Aspects of Cognitive Neuroergonomics and Human Factors in the Operators of Electric Power Control and Operation Centers: Case Study in Brazil

Melo, Miguel; Bueno, Luiz; Torro, Nelson; Souza, Erivaldo
Federal University of Paraiba, Cidade Universitaria, João Pessoa-PB, 58051-900, Brazil
mobcmelo@ct.ufpb.br

ABSTRACT: The operators of Electric Power Control and Operation Centers has activities very complexes and with a large cognitive workload. A error can cause failures that result in significant economic losses, physical damage, or threats to human life. Taking into account the cognitive aspects that require that operator attention and accuracy are fundamental for the implementation of its activities, it can be concluded that certain levels of requirements in a given time can cause possible errors that may cause harm to the electrical systems. The research used a sample of operator Control Centers in North Eastern Brazil. It was used the measures with a Eletroencefalogram (EEG) equipment EMOTIV Insight 5 Channel Mobile of six cognitive variables: Stress, Engagement, Focus, Interest, Relaxation and Excitement. Also, It was used the NASA-TLX method to obtain information on the following variables of work perception: MD (Mental Demand), RP (Requirement Physics), TR (Temporal Requirement), LA (Level of Achievement), LE (Level of Effort) and LF (Level of Frustration). The results of MD and LE were high. The Attention and Concentration variables there was an increase in the average value measured before the beginning of the workday and after the six-hour shift of 17% and 11% respectively. There was also a 4% reduction in Stress Level. These results provide support for the preparation of a new working methodology for the operators of the Electric Power Control and Operation Centers and contributing to a reduction of human error operation and better quality system.
Keywords: Workload; Ergonomics; Mental Demand; EEG Measurement; NASA-TLX.

1. INTRODUCTION

One of the major challenges that companies increasingly face is related to the health and well-being of workers especially those directly related to the operation and maintenance of electrical systems. These technicians have to perform tasks that mobilize knowledge and reasoning for which they received training, which from the point of view of the current rules are adequate. In these systems, a confusing Human Machine Interface (HMI) with an operator can result in misinterpretation and induce errors during decision making. There are some factors that need to be improved because there are still accidents and incidents caused mainly by high workload that may lead to fatigue and decreased attention and concentration (Vieira, *et al*. 2009).

May (2008) in turn highlights the complexity of the HMI in the Operation and Control Centers, for the following operational technical reasons:

1-Greater integration and increase the size of the national and regional networks,

2-Increased level of automation involving distributed measurements and automatic decisions.

3-Increased complexity of coordination due to the implementation of optimal power flow based on the electricity markets.

4-Increased demand for resilient energy networks, in the form of permanent "micro-networks" or "islanding" that can help protect the largest voltage instability networks.

5-Other complications include the maintenance condition of transmission and distribution and the lack of qualified operators in the control room and updated procedures and training.

Demand for power generation sustainable leading to an increased number of sources variable power generation with low predictability, for example, power wind.

Figure 1 shows a typical installation of an Electric Power of Operation and Control Centers.

Figure 1.Typical Installation of a Room of the Electrical Power Control and Operation System (source: ONS, 2014).

In these systems, an interface with the operator who seems confused can result in misinterpretation and induce errors during decision making. Therefore, these systems require quality, safety, adaptability to different users and levels of experience, and training facility associated with their learning and use (VIEIRA et al. 2010).

The state of the art presents several aspects and definitions about fatigue and also the concentration of the control room operators of the electric substations. It can initially be understood as a set of manifestations produced by work, or prolonged exercise, resulting in decreased functional capacity to maintain or continue the expected performance. The term fatigue has been defined, physiologically in some research, as the inability to maintain the power of income. The fatigue is also relationship from the point of view of ergonomic aspects, workload and physical (REBELO et al. 2003a, 2003b)

Thus, several factors act in conjunction with different degrees of influence and contribute to the development of fatigue depending on the type of work performed, such factors may be according to the duration and intensity of work, individual's physical capacity, diet, environmental conditions (OLIVEIRA, 2009).

