data during experiments and detailed analysis of the data.

Through the detailed analysis of the obtained data this study can have various implications on the topics related to chess, lighting and cognitive study. By detailed insights it will help to create a lighting system or model, which will help in the optimization of human task.

1.3 Aim of the Thesis:

This thesis aims to analyse effects of different lighting conditions, specifically correlated to colour temperature of a LED light source on the mood, attention and reaction time of the chess players and to investigate the electrical activity of their brain using electroencephalogram (EEG) study. In this case, three different CCT's 3000k, 4000k and 5000k has been used for the experiment. Main objectives of the work is to find out,

(i) Through the analysis of EEG data, brain response and its effect on the cognitive behaviour of the chess player obtained.
(ii) Game analysis and performance analysis of the players through an online chess platform under three different CCT's.
(iii) Galvanic skin response (GSR) sensor data analysis.

The findings from this thesis will enhance more opportunity in field of cognitive study and its utilization using mind games like chess, sudoku or puzzle. It will also help to create a CHESS MODEL as a part of cognitive study mechanism.

CHAPTER-2

2.1 Background of the work:

Relation between chess and cognitive study is very old, as chess is a game of concentration and strategies, it can be very useful for scientific studies. Studies related to memory and attention can be examined by the effective use of chess game. Famous Dutch psychologist Adriaan de Groot has conducted many experiments and studies in the field of cognitive science with the help of chess game.

As this thesis is related to chess, brain analysis through EEG and most importantly effect of light, the literature review consists of three different parts. First part discusses about the previous works based on chess and its effect on cognitive study. Second part focuses on studies that relates the chess game and Electroencephalogram. Lastly, previous works based on effect of lighting parameters and conditions on human behaviour and performance.

Without light we can't see, that's true but light is responsible for both visual and non-visual purpose. Previously, different research and studies shows that lighting parameters directly effects task performance. Light has a significant influence on Circadian System, the biological clock. Growth of LED light sources not only helped to fulfil the purpose of proper and economical lighting design but also drives motivation towards more interesting researches. Integration of modern technologies and LED light sources helped in developing more fundamental research topics in the field of lighting. Research topics like lighting parameters and artificial intelligence tools, lights and its relation with neurocognitive parts as well as neuroscience and many more are the fruit of these collaborative developments. The paper, ' Artificial Intelligence : application to lighting products, by Dr. Anand Hindolia and Shakti Lekha, aimed to understand the technology of lighting products and how artificial intelligence can be adopted in developing lighting products. It is provided with an understanding that how future of lighting and application of artificial intelligence related with each other. This paper also aimed to develop a conceptual model of integration of AI with lighting products.

Another great aspect of this collaboration is Human Centric Lighting (HCL). By using modern technologies, human can control lights in their surrounding according to their moods and needs. Purpose of any indoor lighting design consists many important factors, types of work, time of the work etc. It is very important for every individual that they can control the lighting conditions around themselves and the lighting should satisfy their needs. The paper titled 'The human centric lighting approach for the design of age friendly products', by M. Di Nicolantanio, E. Rossi, A. Marano, aimed to show the use of human centric lighting as a new approachable design to help the designers to develop a wide range of different lighting solutions from the study of human conditions, also it discussed a research process to design a human centric lighting-based system. Another advantage of modern technology and LED lighting source is smart lighting solution. A paper titled, 'Design and Development of Energy Efficient Lighting Controller', by A. Saha, D. Paul, R. Jana, S. Datta and A. Roy, integration of artificial lighting with daylight achieved using different sensor and microcontroller programming for a model classroom.

Peter R. Boyce in his book, in the chapter named 'Lighting and Work' mentioned that, it is very much necessary to understand the routes by which lighting can affect human performance. He mentioned three such routes, through visual system, through the circadian timing system, and through mood and motivation.

Figure shows the, Conceptual framework involving the three routes whereby lighting conditions can influence human performance.

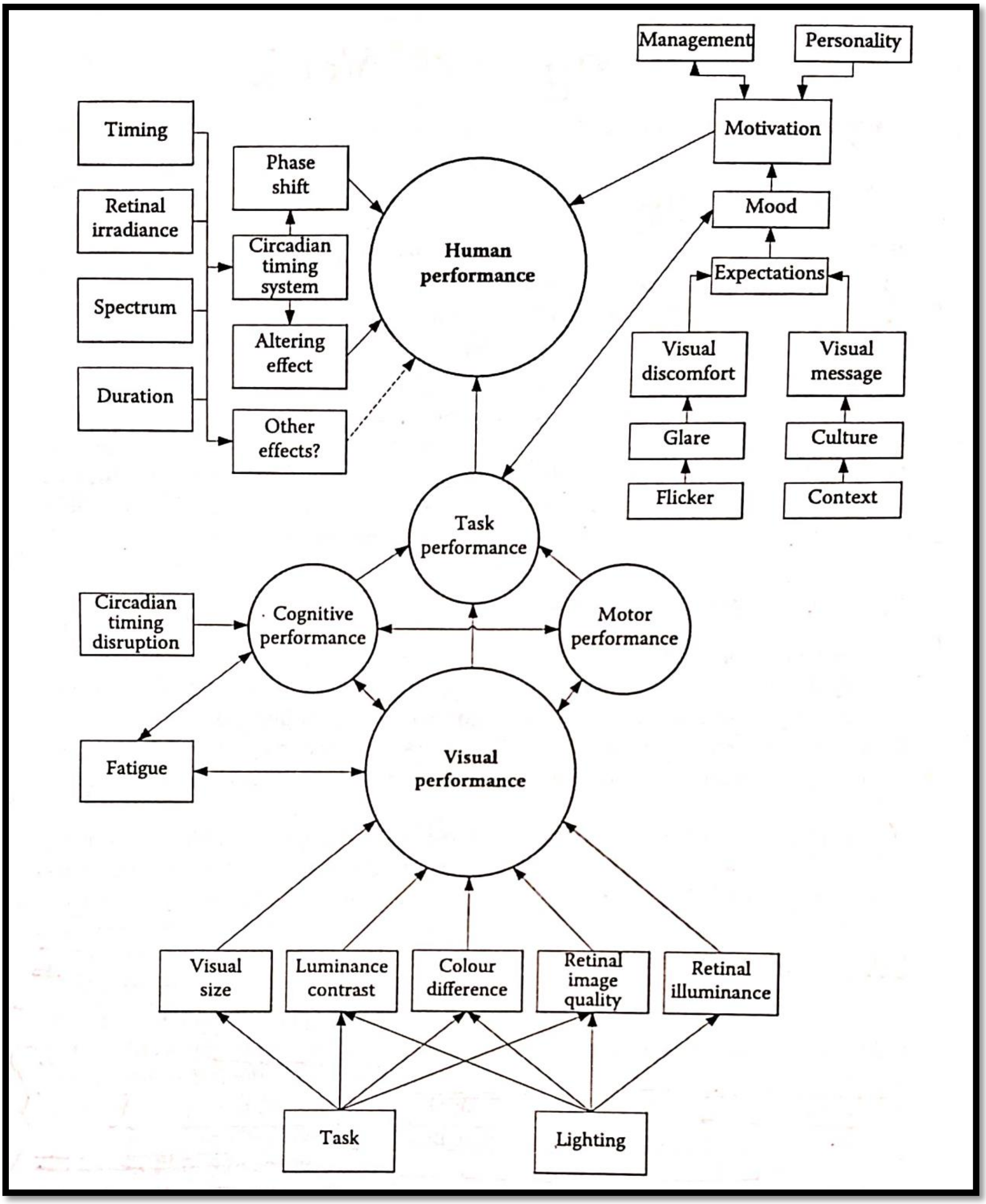


Figure 1: A conceptual framework setting out the three routes whereby lighting conditions can influence human performance.

He also mentioned that the impact of lighting conditions on work performance studied based on the operation of the visual system. He talked about three different approach, real time studies, simulated work and analytical methods.

2.1.a Previous works based on chess and cognitive study:

Chess not only enhance the mathematical and scientific skills but, also it has a very significant link with behavioural and personality development. Previously several papers studied effects of chess as a mind game on human cognitive behaviour and how chess can be useful as a cognitive study model. Chess can be very effective tool to channelize human emotions and also can be useful as a clinical tool for managing diseases such as dementia and other behavioural disorders.

The term Chess Personality defines as individual's personality traits based on instant reactions, strategic movements, understanding of the game and tactics used behind any particular move and the game. Several chess engines and chess related software performs this chess personality test by providing questions based on chess.

The term Chess Therapy is a form of psychotherapy which uses chess game as a tool to form a stronger bond between the therapist and the patient. Chess therapy can be very useful to cure panic attacks. Use of chess therapy to confront behavioural disorders is an exciting area of study among the research enthusiasts.

A review paper titled, 'Chess and the human brain- Demystifying the therapeutic value of a board game', by Singh S aimed to review the structural and functional changes in the brain caused by the chess game and also tried to explore the utility of chess game in confronting neuro-cognitive and behavioural disorders. This review paper mentioned other research works that shows the significant impact of chess on the different aspects of neuro-cognitive studies. Also mentioned some of the works that didn't find any positive impact of playing chess on the mood or attention. The review illuminates light on the multi-dimensional nature of the chess brain connection.

Neil Charness, in, 'The impact chess research on cognitive sciences', focused and assessed the impact of chess on cognitive studies by three approaches, firstly by looking at the objective measure of citations by scientists working in the field of social sciences, secondly by assessing the citations in textbooks about the cognitive science and lastly, by evaluating the problems related to cognitive psychology and artificial intelligence and the impact of chess on both of them. In the conclusion part, he mentioned that cognitive psychologists use chess for three purposes, first to understand the basic cognitive process, specifically related to memory, attention, second, understanding the chess game as a topic in its own right and lastly to be able to differentiate between the different chess players and also to understand the chess expertise.

The paper titled, 'Malleability of Working Memory Through Chess in School Children- A Two Year Intervention Study', by E. Joseph, V. Easvaradoss, S. Abraham, S. Vaddadi, aimed to find out the effects two years chess training on the working memory of children. Two groups were present, experimental and control group. The link between the training and working memory showed that the children can evaluate their positions, they can justify each move based on the information present at that time in their mind. Experimental group underwent to weekly chess training for continuous two years, where the control group was actively involved in sports and extracurricular activities. Analysis showed that experimental group had significant gain in working memory. Children who received training have acquired the ability to think the reason behind each move and also used the information for doing particular task gained during the training. Impact of chess on the working memory is a significant goal for future chess trainings and chess related research.

Hebert A. Simon and William G. Chase published several papers related to chess game skills and its utilization in field of cognitive studies, Simon and Chase in the paper, 'Skill in chess, experiments with chess playing tasks and computer simulation of skilled performance throw light on some human perceptual and memory processes ', mentioned that, like genetics psychology also needs a task environment model to enable more knowledge and understanding. Chess game has the ability to serve as the model. In the paper, 'Perception in chess', they aimed to develop a technique for isolating and studying the perceptual structures that chess players perceive. Three players of different levels were part of the study and two types of tasks, perception and memory tasks were performed.

2.1.b Previous studies based on effects of lighting parameters specifically Correlated colour temperature (CCT):

Apart from the illuminance level, other lighting parameters also has a significant effect on the work performance and cognitive studies. A proper lighting design not only depends upon the standard illuminance value, it can be determined and effected by other parameters also. Correlated colour temperature has an important role on influencing the mood, attention and work performance. Development of LED lighting technology helped the researchers and the developers to focus more on the other parameters and specify the effects of them on human being. Warm white is more suitable for relaxing and comfortable environment and cool white is effective for more productive environment. Several studies held to determine the effect of CCT on the comfort, mood and work performance. Some studies showed that the work performance enhanced by adopting the higher CCT, other research showed that correlated colour temperature can influence the visual comfort and cognitive behaviour. Earlier kruithof found that, generally people preferred low CCT with low illuminance value and high CCT with high illuminance value.

The paper titled, 'Influence of colour temperature on comfort and preference for LED indoor lighting ', by Q. Wang, Z. Wang, H. Xu, F. Zhang, aimed to study the influence of CCT on the comfort and preference for both working and relaxing mode. This paper also showed that illuminance level is not only the influencing factor to determine the comfort or preference. The experimental setup consists of twelve different CCT values and three illuminance levels with 36 different lighting conditions. A printed photograph with several typical images were used for subjects to assess the given lighting conditions and they were asked to assess the conditions based on the brightness and lighting tint. Multiple analysis of variance algorithm showed that the CCT and scenario have the significant influence on the subjective estimations. The optimal CCT's for comfort and preference of both relaxing and working modes had small difference between each other. Later the paper also proposed different models to predict the CCT for comfort and preference and a supplemental experiment with three different CCT's and at a particular illuminance level was also held to asses those models in the given lighting conditions.

Another paper titled, 'Effect of light colour temperature on human concentration and creativity ', by W. U. Weitbrecht, H. Barwolff, A. Lischke, S. Junger, studied the influence of three different colour temperatures with a high intensity on concentration and creativity of several students and employees. Experiment was of word test, logic test, creativity test and students were asked to assess their impression under different lighting conditions through question answers. Further another test was performed using random colour temperatures to found the circadian and learning effects. Results showed that creativity was better under the warm light and concentration was better under the cool light.

The next paper titled, 'The effect of correlated colour temperature and illuminance level of LED lighting on visual comfort during sustained attention activities ', by X. Fu, D. Feng, T. Wu, X. Jiang, aimed to explore the influence of correlated colour temperature and illuminance level on the human visual comfort. Electroencephalogram response, sustained attention to response test (SART) and subjective evaluation parameters were obtained. SART was performed with nine different combinations under given lighting condition, and a total number of 46 students were part of the experiment. Results showed that, lighting with 3000k CCT and 300 lux combination was more comfortable than other conditions. Subject perception implies that 4000k was good for visual comfort and it caused good task performance.

2.1.c Previous studies which linked chess and electroencephalogram (EEG):

Chess as a strategic game enables basic cognitive studies in which memory, concentration, self-evaluation these parameters are involved. As mentioned earlier chess game is a very useful tool for cognitive and behavioural researches and several studies were performed in this area. Electroencephalogram is a significant part of modern neuroscience studies. It helps to analysis the electrical activity of the brain responses and also gives productive output about an individual's mental behaviour while doing a particular task. From many years, several neurocognitive studies have been held using electroencephalogram, and currently in the lighting world it is becoming an important aspect of some researches.

