Ergonomics Analysis of a Control Room Operators' Workstation in an Electric Power Supply Company: An analysis of the Built Environment

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ABSTRACT

This article sets out an ergonomic analysis of the built environment of the control room of the Integrated Operations Centre (IOC) of a company that supplies electricity in the state of Pernambuco, Brazil. The Methodology of the Ergonomic Analysis for the Built Environment proposed by Villarouco (2009) was used as a research tool. As part of the study, the following forms of analysis were used: analysis of the physical aspects of the work environment, including taking measurements of noise, lighting and temperature; analysis of the problems identified and analysis of the user's perception. Suggestions for improvements to the workstation were proposed.

Keywords: control room, built environment, ergonomics

INTRODUCTION

The perspective taken by Ergonomics when studying the built environment is that of checking the variables that match the physical environment, the user and the tasks performed. The methodology of analysis of such an environment is based on understanding the functioning of human actions performed in the workplace with a view to identifying possible solutions to any problems encountered (Vasconcelos et al , 2010) .

Therefore, in conducting any human activity there must be a given space that can generate a positive or negative impact on the tasks that users perform (Villarouco and Andreto, 2008).

Thus, this article sets out the results for a control room that arise from applying the Ergonomic Method of Assessing the Built Environment (MEAC, in Portuguese), which was proposed by Villarouco (2011, 2012). MEAC aims at being able to adapt the environment to the user, thereby making the space more attractive and functional. The best way to solve this problem is to include ergonomics from the start of the stage for designing a physical environment, thereby taking into consideration individuals' physical, cognitive and psychological needs so that the environment may be adjusted to meet these needs.

Ergonomics when used early in the design of control rooms should be applied from the initial stages until completion, and include defining the work environments, the furniture, the computer equipment, configuring the screens and recruiting people and shaping and organizing work.

According to IIDA (2001), Ergonomics is the study of adapting work to people, and involves the physical

environment, the organization of how such work is programmed and controlled to produce the results desired. The adaptation occurs from work to people but the converse is not always true since there are difficulties in adapting people to work. It is in this context that research studies were conducted from the standpoint of ergonomics to evaluate the relationships among the workers in a control room of the hydro-electric sector and the systems with which it interacts in order to make an ergonomic analysis of the built environment. This was done by observing real work situations in the control room of a hydro-electric power supply company for which recommendations and proposals for improving and reorganizing the work environment will be made.

THE ACTIVITY IN CONTROL ROOMS

The activities performed in a control room directly affect people's daily lives worldwide. These services which are coordinated through control centers can be found for example where electricity and gas are supplied and in subway transport lines and air traffic control rooms.

In developing the design of control rooms, sometimes by including new technologies, thus changing the configurations of equipment, sometimes by transforming the layout of the physical space, it becomes important and appropriate to analyze the user´s practice and to learn about the work. Given this circumstance, this study provides a concise explanation of the characteristics of work in control rooms of an electric power system.

Vasconcelos, Soares and Martins (2008) argue that in the course of economic development, new technologies have emerged, the objective of which is to transform ways of organizing work and which require the operators to receive more training. This involves, according to the authors, a substantial change in the relationships between users and the means of production. Currently, modern communication systems and powerful computers make it possible to centralize several activities in a single control center.

Control rooms represent the fruit of this technological evolution, where transmission is carried out remotely by bringing together most commands and actions in one place.

A person´s task in a control room is essentially to be watchful. This involves interpretation, diagnosis and intervention in order to avoid potential problems that should be detected before they have serious consequences. Thus, operators deal continuously with information in order to diagnose and solve problems that occur in real time.

ERGONOMICS AND THE DESIGN OF CONTROL ROOMS

According to IIDA (2005), ergonomics is the study of adapting of work to human beings, and this includes the physical environment and its system of scheduling production.