Another factor that contributes to fatigue is shift work. This kind of activity can cause sleep disorders, gastrointestinal disorders, cardiovascular and psychiatric disorders, and in relation to social and family life, we highlight the damage in organized social activities such as education, culture, sports, among others. In addition, night work can cause severe sleepiness, reduced performance, and the risk of major accidents (AKERSTEDT, 1998; BAULK, 2009). The concept of mental workload is related to Cognitive Neuroergonomics, as this branch deals with cognitive aspects related to the task (MURATA, 2005; CAÑAS, 2010, DI STASI, 2011; MEIMAN, 1997).

Neuroergonomic is the scientific discipline that studies the cognitive processes in the design of technology and the environment in which present technology is used by people. It is an emerging science that is defined as the study of the human brain in relation to performance at work and in everyday settings. This concept has emerged with the increasingly rapid technological development in the present times and the nature of work. The types of tasks used by workers are increasingly characterized by the high demand for cognitive components, especially those related to memory, attention and problem solving, associated with the accuracy of information content and speed of care. (METHA, R. K; PARASURAMAN, RAJA, 2013; CAÑAS, 2008).

Thus, we seek to understand human cognition in a situated and finalistic way, that is, in a context of action and focused on a specific goal. Therefore, the processes must be researched in order to understand how the worker manages his work and the information available so that from this starting point the articulation that he builds and that leads him to perform certain action is understood. During the analysis and intervention procedure, the capabilities and limits should be considered, both those related to the physiological and cognitive nature of the individual, thus explaining the genesis of errors and incidents attributed to human failure (QUESADA et al., 2003).

2.MATERIALS AND METHODS

The methodology used a sample of operators of Control Centers with 32 operators in Northeastern Brazil. NASA-TLX method questionnaires were given to evaluate the ergonomics aspects and to obtain information on the following variables: MD (Mental Demand), RP (Requirement Physics), TR (Temporal Requirement), LA (Level of Achievement), LE (Level of Effort) and LF (Level of Frustration), as shown Table 1.

Table 1 – Factors considered in the NASA-TLX Method
Source: Diniz (2003)

Factors considered	Low Limit Level 1	High Limit Level 20
Mental Demand	Tasks considered easy, simple, goals achieved without difficulties.	Difficult, complex tasks, requiring much mental effort to achieve the goal
Requirement Physical	Light, slow, easily accomplished tasks.	Heavy, quick, strong, and lively tasks.
Temporal Requirement	Slow and relaxed pace, with low pressure to the termination of activities.	Fast and furious pace, with lots of pressure for completing the activities
Level of Achievement	You become no satisfied and almost no one notices your work.	You feel very happy and are praised when it reaches the goals
Level of Effort	Surface concentration, muscle strength light weight, and simple reasoning are required	Deep concentration, muscle strength, intense, complex reasoning, and great skill are needed
Level of Frustration	You feel safe, happy, and relaxed when you run the task	You feel insecure, discouraged, angry, and bothered with the task

Pearson's linear correlation significance statistical methods were used and linear regression studies between the NASA variables. This correlation method was used due the normal distribution of the variables.

In the correlations between the six cognitive variable were calculated by the Kendall method

Next, psychometric tests were performed, composed of letters and symbols where the respondent marks the required letter or symbol. This application was performed before the beginning of the shift and at the end of the workday. Also, it was realized the measures with a Eletroencefalogram (EEG) equipment EMOTIV Insight 5 Channel Mobile of six cognitive variables:

- Interest: Measures how much you like or dislike something;
- Engagement measures how immersed you are in what you are doing or experiencing; Excitement: Measure of your mental stimulation;
- Stress measures: how comfortable you are with the current challenge you are facing; Relaxation is your ability to switch off and reach a calm mental state;
- Focus is your ability to concentrate on one task and ignore distractions.

It is noteworthy that the device is the only device in the consumer EEG category that measures the activity of all cortical lobes in the brain, providing detailed information that is usually found only in the complex and sophisticated research devices shown in Figure 2.