The paper titled, 'Electroencephalographic response of chess players in decision making processes under time pressure ', by Santos, Daniel, Ricardo. Juan Pardo, N. Gusi, aimed to describe and compare the brain electrical activity pattern of chess players in two different game modes under time pressure. Two different mode was rapid game, 15 minutes plus 10 second additional per move and lightning game, one minute game. Total 14 right-handed male chess players were participated in the experiment and they played the matches through computer software. Mainly lightning game involved less time and long-term memory but rapid game had more time which combined long term memory and working memory. In the results, researchers found that right hemisphere was more activated during both lightning and rapid both games but differences found in theta power in posterior areas. In rapid game, frontal theta power was higher. Also, beta power increments were observed during lightning chess game in the posterior region.

In another paper titled, ‘Heart and Brain responses to real versus simulated chess games in trained chess players: A Quantitative EEG and HRV Study ‘, by Juan Pedro, T. Pereira, Maria Antonio, Antonio Carvalho and Santos, aimed to investigate how heart and the brain reacts to playing chess with a computer versus in a real context in chess players. Chess players were divided into two groups, familiarized and unfamiliarized with playing chess with computer. A total number of 27 experienced chess players were part of the cross-sectional study. Statistically significant differences were not found in real versus simulated environment, but unfamiliarized chess players obtained less EEG theta power spectrum and high HRV values while playing in a computer. However, the results obtained from the experiment could be relevant in the chess training.

In paper titled, ‘Performance analysis of chess players comparing traditional and novel cognitive perception ranking measures ‘, by L. S. Junior, Wilson Da Silva, C. Thomaz, aimed to study the performance analysis of the chess players by comparing a standard ranking measure with a new cognitive approach by analysing participants eye movement and brain signals. A total number of 32 participants aged between 6 to 54 years were participated in the experiment with different qualifications. The experimental design consisted of 50 questions related to chess board and moves and were divided into five categories. The results and analysis showed rise in the accuracy level when cognitive approach was used. Results gave better human proficiency due to cognitive approach.

In another paper named, ‘EEG correlates of cognitive demand in experts chess players ‘, aimed to investigate the effect of different attentional and cognitive demands within the game of chess and also the behavioural and electroencephalographic measurements through designing a chess problem of different difficulty level.

CHAPTER-3

3.1 Experimental setup:

This thesis motives to find out the effects of different lighting conditions, specifically correlated colour temperature of a LED light source on mood, attention and reaction time of the chess players, so the objective demands experimentation under specified lighting conditions. This type of studies where assessment of human performance for a lighting condition is required, it becomes the part of real-task studies. In a book written by Peter R. Boyce, he mentioned that, the studies related to impact of lighting conditions on work performance, can be classified into two groups, one is real-task studies and another is abstract studies. Difference between these two groups were made by face validity and generality.

Real-task studies means a practical task that participants actually do by measuring the performance of that particular task under different lighting conditions, where the conditions can be change accordingly. Measurements for this type experiments are made using real-task in the field or by the simulated version in the laboratory. Real-task studies have high value of face validity and little generality. They lack generality because of the results obtained from these studies strictly applicable only to the given task and the particular lighting installation and condition. By examining the results of this studies, it is possible to analyse and predict the effects of given lighting conditions on the visual and human performance. Whereas abstract studies have high value of generality and low face validity. These types of studies are ideal for some visual tasks whose lighting conditions are not specified. The experiment has been designed to find out the human performance under the given lighting conditions and to find out the cognitive data for the specified scenario.

3.1.a Approach and Process:

The aim is to find out the effect on mood, attention and reaction time under the specified conditions and analysis of their brain responses using electroencephalographic study. In the context of this objective, the term human performance refers to the players performance through the game analysis and the cognitive performance, response of the brain under the particular lighting condition.

The performance of the players under specified the lighting conditions requires a controlled lighting environment, the face validity of such experiment is high. The process for the experiment was very simple and actually the surrounding environment was quite suitable for the particular task. For playing chess a peaceful and calm condition is needed, so that external noise or chaos in the surrounding cannot influence the player's mind. Three different correlated colour temperatures were determined to conduct the experiments, 3000k, 4000k and 5000k. The subjects played under this three different CCT's and experiments were conduct for three days with having prior gap between them. The environment was calm and there was no additional activity and noise, temperature was normal.

The planning for the matches were based on the home-away concept, like the football matches in some competitions. The behavioural data was obtained using the Galvanic skin response (GSR) sensor and the cognitive data was collected using the electroencephalogram headset. The experimental patterns are as follows

	CCT (k)	Match 01	Match 02
Day 1	3000	P1(EEG) vs P2	P1 vs P2(EEG)
Day 2	5000	P1(EEG) vs P2	P1 vs P2(EEG)
Day 3	4000	P1(EEG) vs P2	P1 vs P2(EEG)

Table1: Schedule of matches for the experiment

Total number of matches were six, under three different CCT values. Here, P1 refers to the subject A and P2 refers to the subject B. In the first match only subject 1 worn the EEG headset and GSR sensor on the fingers and accordingly in the second match only subject 2 worn the headset and GSR sensor. This method continued across all experimental days and in this way behavioural and cognitive data was collected form the subjects.

3.1.b Subjects for the experiment:

The study needed subjects who are well known with chess game and regularly plays the game. Total number of two right handed professional male chess players were took part in the whole experimental process, they played chess at the competitive and national level. The recruited participants were healthy and none of them were on medication that could affect experimental process and the nervous system. Upon arrival, subjects were made comfortable and provided proper hospitality before they were assigned to play the matches. There was a 5-10 minutes gap before the two matches, so that the participants can made themselves comfortable and can feel relaxed. One participant was with glasses in the eye and another was without glasses, but both of them had normal or corrected to normal vision. Before the experiment, all the subjects were well instructed and made conscious about the whole procedure and signed the consent form before the task. All the procedure approved the Institutional Ethics Committee. After both the matches, refreshments were given to the participants. Same process continued for all the three days and after completion of full procedure participants were fully fit and satisfied with the whole procedure.

Serial no	List of subjects	Age	Elo Rating
01	Subject A (P1)	19+	1943
02	Subject B (P2)	18+	1830

Table 2: Summary of subject's details

3.1.c Setup:

The whole experiment for the research has been conducted in the Illumination Engineering laboratory, Department of Electrical Engineering, Jadavpur University. The task was carried out in the dark lab, only one light source was present for the specific requirement. Across all days, experiments were carried out in the evening time only.

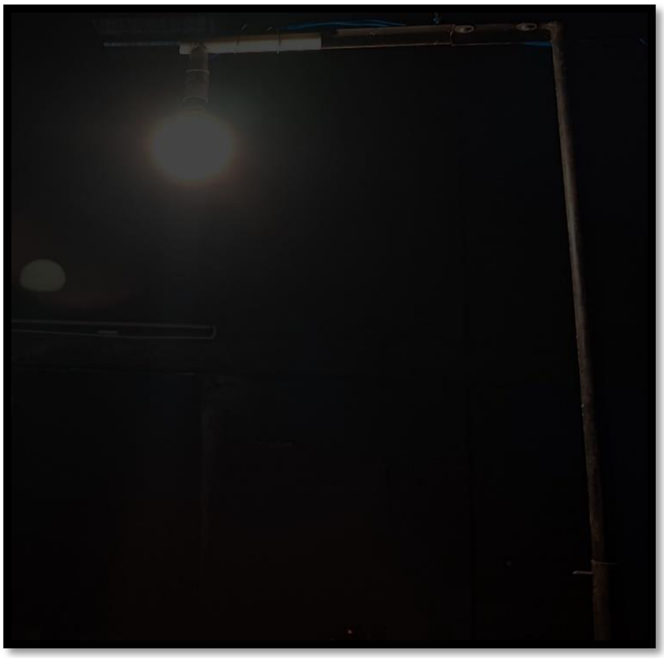


Figure 2: 10 Watt smart LED light source

Above picture consists of a smart LED bulb of 10 watt which was used for required minimum illuminances value and most importantly for fulfilling the requirement of specified correlated colour temperature value. The light source controlled using a mobile application and connected with the application through the wi-fi. So by changing the CCT on the mobile app or any other features, light source can be used. The distance of the source to the nadir point on the table was 1.22 meter.

The matches were played on a table of dimension 1.22m x 0.74m. A grid was made on the table to find out the nadir point and the average illuminance values under different correlated colour temperature.

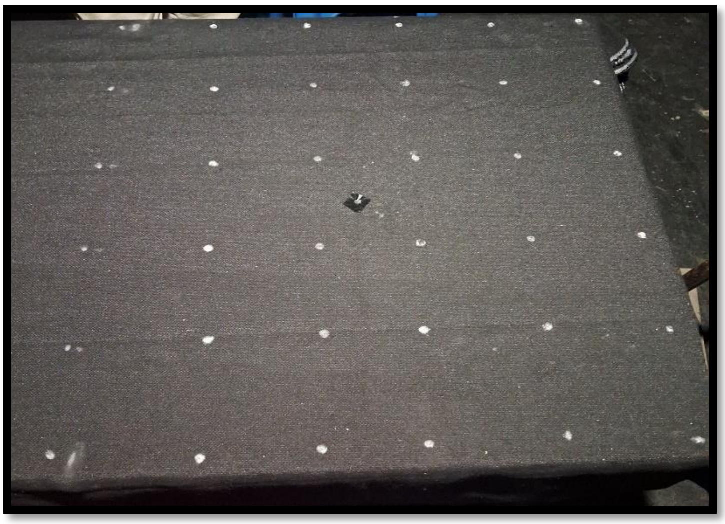


Figure 3: Grid made on the table

The basic apparatus required for the experiment is as follows:

1. A smart wi-fi led light source
2. Chess board and pieces
3. Clock
4. Galvanic Skin Response (GSR) sensor
5. EEG headset
6. Laptop
7. Tripod

The complete description of the apparatus is given in the annexure. The players were situated at the chairs playing against each other. As both of them were righthanded players, one who worn EEG headset also had GSR sensor connected on the index finger and middle finger of the left hand throughout the full match. Rapid chess game of 50 minutes (25+25) has been conducted for each study.

Figure 4: Subject with an EEG headset on the head and a GSR sensor on the fingers

The table was covered with black plain cover and chess board, clock and A4 size papers were situated on it.

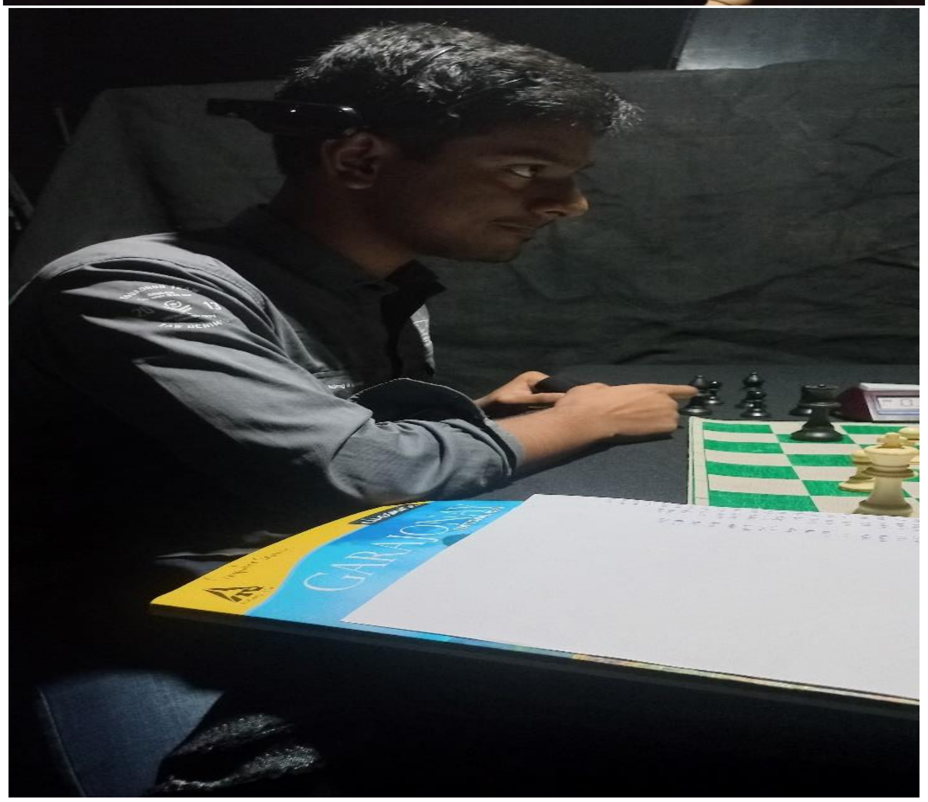
In the next part detailed procedure about the cognitive experiment is explained with figures of all the experimental days. The experimental room was calm and temperature was normal, air conditioner was present in the laboratory. Apart from the subjects, only two members were present at the experimental spot.

3.1.d Cognitive Experiment:

As the objective of the research was to study the brain responses of the chess players under specified correlated colour temperature, hence the cognitive data during the chess match was collected using the EEG headset. At a time, only one subject worn the headset. The cognitive data was gathered with the help of 14 channel emotive epoch x EEG headset and the cap was mounted with the electrodes. Before the experiment, the felt pads should be immersed at the fresh solution and after the whole experiment it should be cleaned using ear buds. The headset was connected wirelessly to a laptop through the wi-fi and was controlled using emotive software installed in the laptop. For the proper placement of headset on the scalp, contact quality and EEG quality can be checked in the application. Before the experiment participant was well instructed about the whole EEG connection process and they were completely comfortable with headset. The complete recording and EEG handling controlled by one of the investigators. After the placement of headset, investigator asked the subject to open and close eyes for 1 minutes respectively and then the match was started, also recording was started. A USB receiver was connected to the laptop to save the data properly. The data and detailed analysis explained in the Experimental data and Result sections respectively.

Few pictures of experiments are as follows:

Figures 5 – 10 show some photos taken during the experiment



CHAPTER-4

4.1 Experimental Data:

In the above section, experimental procedure and design was discussed briefly. The experimental data consists of three types of data, data obtained from the galvanic skin response (GSR) sensor, the chess pieces movements i.e. chess notations for each match and the cognitive data. GSR sensor data and chess notations used for the purpose of game analysis and behavioural study, whereas data obtained through EEG headset used for the purpose of cognitive analysis.

