Evaluating Mental Workload for Improved Workplace Performance

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A volume in the Advances in Psychology, Mental Health, and Behavioral Studies (APMHBS) Book Series

IGI Global
DISSEMINATOR OF KNOWLEDGE

Published in the United States of America by
IGI Global
Medical Information Science Reference (an imprint of IGI Global)
701 E. Chocolate Avenue
Hershey PA, USA 17033
Tel: 717-533-8845
Fax: 717-533-8661
E-mail: cust@igi-global.com
Web site: http://www.igi-global.com

Library of Congress Cataloging-in-Publication Data

Names: Realyvasquez, Arturo, 1984- editor. | Arredondo-Soto, Karina Cecilia, 1983- editor. | Hernández-Escobedo, Guadalupe, 1971- editor. | González-Reséndiz, Jorge, 1966- editor.
Title: Evaluating mental workload for improved workplace performance / Arturo Realyvásquez-Vargas, Karina Cecilia Arredondo-Soto, Guadalupe Hernández-Escobedo, Jorge González-Reséndiz, editors.
Description: Hershey, PA : Medical Information Science Reference, [2020] | Includes bibliographical references and index. | Summary: “This book provides comprehensive research on mental workload and the effects, both adverse and positive, that it can have on employee populations as well as strategies for decreasing or deleting it from the labor sector”--Provided by publisher.
Identifiers: LCCN 2019024767 (print) | LCCN 2019024768 (ebook) | ISBN 9781799810520 (hardcover) | ISBN 9781799810537 (ebook)
Subjects: MESH: Workload--psychology | Work Performance | Total Quality Management--methods | Employee Performance Appraisal--methods
Classification: LCC RA972 (print) | LCC RA972 (ebook) | NLM BF 481 | DDC 362.11068/3--dc23
LC record available at https://lccn.loc.gov/2019024767
LC ebook record available at https://lccn.loc.gov/2019024768

This book is published in the IGI Global book series Advances in Psychology, Mental Health, and Behavioral Studies (APMHBS) (ISSN: 2475-6660; eISSN: 2475-6679)

British Cataloguing in Publication Data
A Cataloguing in Publication record for this book is available from the British Library.

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Chapter 1

Combined Methods for Physical and Mental Workload:

Fatigue Evaluation – A Systematic Literature Review

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ABSTRACT

This chapter presents information about the methods that combine physical and mental workload/fatigue during ergonomic evaluation. The methods were identified through a systematic literature review. The search criteria were done through a literature search in databases like SciFinder, SciELO, ScienceDirect, etc. As result, the following methods are described: Global Load Scale, Multivariate Workload Assessment, Subjective Fatigue Symptoms Test, Fatigue Assessment Scale, Scale of Recovery for Exhaustion of Occupational Fatigue, Scale of Estimated Fatigue-Energy Points, Swedish Occupational Fatigue Inventory, NASA-TLX, Combined Cognitive and Physical Assessment, Laboratory Method of Economics and Sociology of Work, OWL Method, Ergonomic Checklist Method, RENAULT Method, Joyce Method, NERPA Method, ARBAN Method, and MAPFRE Method. As a conclusion, it is possible to affirm that there are some evaluation methods that provide better elements for an accurate evaluation, and others lack basic elements, which causes an incomplete/not accurate evaluation.

DOI: 10.4018/978-1-7998-1052-0.ch001

INTRODUCTION

The changes in job processes and work design happened in the last decades were, predominantly, demographic, economic, political, and technological (Bailey & Iqbal, 2008). These changes have caused that the current work must be performed developing physical and mental efforts in a combined and/or simultaneous way (Gil-Monte, 2012). Currently, modern technology has involved new changes in industrial work, especially in decision-making involving high levels of mental load (Demands & De, 2018). As a result, the mental workload is one of the most researched concepts in ergonomics and human factors and represents an issue of increasing importance (Ayaz, 2012). In work environments, more and more cognitive demands are imposed on operators, while physical demands decrease in tasks, understanding how the mental workload affects performance is increasingly critical (Hernandez Arellano, Serratos Perez, Alcaraz, & Maldonado Macias, 2018; Young, Brookhuis, Wickens, & Hancock, 2015).