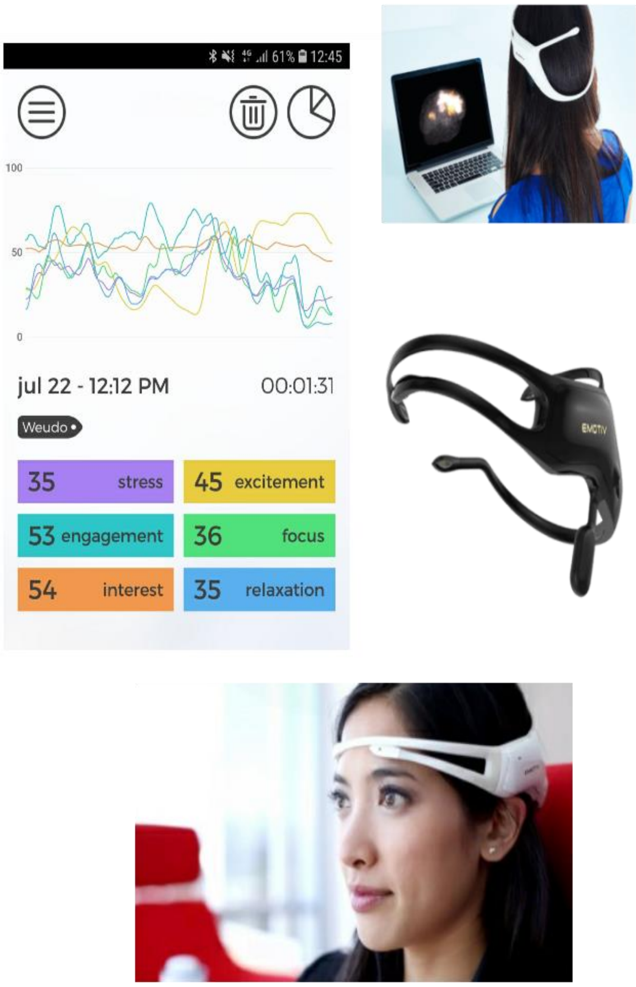

Figure 2 - Eletroencefalogram (EEG) equipment EMOTIV Insight 5 Channel Mobile of six cognitive variables.
Source: Emotiv (2019).

3. RESULTS

3.1 *Method NASA - TLX Variables*

Figure 3 shows the Method NASA-TLX indicators for an absolute value scale between 1 and 20, where 1 represents the smallest value and 20 the largest.

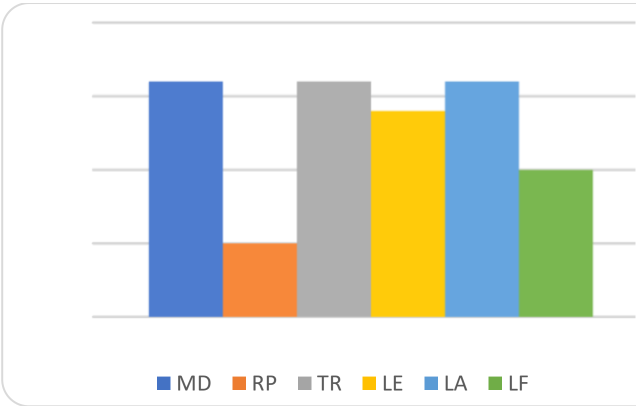

Figure 3 - NASA-TLX subjective assessment tools: MD (Mental Demand), RP (Requirement Physics), TR (Temporal Requirement), LA (Level of Achievement), LE (Level of Effort) and LF (Level of Frustration).

From the data in Figure 3, operator perception has some very high values. The variables Mental Demand (MD) and Temporal Requirement (TR) and Level Effort (LE) are high: 16, 16 and 14. Figure 4 presents a possible interpretation of the associations investigated in Figure 5 and explain the results of the significance tests Pearson's correlation coefficient.