4.1.a GSR sensor data:

As discussed in the above chapter, subjects worn sensor in the index and middle fingers of their left hand. Galvanic skin response (GSR) also referred as Electrodermal activity (EDA). Human being experiences something emotional or other activity while doing an important task. This sensor measures the electrical conductivity of the skin as a response to some stimuli. When an individual experiences some excitement or emotional feelings while doing a task, it triggers sweat glands, where skin becomes more conductive to electricity. GSR is an attractive tool in such a way that it can measure someone's emotional arousal level without requiring them to articulate their feelings or without hiding them. GSR sensor widely used for the biological and physiological research works. The signal can be used for capturing the autonomic nerve responses as a parameter of the sweat gland function. As chess is the game of mind and strategy, GSR sensor helped to the record the emotional mindset of the subjects while playing the matches through the data, be it positive, joyful or negative. GSR sensor does not represent any emotional state but reflects the intensity of the state.

In a paper titled, 'A brief introduction and review on galvanic skin response ', by M. Sharma and S. Kacker, stated that review on GSR discloses three principal theories, Muscular activity, Vascular changes and Secretory changes. This paper stated the working principle of the GSR sensor and called it an accessible and sensitive index of peripheral sympathetic nervous activity, reflecting peripheral autonomic change.

The paper named, 'A stress sensor based on Galvanic skin response (GSR) controlled by Zigbee ', by Maria, Amaia Mendez, aimed to designed a stress sensor based on galvanic skin response and controlled by Zigbee, total 16 adult subjects were part of the different tests. Results showed that, GSR was able to detect different state of each subject.

In another paper, 'Human emotion recognition based on galvanic skin response signal feature selection and SVM ', by Di Liu, X, Zhang, X. Gong, aimed to create a human emotion recognition method based on automatically selected galvanic skin response features and then proposal of SVM. Support vector machine (SVM) was a set of machine learning approaches. Results indicated that proposed method leads to good human emotion recognition.

The GSR sensor data was obtained for each match during every experimental days as follows (Figures 11 - 16):

```
2024-3-18 19:30:57 -- gsr_average = 140,
2024-3-18 19:30:58 -- gsr_average = 138,
2024-3-18 19:30:58 -- gsr_average = 134,
2024-3-18 19:30:59 -- gsr_average = 134,
2024-3-18 19:30:59 -- gsr_average = 135,
2024-3-18 19:31:0 -- gsr_average = 139,
2024-3-18 19:31:0 -- gsr_average = 143,
2024-3-18 19:31:1 -- gsr_average = 144,
2024-3-18 19:31:2 -- gsr_average = 146,
2024-3-18 19:31:2 -- gsr_average = 144,
2024-3-18 19:31:3 -- gsr_average = 145,
2024-3-18 19:31:3 -- gsr_average = 149,
2024-3-18 19:31:4 -- gsr_average = 149,
2024-3-18 19:31:5 -- gsr_average = 152,
2024-3-18 19:31:5 -- gsr_average = 147,
2024-3-18 19:31:6 -- gsr_average = 146,
2024-3-18 19:31:6 -- gsr_average = 145,
2024-3-18 19:31:7 -- gsr_average = 148,
2024-3-18 19:31:8 -- gsr_average = 150,
2024-3-18 19:31:8 -- gsr_average = 152,
2024-3-18 19:31:9 -- gsr_average = 154,
2024-3-18 19:31:9 -- gsr_average = 154,
2024-3-18 19:31:10 -- gsr_average = 157,
2024-3-18 19:31:11 -- gsr_average = 159,
2024-3-18 19:31:11 -- gsr_average = 161,
2024-3-18 19:31:12 -- gsr_average = 160,
```

```
2024-3-18 18:13:29 -- gsr_average = 201,
2024-3-18 18:13:29 -- gsr_average = 200,
2024-3-18 18:13:30 -- gsr_average = 199,
2024-3-18 18:13:31 -- gsr_average = 206,
2024-3-18 18:13:31 -- gsr_average = 200,
2024-3-18 18:13:32 -- gsr_average = 194,
2024-3-18 18:13:32 -- gsr_average = 187,
2024-3-18 18:13:33 -- gsr_average = 178,
2024-3-18 18:13:33 -- gsr_average = 167,
2024-3-18 18:13:34 -- gsr_average = 162,
2024-3-18 18:13:35 -- gsr_average = 154,
2024-3-18 18:13:35 -- gsr_average = 143,
2024-3-18 18:13:36 -- gsr_average = 133,
2024-3-18 18:13:36 -- gsr_average = 127,
2024-3-18 18:13:37 -- gsr_average = 125,
2024-3-18 18:13:38 -- gsr_average = 123,
2024-3-18 18:13:38 -- gsr_average = 118,
2024-3-18 18:13:39 -- gsr_average = 115,
2024-3-18 18:13:39 -- gsr_average = 117,
2024-3-18 18:13:40 -- gsr_average = 122,
2024-3-18 18:13:40 -- gsr_average = 127,
2024-3-18 18:13:41 -- gsr_average = 129,
2024-3-18 18:13:42 -- gsr_average = 129,
2024-3-18 18:13:42 -- gsr_average = 126,
2024-3-18 18:13:43 -- gsr_average = 125,
2024-3-18 18:13:43 -- gsr_average = 123,
```

Figures 11 & 12: GSR data of subject A and B under 3000k CCT

2024-3-20	19:21:28 -- gsr_average = 349,
2024-3-20	19:21:29 -- gsr_average = 346,
2024-3-20	19:21:29 -- gsr_average = 350,
2024-3-20	19:21:30 -- gsr_average = 346,
2024-3-20	19:21:31 -- gsr_average = 350,
2024-3-20	19:21:31 -- gsr_average = 346,
2024-3-20	19:21:32 -- gsr_average = 350,
2024-3-20	19:21:32 -- gsr_average = 345,
2024-3-20	19:21:33 -- gsr_average = 348,
2024-3-20	19:21:34 -- gsr_average = 346,
2024-3-20	19:21:34 -- gsr_average = 350,
2024-3-20	19:21:35 -- gsr_average = 346,
2024-3-20	19:21:35 -- gsr_average = 347,
2024-3-20	19:21:36 -- gsr_average = 340,
2024-3-20	19:21:36 -- gsr_average = 341,
2024-3-20	19:21:37 -- gsr_average = 335,
2024-3-20	19:21:38 -- gsr_average = 336,
2024-3-20	19:21:38 -- gsr_average = 332,
2024-3-20	19:21:39 -- gsr_average = 332,
2024-3-20	19:21:39 -- gsr_average = 328,
2024-3-20	19:21:40 -- gsr_average = 328,
2024-3-20	19:21:41 -- gsr_average = 319,
2024-3-20	19:21:41 -- gsr_average = 320,
2024-3-20	19:21:42 -- gsr_average = 312,
2024-3-20	19:21:42 -- gsr_average = 311,
2024-3-20	19:21:43 -- gsr_average = 307,

2024-3-20 19:3:11 -- gsr_average = 226,
2024-3-20 19:3:11 -- gsr_average = 227,
2024-3-20 19:3:12 -- gsr_average = 227,
2024-3-20 19:3:12 -- gsr_average = 230,
2024-3-20 19:3:13 -- gsr_average = 229,
2024-3-20 19:3:13 -- gsr_average = 232,
2024-3-20 19:3:14 -- gsr_average = 231,
2024-3-20 19:3:15 -- gsr_average = 231,
2024-3-20 19:3:15 -- gsr_average = 232,
2024-3-20 19:3:16 -- gsr_average = 233,
2024-3-20 19:3:16 -- gsr_average = 234,
2024-3-20 19:3:17 -- gsr_average = 234,
2024-3-20 19:3:18 -- gsr_average = 237,
2024-3-20 19:3:18 -- gsr_average = 236,
2024-3-20 19:3:19 -- gsr_average = 236,
2024-3-20 19:3:19 -- gsr_average = 239,
2024-3-20 19:3:20 -- gsr_average = 239,
2024-3-20 19:3:21 -- gsr_average = 244,
2024-3-20 19:3:21 -- gsr_average = 236,
2024-3-20 19:3:22 -- gsr_average = 245,
2024-3-20 19:3:22 -- gsr_average = 244,
2024-3-20 19:3:23 -- gsr_average = 244,
2024-3-20 19:3:24 -- gsr_average = 238,
2024-3-20 19:3:24 -- gsr_average = 239,
2024-3-20 19:3:25 -- gsr_average = 238,
2024-3-20 19:3:25 -- gsr_average = 234,

Figures 13 & 14: GSR data of subject A and B under 5000k CCT

2024-4-3 19:28:40 -- gsr_average = 83,
2024-4-3 19:28:41 -- gsr_average = 82,
2024-4-3 19:28:41 -- gsr_average = 83,
2024-4-3 19:28:42 -- gsr_average = 82,
2024-4-3 19:28:42 -- gsr_average = 83,
2024-4-3 19:28:43 -- gsr_average = 97,
2024-4-3 19:28:44 -- gsr_average = 83,
2024-4-3 19:28:44 -- gsr_average = 79,
2024-4-3 19:28:45 -- gsr_average = 72,
2024-4-3 19:28:45 -- gsr_average = 65,
2024-4-3 19:28:46 -- gsr_average = 57,
2024-4-3 19:28:47 -- gsr_average = 48,
2024-4-3 19:28:47 -- gsr_average = 42,
2024-4-3 19:28:48 -- gsr_average = 37,
2024-4-3 19:28:48 -- gsr_average = 34,
2024-4-3 19:28:49 -- gsr_average = 31,
2024-4-3 19:28:49 -- gsr_average = 31,
2024-4-3 19:28:50 -- gsr_average = 29,
2024-4-3 19:28:51 -- gsr_average = 29,
2024-4-3 19:28:51 -- gsr_average = 26,
2024-4-3 19:28:52 -- gsr_average = 24,
2024-4-3 19:28:52 -- gsr_average = 23,
2024-4-3 19:28:53 -- gsr_average = 22,
2024-4-3 19:28:54 -- gsr_average = 21,
2024-4-3 19:28:54 -- gsr_average = 20,
2024-4-3 19:28:55 -- gsr_average = 19,

2024-4-3 18:28:20 -- gsr_average = 253,
2024-4-3 18:28:20 -- gsr_average = 255,
2024-4-3 18:28:21 -- gsr_average = 255,
2024-4-3 18:28:22 -- gsr_average = 254,
2024-4-3 18:28:22 -- gsr_average = 253,
2024-4-3 18:28:23 -- gsr_average = 254,
2024-4-3 18:28:23 -- gsr_average = 262,
2024-4-3 18:28:24 -- gsr_average = 255,
2024-4-3 18:28:24 -- gsr_average = 253,
2024-4-3 18:28:25 -- gsr_average = 251,
2024-4-3 18:28:26 -- gsr_average = 249,
2024-4-3 18:28:26 -- gsr_average = 250,
2024-4-3 18:28:27 -- gsr_average = 250,
2024-4-3 18:28:27 -- gsr_average = 249,
2024-4-3 18:28:28 -- gsr_average = 247,
2024-4-3 18:28:29 -- gsr_average = 245,
2024-4-3 18:28:29 -- gsr_average = 243,
2024-4-3 18:28:30 -- gsr_average = 244,
2024-4-3 18:28:30 -- gsr_average = 244,
2024-4-3 18:28:31 -- gsr_average = 242,
2024-4-3 18:28:31 -- gsr_average = 241,
2024-4-3 18:28:32 -- gsr_average = 241,
2024-4-3 18:28:33 -- gsr_average = 242,
2024-4-3 18:28:33 -- gsr_average = 243,
2024-4-3 18:28:34 -- gsr_average = 243,
2024-4-3 18:28:34 -- gsr_average = 244,

Figures 15 & 16: GSR data of subject A and B under 4000k CCT

The above datasets are the part of the continuous dataset obtained from each match for both the subjects, detailed table of data with the timespan and average data for both the subjects for each specified correlated colour temperature will be discussed in the next chapter.

4.1.b Chess pieces notations:

Total number of matches was six, two for each three specified correlated colour temperature. Detailed analysis of each match will be discussed in the next chapter. In the game of chess, each player eight pawns, two knights, two bishops, two rooks or castles, one king and one queen.

Piece	Notation	Symbol
King	K	♔
Queen	Q	♕
Rook	R	♖
Knight	N	♘
Bishop	B	♗
Pawn	P	♙

Table 3: Chess pieces names, notations and symbols

The goal of the game is to capture the opponent's king. Pawn can only move straight forward; it may move two squares only for the first move but one square for all the other moves. Bishops can move diagonally only and may move into any number of squares. Rook can move straight, backward, right and left, and also it may move any number of squares. Knight can move two squares forward or backward, then one square to either left or right. Queen can move anywhere within the board as many squares as it requires and finally the king can move only one square in any direction.