Thus, Ergonomics is a reality designed to optimize solutions to difficulties by using methods and techniques that benefit from the expertise of scientific disciplines such as anthropometry, biomechanics, environmental comfort, physiology, cognitive psychology and some aspects of the organization of work. Thus, Ergonomics is seen to be an essential discipline in design practices for control room environments.

METHODS OF ANALYSIS

The use of an ergonomics methodology starts with a "field" activity, which analyzes the tasks and activities that a worker performs, by using several techniques based on understanding activities conducted in real work situations, and which respects the context and the human diversity of the participants.

In this regard, according to Villarouco (2007), aspects of the built environment highlight the importance of a proper ergonomic methodology. To evaluate the control room environment, the Method of Ergonomic Analysis of the Built Environment (MEAC, in Portuguese), proposed by Villarouco et al (2011, 2012), was used.

The research was conducted using the following methodological steps: (1) Global Analysis of the Environment (a questionnaire and a Walkthrough Analysis which help the researcher to form a first view); (2) Identification of the Environmental Setting (Surveys of the physical, furniture and equipment aspects); (3) Evaluation of the Environment in use (systematic observations, using photographs, film, diagrams); (4) Environmental Perception by the User (Constellation of Attributes); and (5) Ergonomic Diagnosis of the Environment and Recommendations. This last step corresponds to the comparison between the results of observing the interactions of the subjects under study and of the users' perception and finally recommendations for improving the performance of the environment are made.

In the context of perception and cognition, there are several instruments of analysis. In this study, use was made of the Constellation of Attributes (Moles 1968 apud Vasconcelos, Soares and Martins, 2008).

The problems were subsequently categorized by taking into consideration the different variations in workstations, the activities undertaken and the investigation of subsystems so as to characterize the human costs associated with the problems identified. After this step, recommendations were suggested for possible corrections of the problems detected.

Thus, this article puts forward an analysis of the built environment of a control room in an electric power company located in the metropolitan region of Recife-PE.

FIELD RESEARCH

The field research used measurements of the physical environment and data collected about equipment and workstations by means of direct analysis, interviews and questionnaires and relates these to the appropriate stage of the MEAC.

Global Analysis of the Environment

The activities were conducted in the Control Room of the Electrical System of the Integrated Operations Center (IOC) of a power supply company in the State of Pernambuco. The Control Room consists of two sections: the Dispatch of Services (two islands, comprising eight workstations each, one pair of operators for each bay of the station) and the Monitoring and Conducting Maneuvers (an island comprising four workstations, one employee for each bay of the workstation) (see Figure 1). The operational structure involves 4 supervision engineers, 45 controllers of the Dispatch of Services sector and 14 controllers of the Monitoring and Conducting Maneuvers sector.

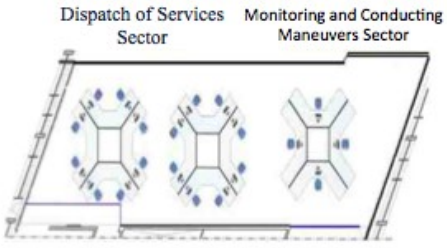


Figure1 – Layout of the control room of the two operational sectors

According to the researchers, the room has clean furniture, but the floor carpeting gives a sensation of breathing unhealthy air, since the site is closed off and has an air conditioning system.

The organization of the workstations is appropriate for the type of activity, and allows employees to communicate with each other, which leads to there being a pleasant sensation of staff collaboration. The organization of the equipment located on the furniture is appropriate.

The noise emitted by communication radios disturbs the concentration of the employees themselves and hinders their communicating with each other.

The purpose of the workstations jobs is: a) to promote meeting requests from the company's customers by managing real-time demand and the available resources; b) to act to re-establish loads should there be sudden occurrences in the system while paying great attention to efficiency, effectiveness and safety; and c) to control the interventions of order programmed in the system. The restrictions on these activities caused by physical environment may adversely affect operators' successful completion of the task.