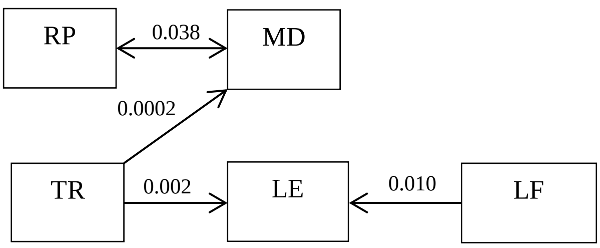

Figure 4 - Interpretation of the results of the significance tests Pearson's correlation coefficient.

Subsequently, a linear regression model was adjusted to measure the expected effect of a variation in Temporal Requirement (TR) on Mental Demand (MD). Figure 5 shows the model of linear regression. It describes well the higher Mental Demand (MD) tendency when having higher Temporal (TR) and also Level Effort (LE) and Temporal Requirement (TR).

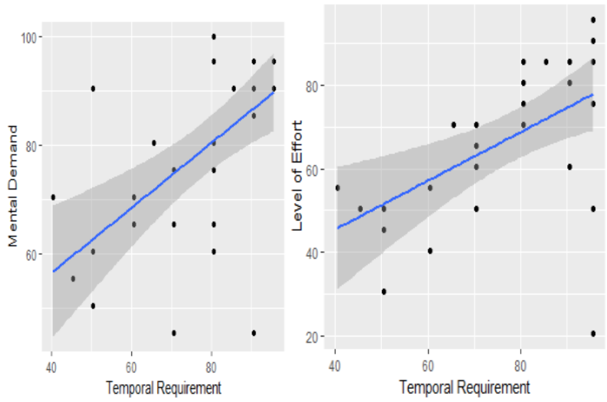

Figure 5 - Linear regression of Mental Demand (MD) Temporal Requirements (TR). and Level Effort (LE) and Temporal Requirement (TR)

3.2 *Results of Measures EMOTIV Insight 5 Channel Mobile EEG*

In the Figure 6 is shown a typical case of EMOTIV Insight 5 Channel Mobile measurement results for operators. The curves of the six cognitive variables: Stress (S), Engagement (En), Interest (I), Excitement Ex), Focus (F) and Relaxation (R) are presented. The average intensity value is shown on the scale from 1 to 100.

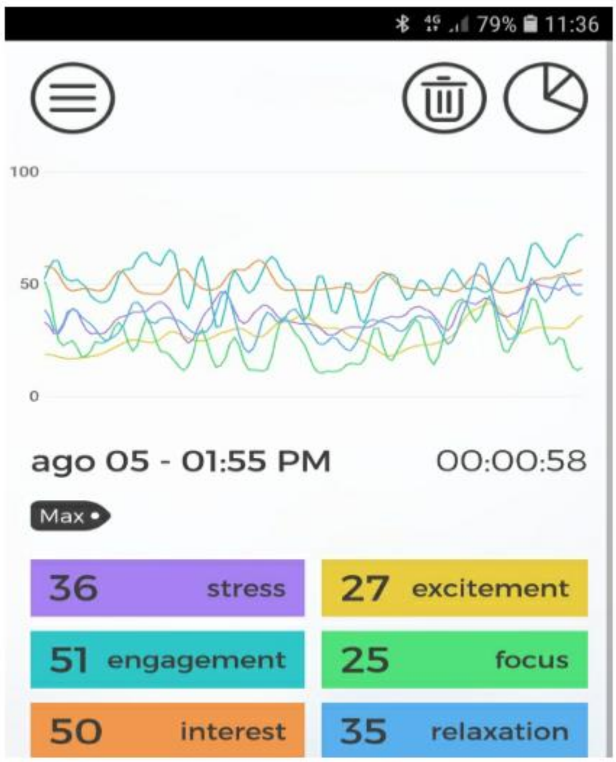

Figure 6 – Typical Measure of EEG of the curves of the six cognitive variables.

They were analyzed through statistical studies of the cognitive mean metric data measured by the Emotiv 5 EEG. These data are show in Figure 7 in the scale 1 to 100.