Figure 17: Chess board and clock

Match 1 under 3000k CCT (Subject A: White and Subject B: Black)

WHITE	BLACK
e4	b6
d4	Bb7
Bd3	e6
Nc3	Nf6
Nge2	d6
0-0	Be7
Kh1	0-0
f4	c5
Be3	c4
Bc4	Ne4
d5	Nc3
Ne3	e5
Be2	Nd7
Qd3	Nf6
Bf3	Rb8
Rad1	ef4
Bf4	Nd7
b4	a6
Ne4	Qc7
c4	Nf6
c5	Ne4
Be4	g6
Rc1	bc5

bc5	Qd8
c6	Resign

Table 4: Chess notations of Match 1 under 3000k

Match 2 under 3000k CCT (Subject A: Black and Subject B: White)

Nf3	d5
g3	c5
Bg2	Nc6
d3	e5
0-0	f5
e4	Nf6
ed5	Nd5
Re1	Bd6
Ne5	Be5
f4	0-0
fe5	Re8
Be3	Ne3
Re3	Qd4
Qe1	Re5
Kf2	f4
gf4	Qf4+
Bf3	Qh2
Kf1	Bh3+
Bg2	Qg2+

Table 5: Chess notations of Match 2 under 3000k

Match 1 under 5000k CCT (Subject A: White and Subject B: Black)

WHITE	**BLACK**
e4	b6
d4	Bb7
Bd3	Nf6
Nd2	e6
Ngf3	d6
0-0	Be7
Re1	0-0
Nf1	h6
Ng3	c5
c3	Nc6
h3	a6
Be3	b5
Qd2	cd4
cd4	d5
a3	de4
Ne4	Na5

Nf6	Bf6
Rad1	Nc4
Bc4	bc4
Qe2	Bd5
Ne5	Qc7
Qh5	Be5
de5	f5
ef6	Rf6
Rd5	Raf8
Rc5	Resign

Table 6: Chess notations of Match 1 under 5000k

Match 2 under 5000k CCT (Subject A: Black and Subject B: White)

Nf3	d5
g3	Nf6
Bg2	c5
0-0	Nc6
d3	e5
Nbd2	Bd6
e4	d4
Nc4	b5
Nd6+	Qd6
Nh4	0-0
Nf5	Bf5
ef5	Rac8
g4	Nd5
g5	c4
a3	Rfd8
Be4	f6
h4	Nf4
Qg4	cd3
cd3	Ne7
Bd2	Ned5
Bb4	Nb4
ab4	Rc7
Ra5	Qb4
Ra1	Rd6
Kh2	Qb2
Qf3	Rdd7
gf6	gf6
Rg1+	Rg7
Bd5+	Kh8
Be6	h5

Table 7: Chess notations of Match 2 under 5000k

Match 1 under 4000k CCT (Subject A: White and Subject B: Black)

e4	c5
Nf3	d6
d4	cd4
Nd4	Nf6
Nc3	a6
Bg5	e6
f4	b5
e5	de5
fe5	Qc7
ef6	Qe5+
Qe2	Qg5
Ne4	Qe5
0-0-0	gf6
Nf3	Qf4+
Kb1	Be7
g3	Qc7
Bg2	Bb7
Rhf1	Nd7
Nd4	0-0-0
Rf3	b4
Rb3	f5
Nd2	Nb6
Bb7+	Qb7
Nc4	Bc5
Na5	Qa8
Ndc6	Rd1+
Qd1	Nd5
c3	Kc7
cb4	Bb6
Qc2	Kd7
Ne5+	Ke7
Nac4	Rc8
Nb6	Nb6
Qd2	Qh1+

Table 8: Chess notations of Match 1 under 4000k

Match 2 under 4000k CCT (Subject A: Black and Subject B: White)

WHITE	BLACK
d4	d6
Nf3	Nf6
Bf4	g6
e3	Bg7
h3	0-0

Be2	Re8
0-0	Nbd7
c3	c6
Qb3	e5
Bh2	e4
Nfd2	d5
c4	Nb6
c5	Nbd7
Qc2	Re6
Nc3	b6
b4	Ne8
Rab1	f5
Qb3	Ndf6
Na4	Bf8
Rfc1	b5
Nc3	a5
a4	ab4
Qb4	ba4
Na4	Ba6
Ba6	Ra6
Nb6	Nd7
Nd7	Qd7
Ra1	Qc8
Ra5	Re7
Rca1	Rea7
Nb3	Be7
Qb8	Ra5
Ra5	Qb8
Bb8	Rb7
Ra8	Rb3
Bd6	Kf8
Be7+	Ke7
Ra7+	Ke6
Rh7	Rb8
Kh2	Rc8
Ra7	Rc7
Ra8	Nf6
Kg3	g5
h4	Nh5+
Kh3	Rh7
hg5	Nf4+
Kg3	Ne2

Table 9: Chess notations of Match 2 under 4000k

4.1.c Average Illuminance Calculation:

Average illuminance value needed to calculate under different correlated colour temperature. A 0.7m x 0.6m measurement was taken in the table, divided into 36 grid points. Illuminance value measured in each grid point with the help of CL-70F instrument. Uniformity also calculated by the division between the minimum and average lux values. A 10 watt smart led bulb was the only light source ON at the time of measurement.

CCT	**Nadir point lux value**	**Avg. Lux value**	**Uniformity (U0)**
2500k	76.6	68.8	0.8
3000k	80.7	72.8	0.8
3500k	80.7	72.6	0.8
4000k	82.5	74.5	0.8
4500k	81.8	73.7	0.8
5000k	84.3	76.1	0.8

Table 10: Average Illuminance values under three CCT's

4.1.d Cognitive Data:

The objective was to analyse the brain responses obtained from the experiment. As per neuroscience, the visual information is processed in the visual cortex. Both hemisphere of the brain contains visual cortex, the visual cortex in the left hemisphere receives signals from the right visual field and vice-versa. Actually, visual cortex is the primary cortical region of the brain that receives and processes visual information. The neurons in the brain communicate with other through electrical signals. Electroencephalogram, analyse the electrical signals of the brain waves, gives a basic idea about the state of brain signals while doing some tasks. EEG headset captures electrical signal through electrodes attached to the brain scalp. One of the investigators observed and controlled the emotive software in the laptop for the successful completion of data collection.

In a paper named, 'Analysis of Electroencephalography signals and its categorization- A study', by J.S. KUMAR AND P. BHUVANESWARI, mentioned that Each hemisphere is divided into four lobes -Frontal, Temporal, Parietal and Occipital.

Brain waves are measured in cycles per second. Brain waves are of five types – alpha, beta, gamma, delta, theta.

BRAIN WAVES	**FRQUENCY**	**FEATURES**
Delta	0.5-4Hz	Slow wave, helps in sleep
Theta	4-8Hz	Subconscious activity, deep relaxation and meditation
Alpha	8-12Hz	Bridge between conscious and subconscious mind, passive attention
Beta	12-38Hz	Behaviour and actions, sense of touch, smell etc.

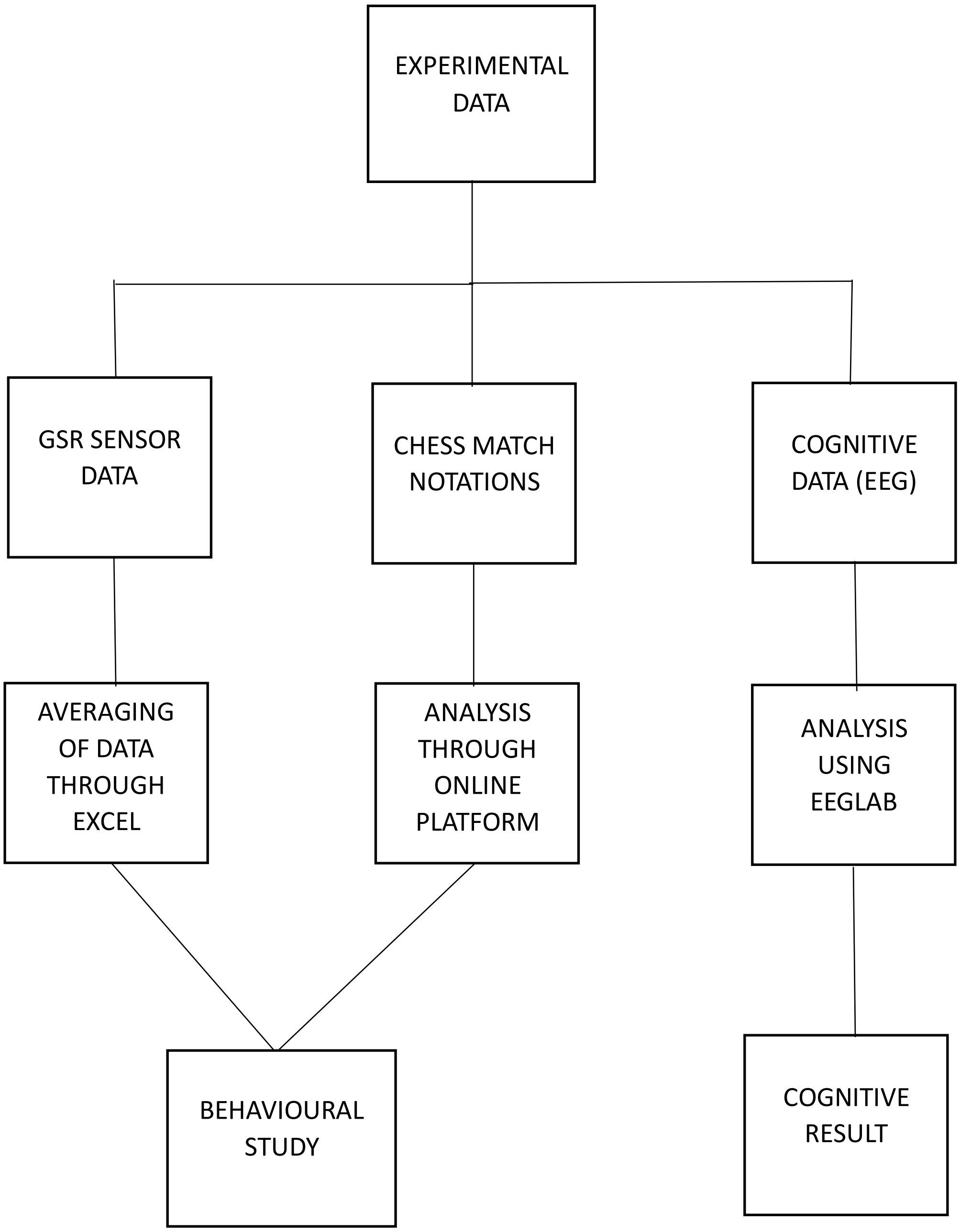
		Dominant at the time of attention
Gamma	38-45Hz	Fast waves, perception, consciousness and concentration

Table 11: Brain waves specifications

CHAPTER-5

5.1 Result and Analysis:

Basic flowchart of the analysis part:



5.1.a Galvanic skin response data:

Galvanic skin response (GSR) sensor measure the skin's electrical changes in response to sweat gland in the fingers and the palms. Due to instant emotional stimuli skin's conductivity varies while doing something important.

GSR data of subject A under 3000k:

TIME SPAN	GSR VALUE
18:13:29-18:14:59	139.1795
18:15:00-18:16:59	131.3178
18:17:00-18:18:52	134.8341
18:18:53-18:19:59	137.6053
18:20:00-18:21:59	165.7097
18:22:00-18:23:30	149.6405
18:23:31-18:25:59	141.0512
18:26:00-18:27:59	127.9005
18:28:00-18:29:59	104.4537
18:30:00-18:32:59	111.2308
18:33:00-18:34:59	107.2327
18:35:00-18:37:59	117.004
18:38:00-18:40:30	117.6509
18:40:31-18:42:59	105.9526
18:43:00-18:45:25	94.55414
18:45:26-18:47:59	96.06612
18:48:00-18:51:00	99.26882
18:51:01-18:53:59	93.61842
18:54:00-18:56:59	73.93506
18:57:00-18:59:30	57.75974
18:59:31-19:00:44	66.70079

Table 12: Averaging of GSR sensor data of subject A under 3000k

Under the specified condition, GSR sensor recorded 4814 values under the time span of 18:13:29-19:00:44 pm. The above table represent the average values for some of the time spans. Average of all these values under the correlated colour temperature 3000k of subject A is 113.

GSR data of subject B under 3000k:

TIME SPAN	GSR DATA
19:21:48-19:23:59	208.7578
19:24:00-19:26:59	223.8095
19:27:00-19:29:59	219.102
19:30:00-19:32:59	176.4719
19:33:00-19:35:59	145.2612
19:36:00-19:38:56	78.6645
19:38:57-19:40:17	41.62044

Table 13: Averaging of GSR sensor data of subject B under 3000k

Under the specified condition, GSR sensor recorded 1880 values under the time span of 19:21:48-19:40:17 pm. The above table is the representation of average values under some of the time spans. Average of all these values under the correlated colour temperature 3000k of subject B is 156.

GSR data of subject A under 4000k:

TIME SPAN	GSR DATA
18:28;20-18:29:59	239.9226
18:30:00-18:32:59	237.7252
18:33:00-18:35:59	229.7952
18:36:00-18:37:59	199.4211
18:38:00-18:40:30	209.7665
18:40:31-18:42:34	194.8563
18:42;35-18:44:46	184.3977
18:44:47-18:45:59	174.7734
18:46;00-18:47:59	183.9133
18:48:00-18:50:00	183.5714
18:50:01-18:51:30	184.0542
18:51:31-18:52:59	173.2566
18:53:00-18:54:58	178.445
18:54:59-18:56:59	190.3443
18:57:00-18:58:59	160.4378
18:59:00-19:00:59	145.1854
19:01:00-19:02:59	149.2671
19:03:00-19:05:59	163.4096
19:06:00-19:07:59	181.9223
19:08:00-19:09;00	179.9706
19:09:01-19:10:59	172.8738
19:11:00-19:12:59	155.9156
19:13:00-19:15:59	133.8676
19:16:00-19:17:18	101.6864

Table 14: Averaging of GSR sensor data of subject A under 4000k

Under the specified condition, GSR sensor recorded 4989 values under the time span of 18:28:20-19:17:18 pm. The above table is the representation of average values under some of the time spans. Average of all these values under the correlated colour temperature 4000k of subject A is 179.5

GSR data of subject B under 4000k:

TIME SPAN	GSR DATA
19:28:40-19:30:59	26.88559
19:31:00-19:32:32	15.59135
19:32:33-19:34:59	12.74611
19:35:00-19:36:59	13.17647
19:37:00-19:39:59	13.25862
19:40:00-19:41:59	13.92895
19:42:00-19:42:49	14
19:42:50-19:44:01	15
19:44:02-19:44:59	16
19:45:00-19:46:41	17.93858

19:46:42-19:48:00	17.15059
19:48:01-19:50:44	19
19:50:45-19:51:04	20
19:51:05-19:51:20	21.48148
19:51:21-19:51:55	13
19:51:56-19:53:06	14
19:53:07-19:53:33	16.75
19:53:34-19:54:59	14
19:55:00-19:57:59	15
19:58:00-19:59:59	15.68296
20:00:00-20:04:50	14
20:04:51-20:05:59	44.87288
20:06:00-20:06:39	38.64286
20:06:40-20:17:02	13

Table 15: Averaging of GSR sensor data of subject B under 4000k

Under the specified condition, GSR sensor recorded 4921 values under the time span of 19:28:40-20:17:02 pm. The above table is the representation of average values under some of the time spans. Average of all these values under the correlated colour temperature 4000k of subject B is 18.

GSR data of subject A under 5000k:

TIME SPAN	GSR DATA
18:25:03-18:26:59	236.26
18:27:00-18:28:59	255.6908
18:29:00-18:30:59	226.3073
18:31:00-18:32:59	236.5196
18:33;00-18:34:59	263.2951
18:35:00-18:37:03	283.6179
18:37:04-18:38:59	287.5248
18:39:00-18:40:59	309.8522
18:41:00-18:42:59	296.1977
18:43:00-18:44:59	287.3284
18:45;00-18:46:59	265.6849
18:47:00-18:48:30	269.0462
18:48;31-18:43;59	266.5197
18:50:00-18:51:59	260.6274
18:52:00-18:53:59	269.7389
18:54:00-18:55:59	261.3137
18:56:00-18:57:59	238.3052
18:58:00-18:59:59	253.8894
19:00:00-19:01:59	243.1366
19:02:00-19:03:26	212.8367

Table 16: Averaging of GSR sensor data of subject A under 5000k

Under the specified condition, GSR sensor recorded 3912 values under the time span of 18:25:03-19:03:26 pm. The above table is the representation of average values under some of the time spans. Average of all these values under the correlated colour temperature 5000k of subject A is 261.