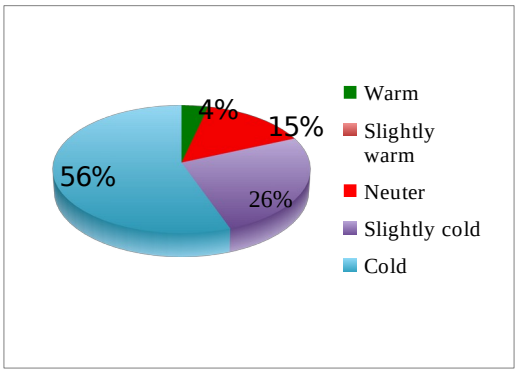
The operators work in eight-hour shifts, twenty-four hours a day per week. They monitor and conduct maneuvers in the system, using monitors, radios that communicate with satellites or GPRS and telephones with extensions of the substations in the metropolitan region of Recife.

The total staff consists of 28 employees who were interviewed (the available at the time of interviews) to obtain their views about the variables of environmental comfort for which the questionnaire on the user's perception was used.

When asked about luminal comfort in their workplace, a large majority of respondents (77.7%, *n*=21) rated it as comfortable. 14.8% (*n*=4) rated it as a little dark and 7.4% (*n*=2) as a little dim.

With respect to acoustic comfort, the opinions of these respondents were split. Slightly more than half (51.8%, *n*=14) considered there was a lot of noise, whereas 40.7% (*n*=11) said there was little noise. 7.4% (*n*=2) said there was neither noise nor silence. The main sources of noise mentioned were: radio (cited by 19 by respondents), telephones ringing (cited by 18 respondents) and people talking (cited by 14 respondents).

Graph 1 below shows the respondents' opinion regarding thermal comfort. As can be seen, most respondents (55%, *n*=15), considered that the environment was cold; 26% (*n*=7) that it was slightly cold. 15% (*n*=4) considered the environment was neutral and 4% (n=1) warm.



Graph 1 – Respondents' opinion with regard to the thermal comfort.

Identification of the Environmental Configuration

In this room, shown in Figure 2, next page, the inflow of people is through the front door and a corridor that allows access to all people, whether or not they have a disability.

The illumination of the site is made by artificial means, using fluorescent lamps and by natural means. During the day, some windows are opened such that sunlight enters, while on other windows, vertical blinds made of a white material block the external light.

Regarding ventilation, the whole environment is cooled by air-conditioning and there is no contact with the external environment to change and renew the air and accordingly, the researchers' perception was that the ambient temperature seemed pleasant.,

The environment is constructed with masonry and its walls are painted white. The floor is covered with a dark gray carpet. The arrangement of the lamps on the ceiling is adequate but burned-out lamps were noticed which cause the place to be poorly lit. The space is sufficient for people to move around within it.

There are between two to five computer monitors, each with a mouse pad, a keyboard and speakers plus a radio and telephone extensions on the white surface of the pieces of furniture.

Access to the bathroom and kitchen is outside the room and these are located on the same floor as the sector. The female and male toilets have two cabins that are not wheelchair accessible.

As part of the Physical Analysis of the Environment, measurements of noise, lighting and temperature were recorded. Measurements of such matters as lay-out, workstations, furniture, floor covering materials, walls, ceiling, colors, access conditions and safety were performed in the morning in the Dispatch Service Sector (five workstations in two islands of operation) and the Monitoring and Conduct of Maneuvers Sector (two workstations).

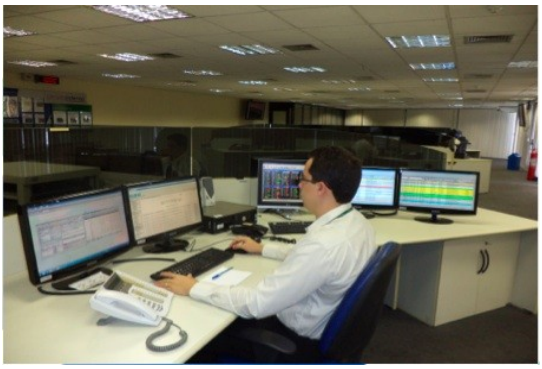


Figure 2 – Control Room of the Integrated Operations Centre.