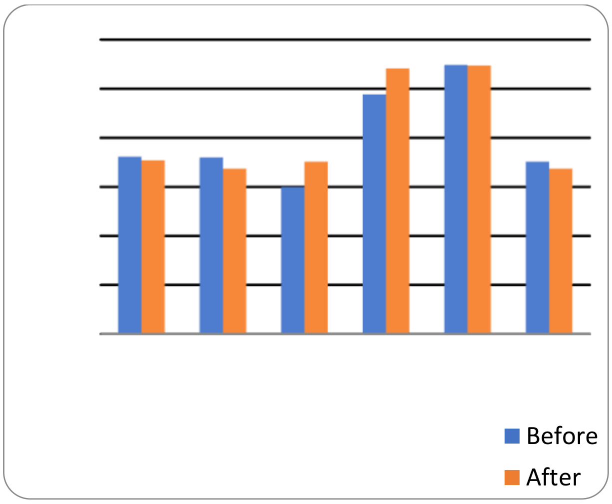

Figure 7 – Cognitive metric data measured by the Emotiv 5 EEG. Value measured before the beginning of the workday and after the six-hour shift.

By analyzing Figure 7, it can be seen that in the cognitive variables Focus (F) and Engament (En) metrics there was an increase in the statistical average value measured before the beginning of the workday and after the six-hour shift. By the data there was a 17% increase in Focus (F) level and 11% in Engagement (En) level. On the other hand, there was also a 4% reduction in the statistical average level of the Stress (S) variable at the beginning of the workday and after the six-hour shift.

We also investigated the correlations between the six cognitive variable recorded. The values were calculated by the Kendall method. We highlight a pair of metric that had significant correlation between Excitement (Ex) and Interest (I), as shown in Table 2.

Table 2 – Correlation between the six cognitive variables recorded by Emotiv Insight 5 Channel Mobile

	R	Ex	F	En	I
Ex	0.060	-	-	-	-
F	0.365	0.113	-	-	-
En	-0.070	-0.323	0.106	-	-
I	0.107	0.637	0.153	-0.235	-
S	0.854	0.123	0.222	-0.242	0.127

2. DISCUSSION

Operator perception data has some very high values. The variables Mental Demand (MD) and Temporal Requirement (ET) and level of Effort (LE) have high amplitudes of 16, 16 and 14 on a scale from 1 to 20. This characterizes a type of work with difficult, complex tasks, requiring a lot of mental effort to reach the goal.

There was an increase in the average value measured of the Focus and Engagement before the beginning of the workday and after the six-hour shift. From the data there was a 17% increase in Focus level and 11% in Engagement level. It is normally expected that after the work shift due to tiredness there will be a reduction in Focus and Engagement. However, this increase can be explained due to the characteristics of this type of work where operators are very concentrated throughout the shift.

There was also a 4% reduction in the absolute level of the Stress variable measured before the start of the workday and after the six-hour shift.

The correlation between Level of Effort (LE) and Temporal Requirement (TR) is significant, ie workers with a higher Temporal Requirement (TR) tend to have a greater perception of Level of Effort (LE) as well.

The correlation between the variables Mental Demand (MD) and Temporal Requirement (TR) is also important. Analysis indicates that the model describes the trend towards higher Mental Demand (MD) well when having higher Temporal Requirements (TR).

From the data analyzed, the perception of employees indicates that the work pace is high, as more than 56% are indicating an Level of Effort (LE) equal to or higher than 16.

Recording the data of the cognitive variables there is a significant correlation between Excitement (Ex) and Interest (I).

3. CONCLUSIONS

Taking into account the cognitive aspects required of the operator where attention and precision are fundamental for the execution of their activities, it can be concluded that due to certain levels of demands at a given time may lead to possible errors causing damage to the safety of the operators. electrical systems.

These results contribute to improve some procedures with an innovative character in human factors management of the Electric Power Control and Operation Centers operators. These new procedures include innovative topics for neuroergonomics assessment of fatigue and mental workload

This research provides data for the improvement of the strategic planning of the electric companies for a better adaptation of the activities of the operators of the Electric Power Control and Operation Centers, contributing to a reduction of the operation errors.

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