ERGONOMÍA OCUPACIONAL

INVESTIGACIONES Y APLICACIONES

VOL. 12

ERGONOMÍA OCUPACIONAL

INVESTIGACIONES Y SOLUCIONES

VOL. 12

EDITADO POR:

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ISBN: 978-0-578-48915-5

CONTENT

ANTHROPOMETRY

COGNITIVE ERGONOMICS

DIFFERENT EQUATIONS USED DURING THE MENTAL WORKLOAD EVALUATION APPLYING THE NASA-TLX METHOD

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Resumen: Los objetivos de la investigación fueron identificar las diferentes ecuaciones utilizadas durante la evaluación de la carga de trabajo mental con el Índice de carga de tareas de la NASA (TLX) y comparar los resultados obtenidos con las diferentes ecuaciones. Se realizó una encuesta de 21 preguntas a 30 estudiantes de la Universidad Autónoma de Ciudad Juárez. Se encontraron cuatro ecuaciones diferentes. Las puntuaciones de las dimensiones y el Índice de carga de trabajo global (ICTG) mostraron diferencias aparentes en los resultados entre las ecuaciones empleadas en esta investigación.

Abstract: The objectives of the research were to identify the different equations used during the evaluation of mental workload with the NASA Task Load Index (TLX) and to compare the results achieved with the different equations. A survey consisted of 21 questions was administered to 120 students from the Autonomous University of Ciudad Juarez using the four different equations identified. The scores of the dimensions and the Global Workload Index (GWI) showed differences in the results between the equations employed in this research.

Keywords: Ergonomics, workload, mental, method, NASA-TLX.

Relevance for ergonomics: This research showed a comparison of different equations used in mental workload evaluation when the NASA-TLX method is used. which serves to other people for obtaining results when performing evaluations with the method used. The publication of this article would help future investigations where the NASA-TLX method is used for the use of different equations depending on the case to apply it.

1. INTRODUCTION

Modern technology has involved changes in industrial work, especially in decision making involving mental workload (Demands & De, 2018). Mental workload is investigated in ergonomics and human factors and represents a topic of increasing

importance (Ayaz et al., 2012). In working environments, high cognitive demands are imposed on operators, while physical demands have decreased. Understand how the mental workload impacts on performance is becoming more critical (Young, Brookhuis, Wickens, & Hancock, 2015).

Due to high levels of mental charge, stress levels are generated that in addition to affecting the worker's performance, affect productivity and these effects can be causes of occupational stress, as well as health problems (Arce & Silvia, 2012). This stress is shown in the physiological plane altering indexes such as the reactivity of the heart rate and the increase in blood pressure. At the behavioral level, the effects of stress are revealed in problems of smoking, alcoholism, drug abuse, antisocial and aggressive acts, which leads to a possible tendency to accidents and errors, as well as problems of relationships at work (González Muños & Gutiérrez Martinez, 2006).

During the assessment of mental workload using the method NASA-TLX, there are equations that can be used to facilitate the use of this method, allowing software supported a quick evaluation. The equations explained in this research was from the following authors: Şeker (2014), NASA (1986), and Enríquez (2018). The equations that can be used have differences between them, from a variety of scales used in scores, using the amount resulting from multiplications of data and equations that with non-stop results.

This article will explain the different equations employed with the method NASA-TLX, showing the scores and comparing the results of the Global Workload Index obtained with the different equations.

2. OBJECTIVES

The objectives of this research are 1) through a literature review, identify the different equations used to determine the global workload index, and 2) compare the results of the Global Workload Index obtained with the different equations.

3. METHODOLOGY

3.1 Study design

This research is a longitudinal study, using a sample of 120 students from the Autonomous University of Ciudad Juárez in the Institute of Engineering and Technology.

3.1 Identification of Equations

The identification of the equations used in the method NASA-TLX arises from a bibliographic review in scientific databases such as SciFinder, ScienceDirect, SciELO, Dialnet, Sage Journals, Research Gate, MDPI, etc. The keywords used were: "Method, ergonomics, mental, cognitive, study, workload, evaluation, NASA-

TLX" during the search of methods selecting the area of knowledge of ergonomics – human factor, where different publications were found, as well quotations used in useful articles for this research.

3.2 NASA TLX METHOD

NASA-Task Load Index (TLX). This procedure developed by Hart & Staveland (1988) distinguishes six dimensions of mental load (mental demand, physical demand, temporal demand, yield, effort, and level of frustration), from which it calculates a global index of mental load. In various laboratory investigations, it has been proven that it is sensitive to a variety of tasks and that each of the six subscales provides independent information about its structure.

The application of this instrument is carried out in two phases: a weighting phase, at the time prior to the execution of the task and another phase immediately after the execution, called the scoring phase. It Is part of the base that the specific sources of load imposed by the different tasks are determinant in the experience of load and the subjective feeling of load, therefore the prerequisite is that the subjects themselves make a weighting in order to determinate the extent to which each of the six factors contributes to the burden on each specific task or subtask.

The objective of this phase is to define the load sources. It consists in presenting to the people the definitions of each one of the dimensions in order to compare them by pairs (binary compares) and choose for each pair, which is the element that is perceived as a greater source of the load. From this election you get a weight for each dimension, depending on the number of times you have been chosen.