For the analysis of noise, a Minipa digital decibel meter, model MSL-1325A was used. The internal noise measured was 70-74dB (A). As per NBR 10152 (2000), the indoor noise level is above that recommended for an administrative area. It should be 55 dB (A) during the day and 40 dB (A) at night. This reference was used because there are no specific data for work in the control room.

In analyzing the level of luminance, a Minipa digital light meter MLM-1011 was used. The level measured was 149 lux minimum and 281 lux maximum. As per NBR 5413 (1992), the illuminance level is below the recommended level for office environments which ranges from 750 to 1500 lux.

To measure the temperature, a Minipa digital thermal anemometer MDA-11 was used. A temperature of between 21.5 and 22.6ºC was obtained. As per NR-17 (2007), this temperature is suitable for office work.

Evaluation of the Environment in Use

Employees when active face postural problems, such as adopting a scoliosis posture, as shown in Figure 3, and a kyphotic one and torsions when seated and are using the telephone or computer or the five screens that monitor the electrical system. The seat height is inadequate for users in the lower percentile as their feet do not rest on the ground.

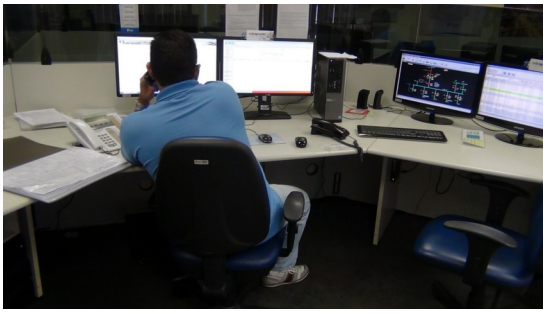


Figure 3 – Sitting posture of the employee.

Regarding the adjustment of the dimensions of the furniture to users, the application of average values is inadequate as the space is insufficient to accommodate legs, beneath the desks.

How the carpeting is cleaned is not adequate, this being carried out by using a broom, which causes particles of dust to be aispersed in the atmosphere which can then cause the spread of contagious diseases and the proliferation of bacteria and viruses due to poor hygiene.

The poor audibility of radio communication when the receiver is not digital can cause delays and/or errors when emergency decisions are being made and can fill the environment with excessive noise.

Noise from the radio reaches the value above the level recommended by NBR 10152 (2000) and the level of lighting is inadequate and below that recommended by NBR 5413 (1992).

The pace of work is intense and repetitive, with small breaks and the demand for precision is excessive which can cause decreased tolerance when decisions are being made, and thus may cause mental overload and work psychopathologies (depression, aggression and obsessiveness). The pressure of deadlines and controls can lead to stress and anxiety behaviors.

The environment does not have accessibility for the visually impaired .

Environmental Perception by the User

The step of Environmental Perception was conducted using the data obtained which contributed to the construction of the Constellation of Attributes.

According to Moles 1968 *apud* Vasconcelos, Soares and Martins (2008), the methodology of the Constellation of Attributes sets out to help design professionals by facilitating an understanding of knowledge of psychological aspects of the user arising from his/her working in the environment.

This experimental technique analyzes the spontaneous associations of ideas to identify the users' perception in relation to the space, through the images used by humans to describe or characterize the environment that is being used.

This method is based on an experimental technique that enables a graphical display of data that are arranged in a succinct and organized manner to be fully understood. This form of display, as in Figure 2, makes it possible to analyze the relationship of the attributes within the space evaluated.