Due to high levels of mental load, levels of stress and fatigue are being generated and affecting the worker's performance, organizational productivity as well as health problems (Arce & Silvia, 2012). Stress is shown in the physiological plane altering indexes such as the reactivity of the heart rate and the increase in blood pressure. In 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 Muñoz & Gutiérrez Martinez, 2006).

The physical workload is the set of physical requirements that the person required during his working day (Moreno, 2015). A physical job occurs when the type of activity required by the task is primarily physical or muscular. On the contrary, the mental workload is the amount of deliberate mental effort that must be made to achieve a specific result, and it is linked to the need for information processing and decision making for the execution of the task (O'Donnell & Eggemeier, 1986).

The mental workload is used in tasks involving mainly cognitive processes, information processing and affective aspects (Arquer de, 1999). All jobs require a certain level of physical load and mental load. However, the working conditions can affect the mental load of the people (Ceballos Vásquez, Paravic Klijn, Moreno, & Barriga, 2014). For example, in work on production lines (application of adhesives, sewing, welding of electronic parts, insertion of components, etc.), transport of materials (manual or automated), and manual assembly lines (assembly of harnesses, automobiles, components electronic, etc.), are some of the jobs where there are high levels of physical and/or mental load. To assess the workload, both physical and mental aspects must be evaluated, so there are different techniques for evaluation. Similarly, physiological, behavioral and subjective changes should be considered. Some physiological measures evaluate the effect of the increase or decrease of the workload, examples of these are heart rate, heart rate variability, eye movement and brain activity (Stanton, Hedge, Brookhuis, Salas, & Hendrick, 2005). However, the number of methods that combined both kinds of efforts are limited in contrast to the great number of methods, tools, and techniques to evaluate physical or mental factors during an occupational task.

Ergonomic Evaluation

Over time, ergonomic studies have been carried out on the workload, theoretical discussions, and reviews of past investigations (Hart & Staveland, 1988; Lysaght, Ouellette-Kuntz, & Lin, 2012). A growing number of different approaches and techniques for measuring workloads have been discussed, developed, and used. Subjective techniques seem to proliferate, this creates an opportunity and a problem for professionals and researchers of human factors. More recent studies (Hart & Staveland, 1988; Lysaght et al., 2012; Moray, 1979) have taken into account the current situation and perspective of the future on occupational stress, as well as the techniques of study for the workload in laboratories (Piñeda Geraldo and Montes Panice 2014). Studies are still being carried out where a high workload is identified and continuous improvements are sought to reduce the mental workload and improve workers' performance (Kakushi & Évora, 2014).

There are many tools that have been developed for a wide variety of situations, and human factors specialists face the choice of the most appropriate tool or tools to be able to find the information needed to make a choice and consequently causes a problem to choose the right tool (Hill et al., 1992). The ergonomic evaluation aims to determine the level of presence of risk factors in workplaces, which can generate physical health problems in workers. There are two types of analysis: that of working conditions to identify risks and risk assessment if they exist. For each factor, there are different methods that help to evaluate the level of risk associated (Asensio-Cuesta, Bastante Ceca, & Diego Más, 2012).

Combined Physical and Mental Workload

The workload is a concept that involves the capacity of the human being in complex systems considering the equipment, the training offered, the organizational, and environmental constraints. Also, it implies diverse perceptions and responses by the Workers (Jung & Jung 2001). More often, we find jobs that require the individual to attend multiple tasks at the same time, make decisions, and solve problems effectively in stable and emergency situations. The growing role of technology and the use of complex procedures have led to greater demand imposed on the worker (Stanton et al., 2005). The workload produced by an activity that responds to the requirements of a task is composed of physical load and mental load. In the next section, combined methods to assess physical and mental workload are presented in chronological order.

Objective

The objective of this research is, through a systematic review of the literature, to identify and describe the methods to evaluate physical and mental workload in a combined way.