These weights can take values between 0 (for the dimension that has not been chosen on any occasion and therefore is not considered relevant) and 5 (for the dimension that has always been chosen and therefore is the most important source of charge). The same set of weights can be used for variations of the same task or for a group of subtasks. In Addition, the weights give diagnostic information about the nature of the workload imposed by the task as they provide data about two sources of interpersonal variability:

A. The interpersonal differences in the definition of the workload in each task considered.

B. Differences in workload sources between different tasks. The second requirement is to award value for each factor, which represents the magnitude of each factor in a given task.

In this scoring phase, people value the task or subtask they have just done in each of the dimensions, marking a point on the scale presented to them. Each factor is presented in a line divided into 20 equal intervals (a score that is reconverted to a scale over 100) and bipolarly limited by some descriptors (for example: high/low and bearing in mind the definitions of the dimensions.

One of the main advantages of this method is its applicability in the real labor framework as people can directly and quickly rate the task done either right after its execution or retrospectively. A video recording can be useful to improve the memory of the activity, stop if necessary, in each segment of the task. In experiences carried out on retrospective valuations, it has been found that there is a high correlation

between the data obtained and the scores obtained in a way Immediate (from Archer & Nogare, 2001).

3.2 Data Collection

The data were obtained with the application of a survey for the assessment of workload and school fatigue applied to students of the Autonomous University of Ciudad Juárez in the Institute of Engineering and Technology. A mental load questionnaire consisting of 21 items was applied in two stages. This research carried out in Ciudad Juárez, Chihuahua, México, is limited the evaluation of tasks where there is a mental workload of through, Hypothetical cases where equations will be used exclusively for the NASA-TLX method and as a support for research in articles, conference reports and book chapters.

3.3 Obtaining the Different Global Workload Indexes

The survey evaluates the 6 dimensions of the NASA-TLX method (mental demand, physical demand, temporary pressure, effort, performance, frustration), where people evaluate and get a score. Continue to ask the evaluated person the 15 binary combinations where the weight is obtained for each dimension evaluated. It performs the multiplication of the score x 100 and divided by 20 to obtain a score converted from the dimensions, to multiply the weight of each dimension by the score converted resulting in the weighted score. Finally, the sum of the values of the weighted score is made, divided by 15 and the value obtained is the global index of workload, which depending on its value will tell us the level of mental load of the evaluation performed.

3.4 Data Analysis

To Verify the reliability of the NASA-TLX method, the Alpha coefficient of Cronbach was calculated for the total scale. For the deep analysis of data and to be able to find differences between the profiles of mental load, an Analysis of Variance (ANOVA) was elaborated with the 6 dimensions evaluated of the method (Barbara G. Tabachnick, 2001).

4. RESULTS

4.1 Equations

Table 1 shows four different formulas identified, the author and the year of use.

Table 1. Equations identified

Author	Year	Equation
(Hart & Staveland, 1988)	1988	Equation 1 - 2

Alper Şeker	2014	Equation 3
Enríquez	2018	Equation 4

Equation 1 NASA-TLX

$$\frac{\sum_{i=1}^{6} Ci}{15} = \frac{\sum_{i=1}^{6}(a\ x\ b)}{15} \qquad (1)$$

Where
Ci: Weighted score
a: Weight
b: Raw rating
15 Number of binaries comparisons

Equation 2 NASA-TLX

$$IC = \frac{(\sum pi\ x\ Xi)}{15} \qquad (2)$$

Where:

- IC Load Index
- Pi Weight obtained for each dimension in the binary table (weighting)
- Xi Score obtained by the dimension in the evaluation stage

Equation 3 Unweighted Score

$$IC = \frac{(\sum pi\ x\ 100\ )}{30} \qquad (3)$$

Where:

- IC Load Index
- Pi Weight obtained for each dimension in the binary table (weighting)

Equation 4 Scale assessment (Scale 5) NASA-TLX

$$IC = \frac{(\sum pi\ x\ Xi\ x\ 5)}{15} \qquad (4)$$

Where:

- IC Load Index
- Pi Weight obtained for each dimension in the binary table (weighting)
- Xi Score obtained by the dimension in the evaluation stage multiplied by five

4.2 Comparative

Table 2 presents the results of the application of the four equations using data from 30 students.

Table 2. Results of the Global Workload Index among 30 students.

Global Workload Index			
Equation 1	**Equation 2**	**Equation 3**	**Equation 4**
92.00	80	160	23.00
82.67	76.66	153.33	20.67
80.00	70	140	20.00
49.33	46.66	93.33	12.33
76.00	66.66	133.33	19.00
68.00	66.66	133.33	17.00
64.00	53.33	106.66	16.00
80.00	70	140	20.00
76.00	66.66	133.33	19.00
50.67	46.66	93.33	12.67
84.00	73.33	146.66	21.00
62.67	60	120	15.67
80.00	76.6	153.33	20.00
84.00	70	140	21.00
50.67	56.66	113.33	12.67
86.67	73.33	146.66	21.67
74.67	63.33	126.66	18.67
81.33	80	160	20.33
70.67	60	120	17.67
88.00	80	160	22.00
77.33	66.66	133.33	19.33
82.67	76.66	153.33	20.67
74.67	73.33	146.66	18.67
66.67	63.33	126.66	16.67
85.33	73.33	146.66	21.33
65.33	56.66	113.33	16.33
90.67	80	160	22.67
86.67	80	160	21.67
57.33	63.33	126.66	14.33
80.00	60	120	20.00

5. CONCLUSIONS

Visual comparison of the results from the four different formulas identified showed apparent differences. Because the results are not deployed on the same scale, a statistical comparison is not possible without the development of data transformation. The use of data from students allowed to get a first approach to explore more about a gold standard method to evaluate workload among different work environments.

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