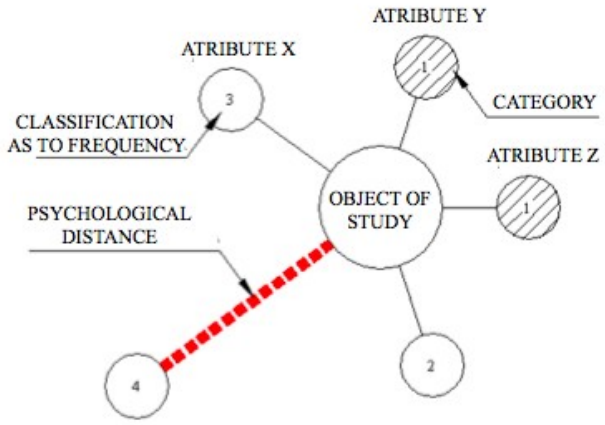


Figure 2 – Diagram of a graph of the Constellation of Attributes.

On analyzing the image, it is possible to identify that the degree of closeness to and/ or distance from the variables is modified in accordance with the proximity of the center, in which the object of study is schematized, and performs a more direct relationship to clarify the phenomenon of perception and adaptation of the space. Items placed at the greatest distance present the phenomenon in question with least attraction.

The Constellation of Attributes tool was used with 28 operators, with the aim of their expressing images and expectations about an imaginary and real environment in a control room as per the spontaneous characteristics and induced characteristics that are given below.

Spontaneous characteristics – 1 st step

This step examines the relationship of the user when he/she is in the space under investigation (Mafra, 1996) using the following question*:*

When you think of the control room environment, what are the ideas or images that come to your mind?

The responses obtained were arranged according to the number of appearances of the variables mentioned and were later plotted by setting the probability of appearance of each attribute (i) with the object evaluated (Pi) using the following equation:

$$Pi = \frac{\text{no of appearances of the attribute}}{\text{Total no. of responses}} \times 100$$

Pi – Probability of the association of the attribute.

Thus let the calculation of the following equation indicate the "psychological distance" that distances each attribute from the object of study:

$$D = \frac{1}{\log}$$

D = Psychological distance of the attribute, in centimeters.

Pi = Probability of the association of the attribute i.

Induced characteristics – 2nd Step

The second stage began with a new question that sets out to recognize the objective and subjective aspects in the user's perception. The question applied is associated with the object under study: *When you think of this electrical system control room, what ideas or images that come to your mind?*

Moreover in the second step, the elements that most inconvenience individuals are the ones that are repeated most. Data were grouped and classified as per the following categories: 1. Organizational aspects; 2. Comfort of the Environment; 3. Facilities; and 4. Equipment as per their affinities, as shown in Tables 1 and 2 next.

In accordance with the values obtained for the psychological distances of each attribute, two Constellations of Attributes were constructed that enable the operators' perception of their control room environment to be evaluated.

As per Vasconcelos, Villarouco and Soares (2010), the response categories were organized with colors as illustrated in Figures 3 and 4 below. It is worth noting that the space between the core and the attributes is directly proportional to the number of responses, where their location when nearest the core corresponds to the attribute most mentioned

in the answers.

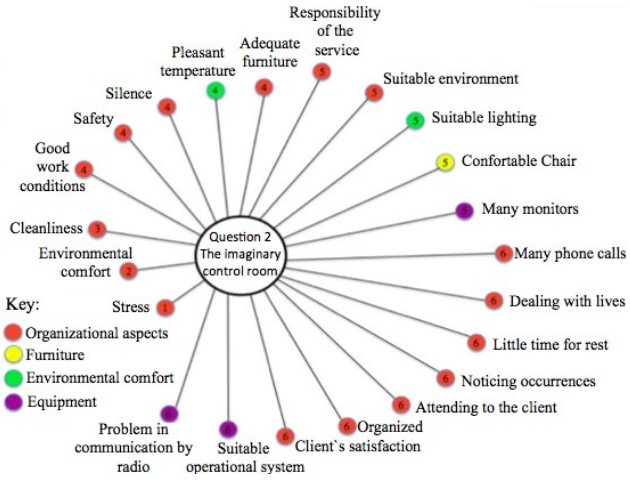


Figure 4 – Constellation of Attributes with the induced characteristics

According to the analysis of the graphs of the Constellation of Attributes it was found that the most mentioned aspects are associated with stress, cleanliness of the environment, lack of time for the operator to go the bathroom. The stress factor when it is pointed out in the idealized environment is also stated in the reality of the room.