GSR data of subject B under 5000k:

TIME SPAN	GSR DATA
19:21:28-19:22:59	311.2308
19:23:00-19:25:00	303.6638
19:25:01-19:26;59	294.7028
19:27;00-19:28:59	273.3971
19:29:00-19:30:59	254.0321
19:31:00-19:32:59	255.0136
19:33:00-19:34:59	262.9118
19:35:00-19:36:59	241.8068
19:37:00-19:38:59	229.2938
19:39:00-19:40:59	236.5828
19:41:00-19:42:59	230.2911
19:43:00-19:44:59	205.9161
19:45:00-19:46:59	218.1914
19:47:00-19:48:59	213.1196
19:49;00-19:50:59	205.0493
19:51:00-19:52:59	203.4083
19:53:00-19:54:59	221.7429
19:55:00-19:56:59	223.4019
19:57:00-19:58:11	209.4513
19:58:12-19:59:59	206.7813
20:00:00-20:01:59	194.5862
20:02:00-20:03:59	190.8927
20:04:00-20:06:08	167.9589

Table 17: Averaging of GSR sensor data of subject B under 5000k

Under the specified condition, GSR sensor recorded 4544 values under the time span of 19:21:28-20:06:08 pm. The above table is the representation of average values under some of the time spans. Average of all these values under the correlated colour temperature 5000k of subject B is 233.

Average GSR data of both the subjects under three specified correlated colour temperature:

CCT(k)	Subject A	Subject B
3000	113	156
4000	179.5	18
5000	261	233

Table 18: Total average of GSR sensor data of both the subjects under all three CCT's

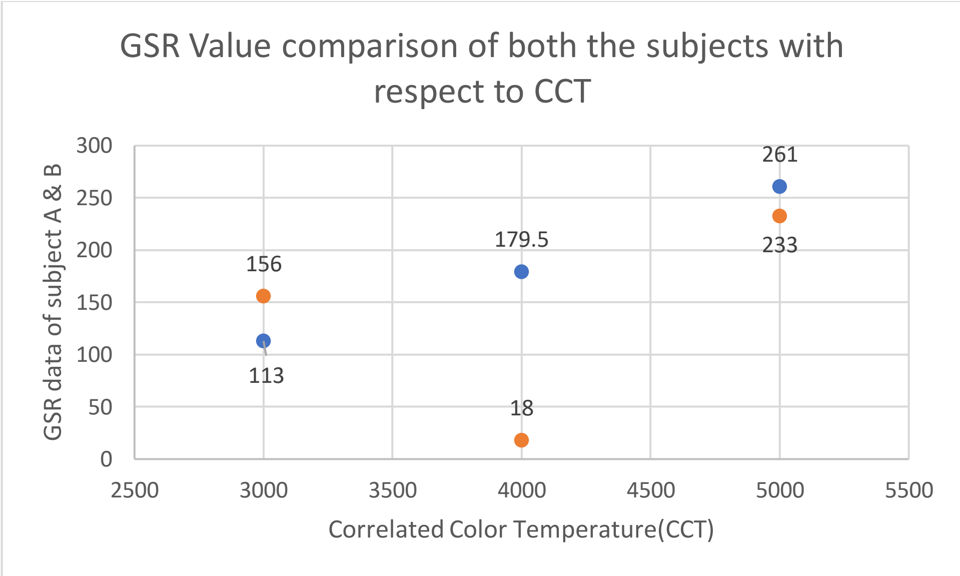


Figure 18: Comparison plot between GSR values of two subjects under three conditions (Blue dot for subject A and orange dot for subject B)

Chess is a game of memory, concentration and intelligence. During match players goes through lot of emotional activities. A accurate or good move create positive activity, on the other side mistakes create negative activity and anything can happen throughout the match. The values of a galvanic skin response (GSR) sensor depicts insight into the autonomic nervous system activity. High GSR value indicates positive arousal in terms of excitement or anticipation. Increment in focus and concentration, implies strong emotional response, Whereas low GSR values depicts low emotional engagement, situations where a individual not experiencing any excitement or intensity of the situation. High GSR value indicates increment in the skin conductance, whereas low GSR value indicates decrement in the skin conductance.

5.1.b Game analysis:

Inaccuracy, mistakes, blunders, average centipawn loss, accuracy these are some of the terms related to chess game analysis. Inaccurate implies a move which is disadvantageous at that time in the perspective of the match, mistakes may imply from winning position to again even position and blunders means more bigger mistake which may leads to lose the match. Average centipawn loss generally means how much value a player drops by making incorrect moves during the match.

Match1 under 3000k CCT, Subject A(EEG) vs Subject B

Parameters	**Subject A (White)**	**Subject B (Black)**
Inaccuracy	01	05
Mistake	01	00
Blunders	00	01
Average centipawn loss	18	36
Accuracy	92%	83%

Table 19: Performance analysis of subject A under 3000k

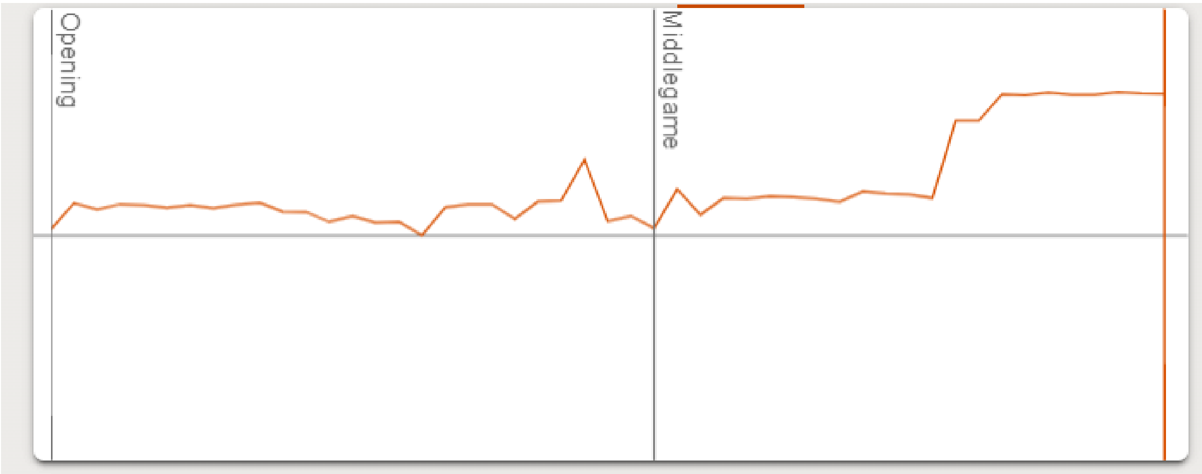


Figure 19: Performance graph of subject A under 3000k

The accuracy of subject A is more, as subject made one blunder at the 20th move, f5 was the best move according to the situation. The above graph represents the status of the match, curve over line the means advantage for white and under the line means advantage for black. As per this match, white was on the advantageous position throughout and the spike after in the curve the midgame depicts more chances of win for white at that stage.

Match2 under 3000k CCT, Subject B(EEG) vs Subject A

Parameters	**Subject A (Black)**	**Subject B (White)**
Inaccuracy	01	02
Mistake	01	00
Blunders	01	02
Average centipawn loss	28	80
Accuracy	86%	65%

Table 20: Performance analysis of subject B under 3000k

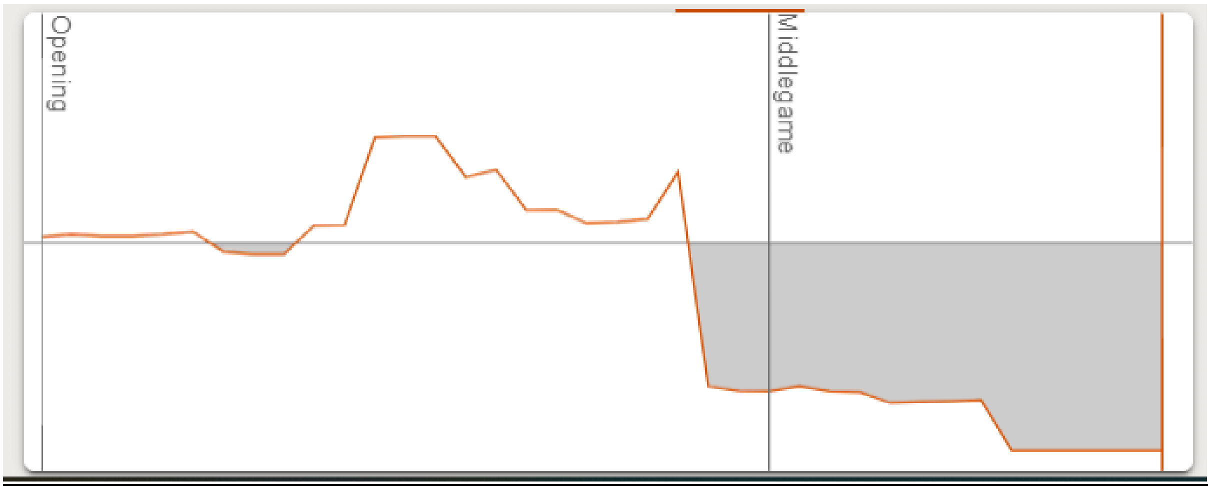


Figure 20: Performance graph of subject B under 3000k

Again the accuracy for subject A is more, as subject B made two blunders at the 12th and 17th move, Na3 was the best option instead of Be3 at 12th move and Kg1 was best in place of Bf3 at 17th move. The graph implies that from the opening white was in advantageous position but just before the midgame black took the charge of the match as white made back to back two blunders.

Match1 under 4000k CCT, Subject A(EEG) vs Subject B

Parameters	Subject A (White)	Subject B (Black)
Inaccuracy	04	05
Mistake	03	02
Blunders	02	01
Average centipawn loss	58	29
Accuracy	78%	88%

Table 21: Performance analysis of subject A under 4000k

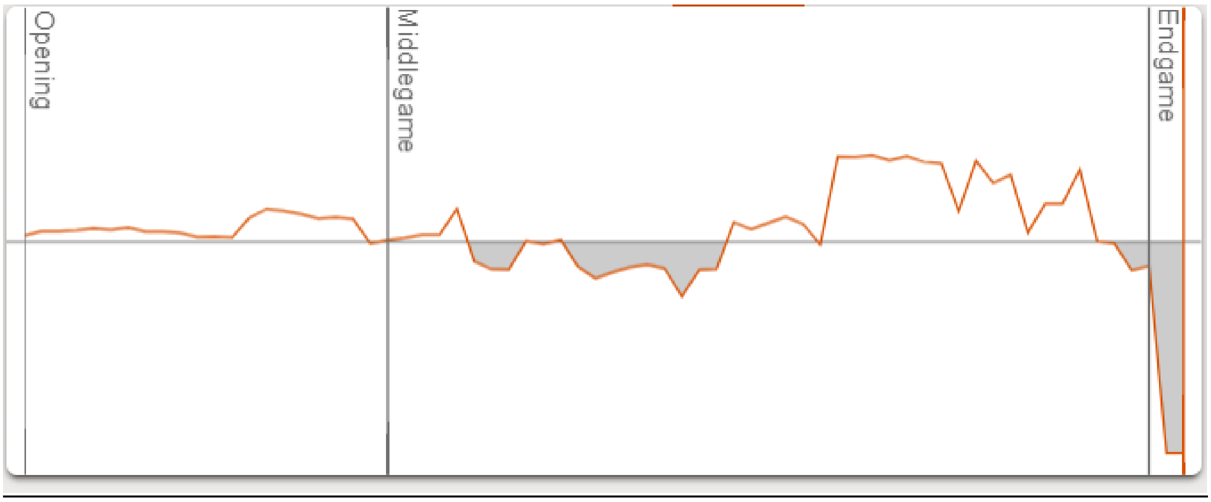


Figure 21: Performance graph of subject A under 4000k

This match was quite tight one as black made more inaccurate moves, but white made two blunders. Subject B has more accuracy in the match. After the midgame it was become quite competitive between the two players, as black made blunder move by giving Bc5 instead of Rd5, but in the white made more blunder by placing Nac4 instead of Nac6+. Nac6+ means knight moves from the a position to c6 position and threatening the opponents king. Subject B was more accurate.

Match2 under 4000k CCT, Subject B(EEG) vs Subject A

Parameters	Subject A (Black)	Subject B (White)
Inaccuracy	06	05
Mistake	00	00
Blunders	00	03
Average centipawn loss	24	47
Accuracy	93%	85%

Table 22: Performance analysis of subject B under 4000k

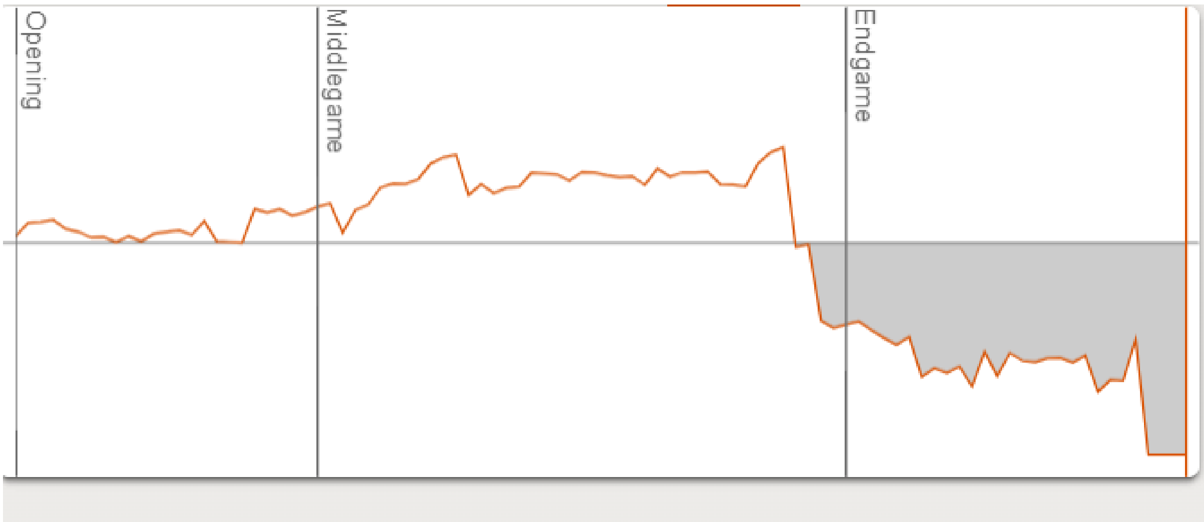


Figure 22: Performance graph of subject B under 4000k

Subject A was more accurate, as subject B made blunders just before the endgame. From the endgame black dominated the match. Subject A (White) made back to back blunders at the 32th and 33th move by placing Qb8 and Ra5 instead of Ra6 and Na5, also made big mistake at 46^{th} move.