The presence of noise and the high volume emitted by radio communication makes the environment buzz and is stressful; as a counterpoint to this, these aspects are evidenced when compared to the idealized environment being silent.

The various activities of the operators at an intense pace, repetitive work, with short breaks, excessive need for precision and accountability in decision making also cause on-the-job stress. Additionally, the assumption of inadequate postures while using the phone, viewing the five monitors and triggering the phone button to control the extensions are noted. Such activities are carried out simultaneously.

Cleaning the carpeted floor of the room is done improperly. The use of a broom causes dust particles to be dispersed into the atmosphere causing allergic reactions as reported in the Constellation of Attributes chart.

The inadequacy of the furniture comes from the lack of being able to adjust the chair, thus causing a lack of space to accommodate the user's legs. The fabric of the chair used is made of synthetic material that slides and does not allow adequate transpiration.

Table 1 – Data relating to the imaginary control room

Cathegories	Attributes associated with the environment	Answers	Classification	Psych Dist.
Organizational Aspetcs	Many phone calls	1	6	4.54
	Stress	7	1	0.93
	Responsibility of the service	2	5	1.88
	Dealing with lives	1	6	4.54
	Little time to rest	1	6	4.54
	Noticing occurrences	1	6	4.54
	Good work conditions	3	4	1.42
	Safety	3	4	1.42
	Cleanliess	4	3	1.20
	Attending to clients	1	6	4.54
	Organized	1	6	4.54
	Client´s satisfaction	1	6	4.54
	Silence	3	4	1.42
	Adequate environment	2	5	1.88
	Total	**29**		

	Comfortable environment	5	2	1.07
	Pleasant temperature	1	4	1.42
	Adequate lighting	2	5	1.88
	Total	**8**		
Furniture	Comfortable chair	2	5	1.88
	Adequate height of table	1	6	4.54
	Adequate furniture	3	4	1.42
	Total	**6**		
Eequipmen t	Adequate operational system	1	10	3.22
	Communication problems with radio	1	10	3.22
	Many monitors	2	5	1.63
	Total	**4**		
TOTAL ANSWERS			59	
TOTAL OF PEOPLE INTERVIEWED			30	

Table 2 – Data relating to the real control room.

Cathegories	Attributes related to environment	Answers	Classification	Psych Dist.
Organizational Aspetcs	Many phone calls	1	7	4.54
	Stress	3	4	1.42
	Good relationship with colleagues	1	7	4.54
	Wear and tear	1	7	4.54
	Not enough time to go to the rest room	4	3	1.20
	Bad posture while answering calls (phone cradled on shoulders supported with the head	3	4	1.42
	Allergy to the carpet	2	5	1.88
	Position of the sectors (islands)	3	4	1.42
	Cleanliess	2	5	1.88
	Adequate place	4	3	1.20
	Silent space	2	5	1.88
	Total	**26**		
Furniture	Comfortable	5	2	1.07
	Pleasant temperature	3	4	1.42
	Noise	6	1	1-2
	Adequate environment	4	3	1.20
	Silence	2	5	1.88
	Unpleasant temperature	1	7	4.54
	Inadequate lighting	2	6	1.92
	Total	**23**		
Eequipment	Uncomfortable chair	4	3	1.20
	Inadequate furniture	2	5	1.88
	Comfortable chair	3	4	1.42
	Inadequate height of table	1	7	4.54
	Total	**10**		
	Meet the needs	1	7	4.54
	Adequate operational system	1	7	4.54
	Communication problems with radio	3	4	1.42
	Many monitors	1	7	4.54
	Total	**6**		
TOTAL OF ANSWERS			59	
TOTAL OF PEOPLE INTERVIEWED			30	

ERGONOMIC DIAGNOSIS OF THE ENVIRONMENT AND RECOMMENDATIONS

The analysis of noise found an oscillation between 70-74dB (A). For indoor environments, NBR 10152 (2000) recommends levels of 55 dB (A) for daytime use and 40 dB (A) at night. The noise emitted by radios operating simultaneously can be considered a source of distraction. This may cause possible deviations in operators' work. Thus, the radios used in loudspeaker mode were considered sources of decreased productivity. The use of headphones and a study for improving the acoustics of the environment is recommended.

Regarding the study of lighting, according to Brazilian standard NBR 5413 (1992), which defines the lighting indices, levels suitable for offices should reach 750-1500 lux. The index found in the measurement ranged from 149-281 lux. Despite this difference, the vast majority of users did not report dissatisfaction (ABNT, 1992). This can be credited in part to the fact that most operators' work bays operators are close to windows, thus allowing natural lighting at work stations.

As to the analysis of temperature, standard NR -17 (2007) recommends that the temperature should be between 20°C and 23°C. The temperature measured in the room was 21.5°C to 22.6°C, measured by an anemometer. Although there are some variations in temperature in the same environment, these can be regulated and standardized by directing and controlling the temperature of the air conditioning system, since most respondents considered the room temperature was cold. To minimize this problem, the users wear jackets.

Problems of various kinds, such as Postural/dimensional, Chemical and Environmental, Communication, Physical and Environment problems, etc. were identified.

Regarding dimensional problems, the bays of the staff work stations have appropriate measurements that are considered appropriate for the patterns of activities undertaken but their height cannot be adjusted. The chairs are ergonomic, but their synthetic fabric is not suitable for the user's perspiration and causes sliding. It is recommended that adaptations be made so as to be able to regulate the height and sizing of the furniture.

With respect to postural problems, it was found that the worker takes up scoliotic and kyphotic postures and torsions due to carrying out different activities done simultaneously. To conduct activities, the operator needs to concentrate on watching the monitors, on answering emergency calls over the radio and by telephone and to operate telephone extensions. These activities associated with the poor sizing of the workstation can cause unsuitable and consequently occupational ailments.

In addition to the activities mentioned, operational problems were noted: high pace and repetitiveness, short breaks, excessive need for precision and reduced tolerance in making decisions on an activity. Given this situation, a new study of the organization of work is suggested that includes the appropriate division of tasks and a system that enables monitoring the supply of energy to be fully monitored bearing in mind that currently five monitors are used for this purpose.

The carpet should be cleaned by a qualified and trained professional.

It was noticed that the disabled, especially the visually impaired, do not have access to this sector. This happens, in part, due to the specificity of the task and the use of software that has images that the visually impaired would be unable to cope with. The company has a program to take on disabled employees in other sectors.

CONCLUSION

This study showed the adequacy of the Methodology of the Ergonomic Analysis of the Built Environment (Villarouco, 2009) in control room environments. The method adopted was effective in identifying problems, analyzing how users perceive the environment and applying questionnaires. This enhanced the analysis of the research findings and suggestions for improvements to be implemented in the built environment.

REFERENCES

Associação Brasileira De Normas Técnicas. (2000), "NBR 10.152: Nível de ruído para conforto acústico". Rio de Janeiro.
Associação Brasileira De Normas Técnicas. (1992), "NBR 5.413: Iluminância de interiores". Rio de Janeiro.

Falcão, C., Soares, M. M., Martins, L. B. (2008), Contribuição da ergonomia do ambiente construído no projeto de salas de controle". In: XV Congresso Brasileiro de Ergonomia, 2008, Porto Seguro. ABERGO 2008.

Falcão, C., Ferrer, N., Villarouco, V. (2011b), Método de avaliação ergonômica do ambiente aplicado em uma biblioteca universitária". III Encontro Nacional de Ergonomia do Ambiente Construído e IV Seminário Brasileiro de Acessibilidade Integral, João Pessoa: ABERGO, IFPB: UFPB.