Match1 under 5000k CCT, Subject A(EEG) vs Subject B

Parameters	Subject A (White)	Subject B (Black)
Inaccuracy	01	02
Mistake	00	01
Blunders	01	02
Average centipawn loss	23	40
Accuracy	91	82

Table 23: Performance analysis of subject A under 5000k

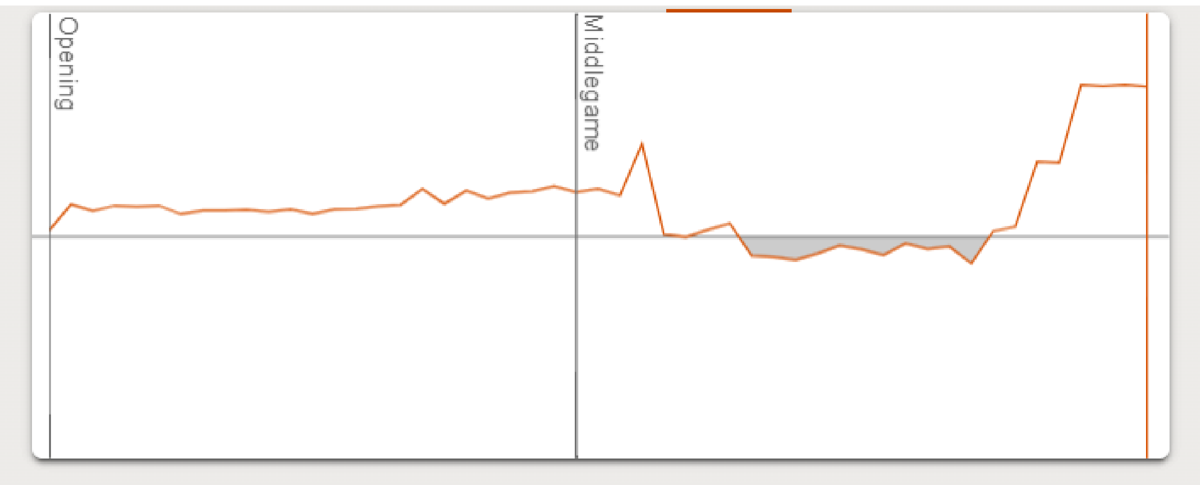


Figure 23: Performance graph of subject A under 5000k

Subject A was more accurate, from the opening white was on the good position, after midgame black tried to comeback but made blunder, white takes the match. Black made back to back blunders in the 23rd and 24th move by not placing Be4 and Qf7.

Match2 under 5000k CCT, Subject B(EEG) vs Subject A

Parameters	Subject A (Black)	Subject B (White)
Inaccuracy	05	06
Mistake	00	03
Blunders	04	01
Average centipawn loss	62	46
Accuracy	70	81

Table 24: Performance analysis of subject B under 5000k

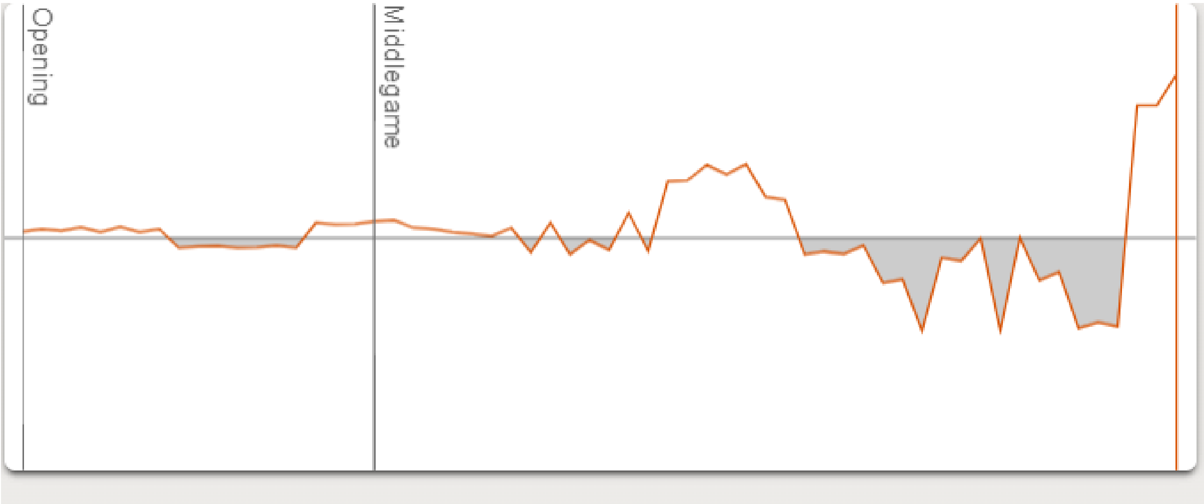


Figure 24: Performance graph of subject B under 5000k.

Subject A was less accurate than subject B, subject A made more blunders. But subject A resigned after the 30th move.

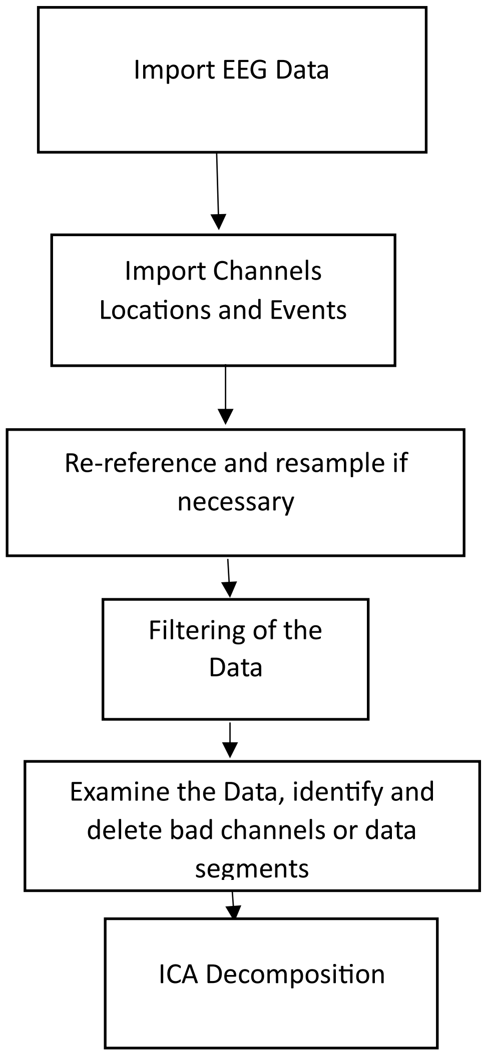
5.1.c EEG Analysis:

In this study, preprocessing of the EEG data has been done. The preprocessing part consisted of several steps which includes importing events and channel locations, re-referencing, filtering, removal of artifacts and ICA decomposition. First, EEG data obtained during the experiment needs to be imported in the EEG lab, then unnecessary channels were selected and deleted. Then the channels locations and events should be imported, after that the raw data should be re-referenced, filtered and examined visually. Bad channels needs to be identified and deleted using several methods. Artifacts such as eye blinks, high noise, muscle artifacts should be identified and deleted by selecting them from the plot and pressing the reject button.

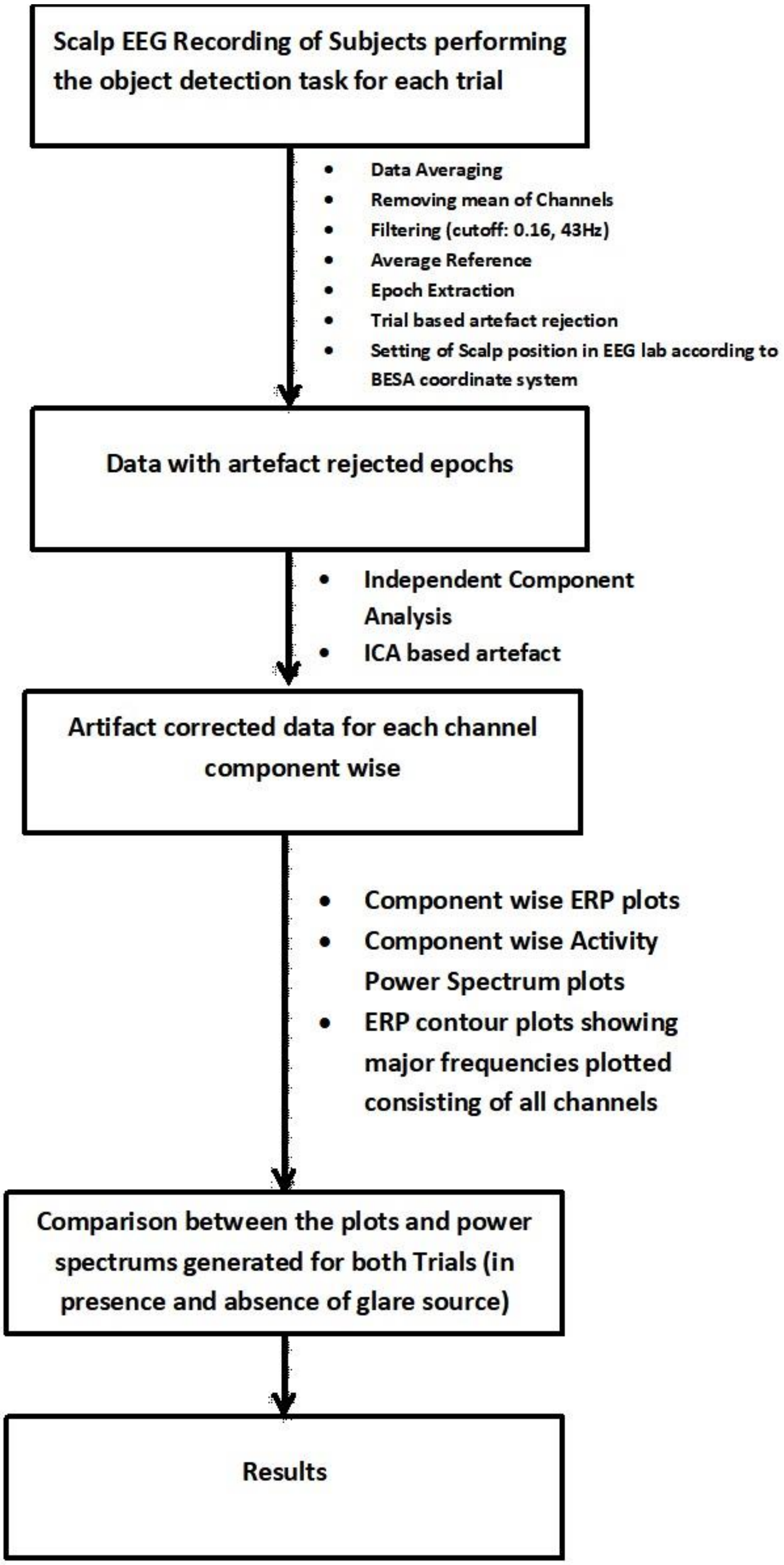
After ICA has been done by selecting decompose data by ICA option from the tools menu. Independent Component Analysis (ICA) is used to subtract artifacts embedded in the data (muscle, eye blinks, or eye movements) without removing the affected data portions.

Generally ICA is a signal processing method to separate independent sources linearly mixed in several sensors.

Detailed preprocessing flowchart as follows:



Detailed flowchart of the EEG analysis procedure:



Different colours in the power spectral density curve provides idea about the degree of engagement of brain regions while doing the given task. Red colour indicates maximum engagement and other colours indicates other level of engagements.

Power spectral density curves of Subject A under three correlated colour temperature:

CCT: 3000k

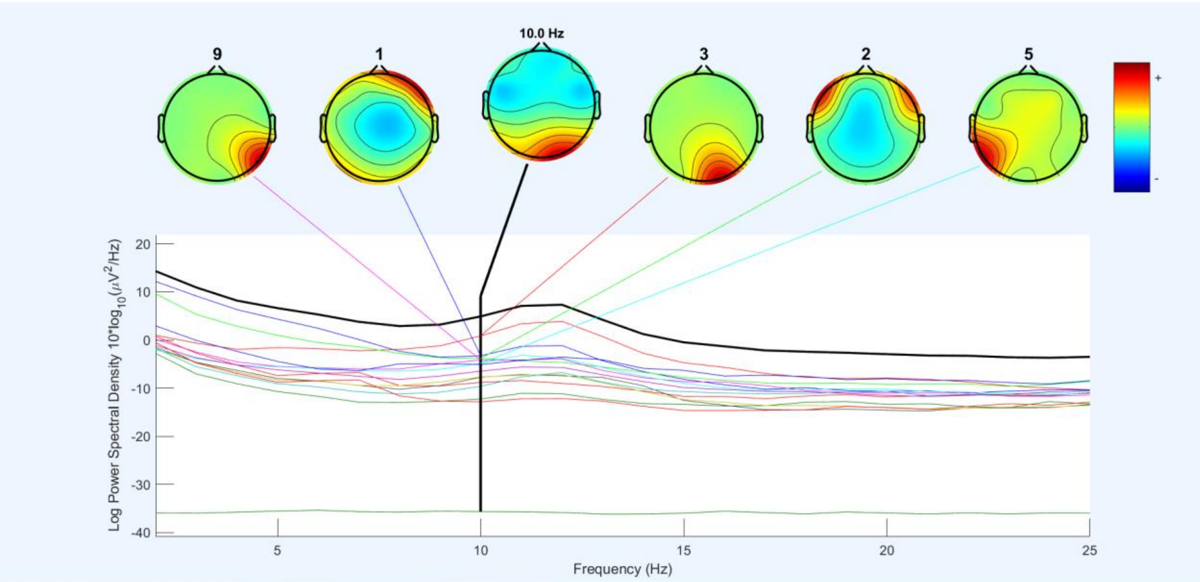


Figure 25: Power spectral density curve of subject A under 3000k

CCT: 4000K

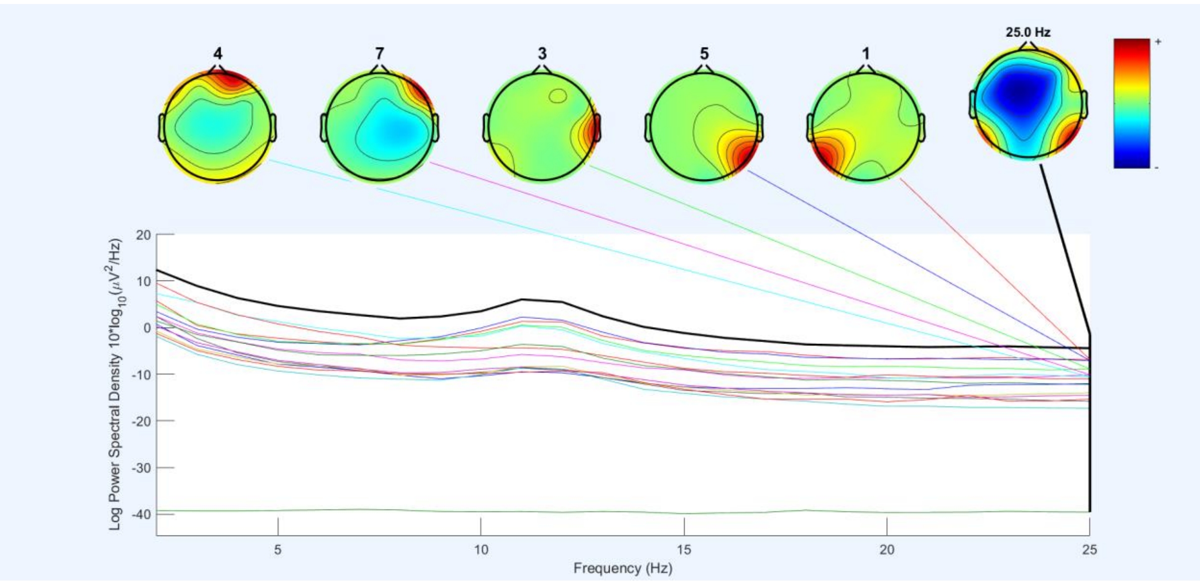


Figure 26: Power spectral density curve of subject A under 4000k

CCT: 5000K

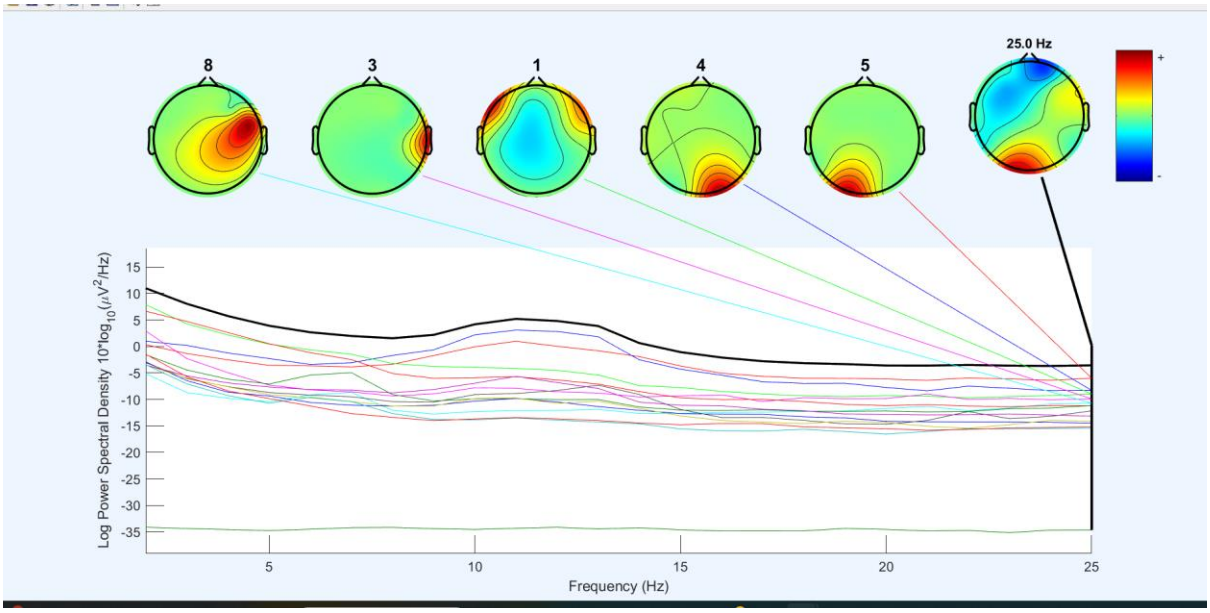


Figure 27: Power spectral density curve of subject A under 5000k

From the above curves, it can be observed that, peak found 10-15Hz region. The engagement is little more around 5000k, concentration and attention increased. Very significant difference in the engagement is not found under three CCT's, player was more or less focused under all three CCT's.

Power spectral density curves of Subject B under three correlated colour temperature:

CCT: 3000K

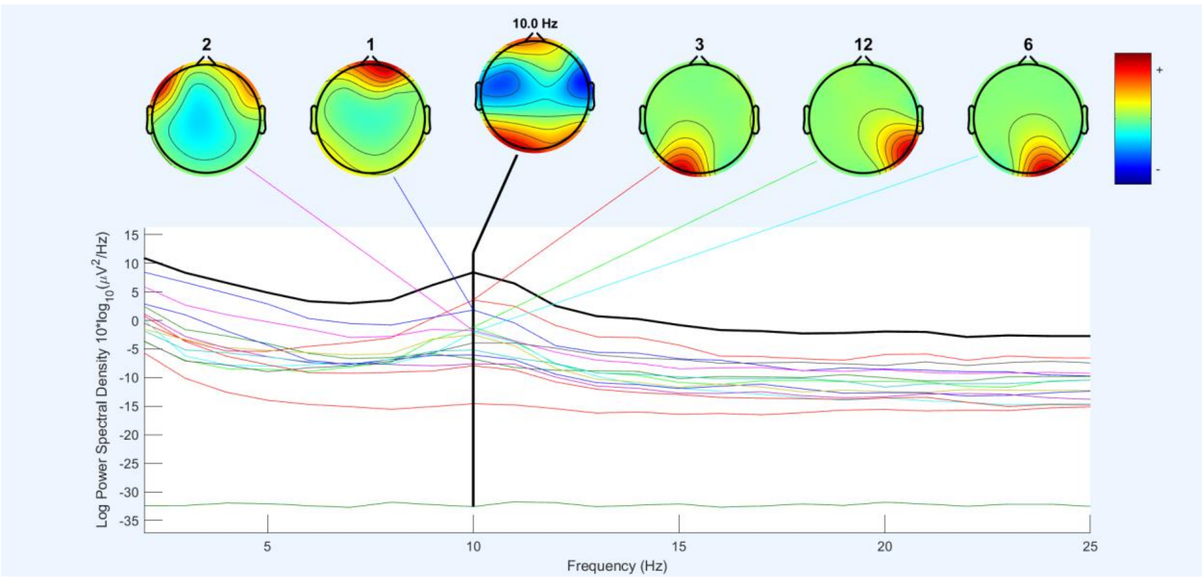


Figure 28: Power spectral density curve of subject B under 3000k

CCT: 4000K

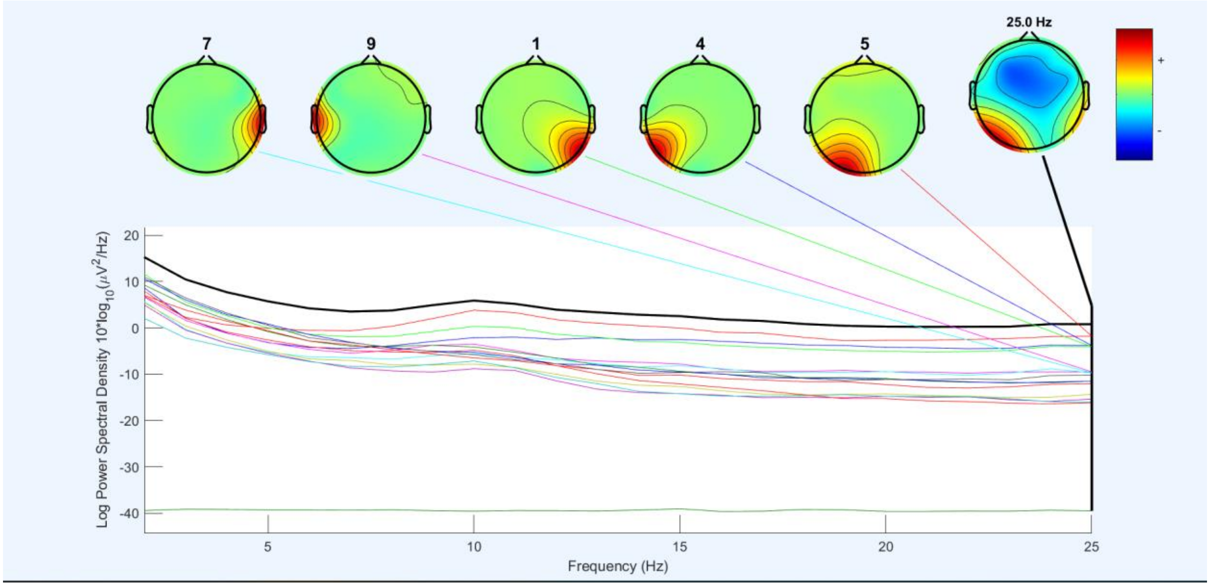


Figure 29: Power spectral density curve of subject B under 4000k

CCT: 5000K

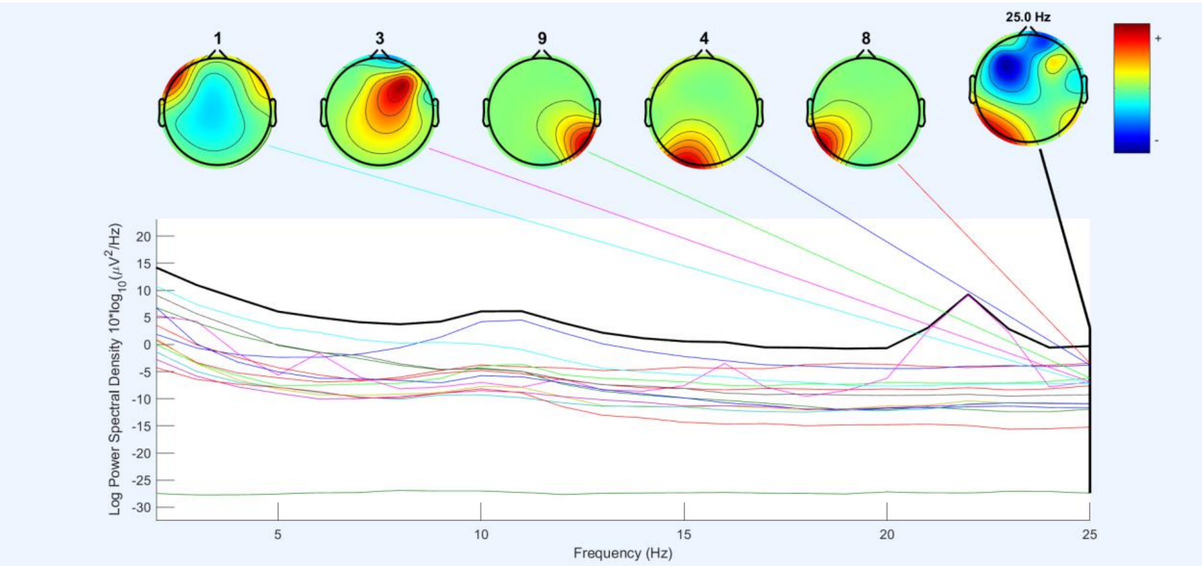


Figure 30: Power spectral density curve of subject B under 5000k

Same for subject B, engagement found more under 5000k, a significant peak around 22.5 Hz (Beta range) is found. At 3000k and 4000k, peak found around (10-15)Hz.

It can be conclude that, concentration increased little bit when the correlated colour temperature varied from warmer to cooler range. The engagement with the game playing was more under 5000k.

CHAPTER 6

6.1 Conclusion and Future scope of the work:

The objective of the thesis was to investigate the effect of different lighting conditions on the mood, attention and reaction time of the chess players and also to study their brain activity under specified lighting conditions. As the part of different lighting conditions, three different CCT's were used for the matches, varying from warmer to neutral to cooler range.

Galvanic skin response sensor was attached to the fingers of the participants during the matches to record their emotional arousal in respect to GSR values. GSR data showed that, value increased for subject A when the CCT was going from warmer to neutral to cooler range, which implies increment in the skin conductance. It means Subject A was more emotionally activate under cooler CCT range, compared to 3000 and 4000k. Also same happened for subject B, but at the 4000k CCT a significant decrement in GSR value observed for the subject B, which indicates less emotional attachment under 4000k for subject B.

In the game analysis part, highest average accuracy for subject A was observed at 3000k and at 4000k for subject B. For subject A, average centipawn loss was less at 3000k due to higher accuracy. At neutral white condition and more cooler CCT condition, the gap in the accuracy between subject A and B was tiny, but it was larger at 3000k.

For the brain response analysis using electroencephalography, detailed preprocessing was conducted. Analysis showed that, beta was more or less activated under all three conditions, little bit more under 5000k. Under all three CCT's, beta wave was strongly present at the occipital region, this region experienced a significant peak around 50 Hz, which implies presence of gamma wave. Presence of alpha wave was found more under 3000k in the different region of the brain. Alpha wave dominated temporal region under 3000k, but under 4000k and 5000k presence of beta wave was found more. As, chess is the game of concentration, players were found concentrated more or less under all three different CCT's.

Specifically, the current emotional state of a chess player much more dependent on the present status of the match. Emotional activity changes based on the match status, in this experiment results also shows that. Brain analysis shows that, players were little bit more concentrated under 5000k compared to 3000k and 4000k.

This thesis work has lot of future scopes and many more works in the field of analysis can be done. After the preprocessing stage, extraction of epochs and event related potential (ERP) analysis can be done in the future. To obtain accurate results related to analysis of the electrical signal of the brain responses average ERP of scalps can be plot for three specified CCT conditions in future. It will give more information about the mental state of the players and influence of different correlated colour temperature in the players during the games.

In this work, only two subjects were added, but for more clear picture more number of subjects who play chess professionally are required. Only one player worn the headset during the match under specified correlated colour temperature. It would be better if both players wear the EEG headset at the time of the match, it will provide more information about the mental state of the players and will clarify their thinking during the same match.

This study only included rapid chess game, but many other types of chess games are there. Subjects can participate in other chess games under time pressure, it will provide more information about behavioural study and EEG analysis in the future study.