Falcão, C., Soares, M. (2011a), "Ergonomia e análise multidisciplinar do ambiente construído". III Encontro Nacional de Ergonomia do Ambiente Construído e IV Seminário Brasileiro de Acessibilidade Integral, João Pessoa: ABERGO, IFPB: UFPB.

Fonseca, J; Mont'alvão C. (2007), "A lacuna da abordagem ergonômica do ambiente construído no ensino do exercício projetual: dificuldades na concepção de ambientes humanizados". Anais do I Encontro Nacional de Ergonomia do Ambiente Construído e II Seminário Brasileiro de Acessibilidade Integral. Recife.

Iida, I. (2005), "Ergonomia: projeto e produção". 2ª. Ed. São Paulo, Edgard Blucher.

Mafra, S. C. T. (1996), "Analisando a funcionalidade a partir da afetividade - um estudo de caso em cozinhas residenciais". Dissertação. PPGEP- UFSC, Florianópolis.

Moraes, A., Mont'Alvão, C. (2012), "Ergonomia: Conceitos e Aplicações". 4ª. Ed. Rio de Janeiro, Editora 2AB.

NR-17 – Norma Regulamentadora 17. Ministério do Trabalho e Emprego. http://port.mte.gov.br/data/files/FF8080812BE914E6012BEFBAD7064803/nr_17.pdf. Capturado em 18 de outubro de 2013.

Santos, N. *et al*. (1997), "Antropotecnologia: A Ergonomia dos Sistemas de Produção". Curitiba: Genesis.

Soares, Marcelo M. (2007), "Atualidades da ergonomia no Brasil e no mundo: uma visão geral". Palestra proferida no 1º. ENEAC – Encontro Nacional do Ambiente Construído, Recife, 12 de novembro de 2007. Comunicação do autor.

Vasconcelos, C. F., Villarouco, V. Soares, M. M. (2010), "Contribuição da psicologia ambiental na análise ergonômica do ambiente construído". Ação ergonômica, 5 (3), p. 14-20.

Vasconcelos, C. S. F. E., Soares, M. M., Martins, L. B. (2008), "Contribuição da Ergonomia do ambiente construído no projeto de salas de controle". In: Anais do ABERGO 2008 - 15o. Congresso Brasileiro de Ergonomia, 6o. Fórum Brasileiro de Ergonomia e 3o. Congresso Brasileiro de Iniciação em Ergonomia. Porto Seguro, BA. 29 de outubro a 02 de novembro. Artigo completo nos Anais em CD-Rom. Editora Gráfica da Universidade Federal de Pernambuco. ISBN: 978-85-89211-093.

Villarouco, V., Soares, M. M., Costa, A. P. L.; Andreto, L. (2012), "Evaluation of a work space based on an ergonomic design methodology of the built environment". Theoretical Issues in Ergonomics Science, v. 13, p. 203-224.

Villarouco, V. (2011), "Tratando de ambientes ergonômicamente adequados: seriam ergoambientes?". In: Mont'Alvão, C.; Vilarouco, V. (Orgs.). *Um novo olhar para o projeto: a ergonomia no ambiente construído*. Teresópolis, RJ: 2AB, p. 25-46.

Villarouco, V. Andreto, L. F. M. (2008), "Avaliando Desempenho De Espaços De Trabalho Sob O Enfoque Da Ergonomia Do Ambiente Construído". Produção, v. 18, n. 3, p. 523-539.

Villarouco, V. (2007), "O ambiente está adequado?" In: *Anais do I Encontro Nacional de Ergonomia do Ambiente Construído e II Seminário Brasileiro de Acessibilidade Integral, ENEAC*. Recife.

ACKNOWLEDGEMENTS

We are grateful for the collaboration received from Alexsandra Andrade, Etiene Louzada and Raul Henrique when this study was being conducted