Hence, chess is a very significant tool in the field of cognitive study, further research of chess game under lighting conditions will provide more outcomes which will be helpful for the chess training and lighting arrangements at the tournaments.

Chess, lighting conditions and neuro-cognitive study can be a important combination for upcoming neuroscience and illumination related researches. A chess model can be create with the help future researches to study the cognitive behaviour.

CHAPTER-7

7.1 References:

1. Book ‘Light and Work’, by Peter R. Boyce, Chapter 4, Human Factors in lighting

2. Neil Charness, ‘The impact of chess research on cognitive science’, Psychol Res (1992) 54:4-9

3. Angel Blanch, ‘Chess Instruction Improves Cognitive Abilities and Academic Performance: Real Effects or Wishful Thinking’, Educational Psychology Review (2022) 34:1371–1398

4. Alexander P. Burgoyne, Giovanni Sala, Fernand Gobet, Brooke N. Macnamara, Guillermo Campitelli, David Z. Hambrick, ‘The relationship between cognitive ability and chess skill: A comprehensive meta-analysis’, Elsevier

5. Elamaran, I., Velkumary Subramanian, Suchitra Balasubramanian and Chandrasekaran Kathiresan, ‘A COMPARATIVE STUDY OF PAPER AND PENCIL NEURO COGNITIVE TEST AND REACTION TIME IN ADOLESCENT CHESS PLAYERS AND NON-PLAYERS’, International Journal of Current Research, Vol.8, Issue, 11, pp.42174-42178, November, 2016

6. Ebenezer Joseph, Veena Easvaradoss, Suneera Abraham, & Sweta Vaddadi, ‘Malleability of Working Memory Through Chess in Schoolchildren— A Two-Year Intervention Study’

7. Singh S, ‘Chess and the human brain- Demystifying the therapeutic value of a board game’, Journal of High School Science

8. Pawel Stepien, Wlodzimierz Klonowski and Nikolay Suvorov, ‘Nonlinear analysis of EEG in chess players’, Stepien etal. EPJ Nonlinear Biomedical Physics (2015) 3:1

9. Santos Villafaina, Daniel Collado-Mateo, Ricardo Cano-Plasencia, Narcís Gusi, Juan Pedro Fuentes, ‘Electroencephalographic response of chess players in decision-making processes under time pressure’, Physiology and Behavior 198 (2019) 140-143

10. Juan Pedro Fuentes-García, Telmo Pereira, António Carvalho Santos, Maria António Castro, and Santos Villafaina, ‘Heart and Brain Responses to Real Versus Simulated Chess Games in Trained Chess Players: A Quantitative EEG and HRV Study’, International Journal of Environmental Research and Public Health

11. Laercio Silva Junior, Wilson da Silva, Carlos Thomaz, ‘Performance analysis of chess players comparing traditional and novel cognitive perception ranking measures’, 2021 34th SIBGRAPI Conference on Graphics, Patterns and Images (SIBGRAPI)

12. Michael J. Wright, Fernand Gobet, Philippe Chassy, Payal Nanik Ramchandani, ‘EXPERT-NOVICE DIFFERENCES IN ERP TO CHESS STIMULI, ERP to chess stimuli reveal expert-novice differences in the amplitudes of N2 and P3 components’

13. Laercio R. Silva Junior, Fabio H. G. Cesar, Fabio T. Rocha and Carlos E. Thomaz. ‘EEG and Eye Movement Maps of Chess Players’, 6th International Conference on Pattern Recognition Applications and Methods (ICPRAM 2017), pages 434-441

14. Juan Pedro Fuentes-García, Juan Luis Leon-Llamas, Narcis Gusi, Santos Villafaina, 'Are there neurophysiological differences behind the play of different chess modalities ?: An international grandmaster case study.', Physiology and Behavior 255 (2022) 113918

15. P. Rozario. B, Tamilmaran K., 'EEG ANALYSIS DURING PROBLEM SOLVING ACCORDING TO BLOOMS TAXONOMY LEVEL'

16. Zulfikar Dharmawan, 'Analysis of Computer Games Player Stress Level Using EEG Data', Man-Machine Interaction Group TU Delft August 2007

17. Suddhasatwa Chakraborty, Debtanu Ray, Ishan Palit, 'An EEG based comparative study on driver's performance under the influence of metal halide and high pressure sodium lighting', Optik- International Journal for Light and Optics 245 (2021) 167676

18. John C. White, 'A MATHEMATICAL ANALYSIS OF THE GAME OF CHESS A MATHEMATICAL ANALYSIS OF THE GAME OF CHESS', Spring 2018

19. J. S. Kumar, P. Bhuvaneswari, 'Analysis of Electroencephalography (EEG) Signals and Its Categorization- A Study', Procedia Engineering 38 (2012) 2525-2536

20. Di Fan, Mingyang Liu, Xiaohan Zhang, Xiaopeng Gong, 'HumanEmotion Recognition Based On Galvanic Skin Response signal Feature Selection and SVM'

21. María Viqueira Villarejo, Begoña García Zapirain and Amaia Méndez Zorrilla, 'A Stress Sensor Based on Galvanic Skin Response (GSR) Controlled by ZigBee', Sensors 2012, 12, 6075-6101

22. Dr. Anand Hindolia, Shakti Leekha, 'ARTIFICIAL INTELLIGENCE: APPLICATION TO LIGHTING PRODUCTS', International Journal of Management (IJM) : Volume 11, Issue 7, July 2020, pp. 1175-1185, Article ID: IJM_11_07_104

23. W.U.Weitbrecht, H. Bärwolff, A. Lischke, S. Jünger, 'Effect of Light Color Temperature on Human Concentration and Creativity' , Fortschr Neurol Psychiatr 2015; 83: 344–348

24. Xiaoyun Fu, Di Feng, Xu Jiang and Tingting Wu, 'The Effect of Correlated Color Temperature and Illumination Level of LED Lighting on Visual Comfort during Sustained Attention Activities'

25. Qing Wang, Haisong Xu, Fuzheng Zhang, Zhehong Wang, 'Influence of color temperature on comfort and preference for LED indoor lighting', Optik 129 (2017) 21-29

26. Herbert A. Simon, William G. Chase. 'Skill in Chess', American Scientist

27. Herbert A. Simon, William G. Chase, 'Perception in Chess', COGNITIVE PSYCHOLOGY 4, 55-61 (1973)

28. Mr. Ashim Datta, Dr. Biswanath Roy, 'SPORTSLIGHTING- FUNDAMENTALS AND DESIGN CONCEPTS' 35th ANNUAL NUMBER SEEAWB

29. FIFA Lighting Guide

30. Amrita Saha, Debabrata Paul, Roni Jana, Soham Datta, Amartya Roy, 'Design and Development of Energy Efficient Lighting Controller', International Journal of Computer Sciences and Engineering, Vol.-7, Special Issue-18, May 2019

31. NLC 2010 SP 72:2010

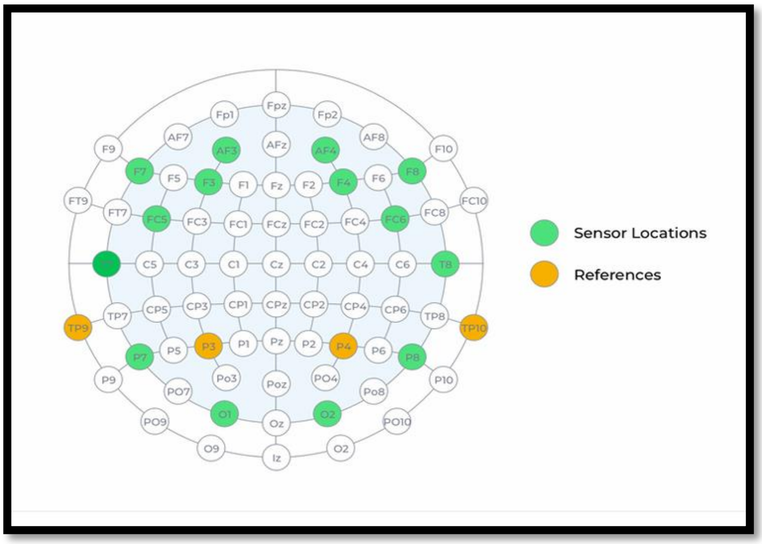
CHAPTER-8

8.1 Annexure:

Apparatus Used:

EEG Headset:

Figure 31: Emotive Epoch X EEG Headset



A Emotive Epoch X headset was used to record the brain activity of the subjects during the matches.

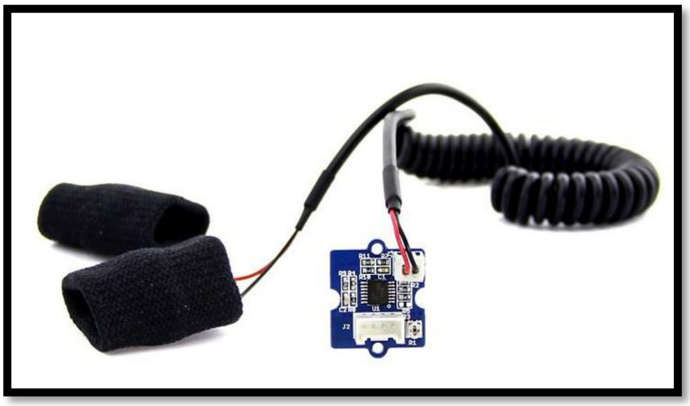
Description:

- 14 channels are AF3 F7 F3 FC5 T7 P7 O1 O2 P8 T8 FC6 F4 F8 AF4
- CMS/DRL references at P3 and P4
- Sampling method: Sequential sampling, Single ADC

- Sampling rate: 128 SPS/ 256 SPS (2048 Hz Internal)
- Filtering: Build-in digital 5^{th} order sinc filter
- Bandwidth: 0.2-45 Hz, digital notch filters at 50 and 60 Hz
- EEG Resolution: 14 bits, 1LSB= 0.51μV (16 bit ADC, 2 bits instrumental noise floor is discarded), settings can be changed to 16 bit.
- Dynamic range: 8400uV (pp)
- Couling method: AC coupled
- Impedance measurement: Real-time contact quality using patented system
- Sensor material: Ag/AgCl, felt pads soaked in saline

GSR sensor:

Figure 32: Galvanic Skin Response Sensor



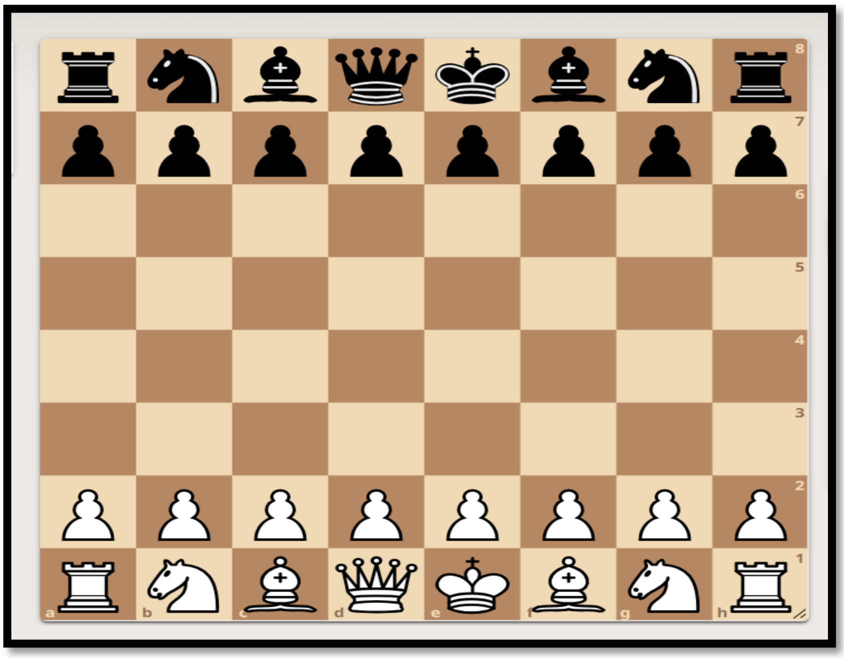
Galvanic skin response sensor used to measure the electrical conductance of the skin based on the sweat gland. GSR sensor helped to record different emotional activity during the matches.

Output signal: Voltage, Analog reading

Human Resistance conversion: (1024+2Serial_Port_Reading)10000/(490-Serial_Port_Reading)

Chess board and clock:

Figure 33: Chess board and Clock



The chess game is played on a board consisting of 64 squares. There are 16 white and 16 black pieces, each player has eight pawns, two castles, two knights, two bishops, one queen and one king.

Chess clock keeps the track of remaining time a player has in a game. Time for one player runs at a time.

Laptop:

Figure 34: Laptop

One laptop was used to record the EEG data, one investigator controlled the laptop throughout the match. EEG headset was controlled through Emotive software which was installed in the laptop.

EEG raw data information:

Figures 35-37: Subject A EEG Data

Channels per frame	14
Frames per epoch	259357
Epochs	1
Events	528
Sampling rate (Hz)	128
Epoch start (sec)	0.000
Epoch end (sec)	2026.221
Reference	average
Channel locations	Yes
ICA weights	Yes
Dataset size (Mb)	16.9

Channels per frame	14
Frames per epoch	337956
Epochs	1
Events	207
Sampling rate (Hz)	128
Epoch start (sec)	0.000
Epoch end (sec)	2640.275
Reference	average
Channel locations	Yes
ICA weights	Yes
Dataset size (Mb)	21.8

Channels per frame	14
Frames per epoch	229977
Epochs	1
Events	226
Sampling rate (Hz)	128
Epoch start (sec)	0.000
Epoch end (sec)	1796.690
Reference	average
Channel locations	Yes
ICA weights	Yes
Dataset size (Mb)	14.9

Figures 38-40: Subject B EGG Data

Channels per frame	14
Frames per epoch	122239
Epochs	1
Events	111
Sampling rate (Hz)	128
Epoch start (sec)	0.000
Epoch end (sec)	954.986
Reference	average
Channel locations	Yes
ICA weights	Yes
Dataset size (Mb)	8

Channels per frame	14
Frames per epoch	326973
Epochs	1
Events	189
Sampling rate (Hz)	128
Epoch start (sec)	0.000
Epoch end (sec)	2554.470
Reference	average
Channel locations	Yes
ICA weights	Yes
Dataset size (Mb)	21.1

Channels per frame	14
Frames per epoch	305400
Epochs	1
Events	174
Sampling rate (Hz)	128
Epoch start (sec)	0.000
Epoch end (sec)	2385.931
Reference	average
Channel locations	Yes
ICA weights	Yes
Dataset size (Mb)	19.7