METHODOLOGY

Step 1. Search Criteria

The identification of the combined evaluation methods presented in this article arises from a literature review, using scientific databases and journals such as SciFinder, ScienceDirect, SciELO, Dialnet, Sage Journals, Research Gate, MDPI and Springer. During the search, the selecting area of knowledge was: Ergonomics and human factors. To identify the results, the following keywords were used: "Method, Ergonomics, Combined, Mental, Physical, Study, Scale, Evaluation, Workload, Human, Factors."

Step 2. Identification of Related Papers

During the literature research using the search criteria, more than 200 related papers where found. All of them were read and separated to classify those that would be useful for research.

Step 3. Selection of Relevant Papers

In the final step, 17 relevant papers we had selected, each paper was used to integrate the information and methods included in this article.

RESULTS: COMBINED METHODS IDENTIFIED

The combined methods in this article were selected based on the most used during investigations and ergonomic evaluations in articles. A total of 17 methods were identified, as shown in Table 1.

Table 1. Combined methods identified

Method	Paper	Author, year	Country	Citation
MAPFRE Method	Practical Ergonomics	(MAPFRE, 1975)	Spain	106
Laboratory Method of Economics and Sociology of Work (LEST)	For an analysis of the working conditions of the worker in the company	(Guelaud, Beauchense, Gautrat, & Roustrang, 1977)	France	95
RENAULT Method	Job profiles “method of analysis of working conditions”	(Renault, 1977)	France	84
Subjective Fatigue Symptoms Test (SFST)	Three characteristic patterns of subjective fatigue symptoms	(Yoshitake, 1978)	Japan	267
ARBAN Method	ARBAN: A new method for analysis of ergonomic effort. Applied Ergonomics	(P. Holzmann, 1982)	Sweden	78
Global Load Scale (GLS)	Absolute Magnitude Estimation and Relative Judgement Approaches to Subjective Workload Assessment.	(Vidulich, Field, & Tsang, 1987)	USA	70
NASA- TLX (Task Load Index)	Development of NASA-TLX (Task Load Index): Results of Empirical and Theoretical Research.	(Hart & Staveland, 1988)	USA	9034
Joyce Method	Applied Industrial Ergonomics Reference Manual	(Joyce Institute Training Design Team, 1992)	USA	3
Swedish Occupational Fatigue Inventory (SOFI)	Perceived quality of fatigue during different occupational tasks Development of a questionnaire Elizabeth Åhsberg	(Ahsberg, Garnberale, & Kjellberg, 1997)	Sweden	168
OWL Method	Establishment of overall workload assessment technique for various tasks and workplaces	(Jung & Jung, 2001)	South Korea	90
Multivariate Workload Assessment (MWE)	Multivariate workload evaluation combining physiological and subjective measures.	(Miyake, 2001)	Japan	165

continues on following page

Table 1. Continued

Method	Paper	Author, year	Country	Citation
Fatigue Assessment Scale (FAS)	Fatigue Assessment Scale (FAS)	(Michielsen, H. J., De Vries, J., & Van Heck, 2003)	Netherlands	204
The Scale of Recovery for Exhaustion of Occupational Fatigue (OFER)	Development and validation of a scale to measure work-related fatigue and recovery: The Occupational Fatigue Exhaustion/Recovery Scale (OFER).	(Winwood, Winefield, Dawson, & Lushington, 2005)	Australia	169
The Scale of Estimated Fatigue-Energy Points (SEFEP)	The fatigue-energy dimension as an indicator of presentism: validity of a scale in Mexican workers.	(Juárez-García, 2007)	Chile	18
NERPA Method	Novel Ergonomic Postural Assessment Method (NERPA) Using Product-Process Computer-Aided Engineering for Ergonomic Workplace Design.	(Sanchez-Lite A, Garcia M, Domingo R, 2013)	Spain	21
Combined Cognitive and Physical Assessment (CCPA)	CCPE: Methodology for a combined evaluation of cognitive and physical ergonomics in the interaction between humans and machines.	(Bligárd & Osvalder, 2014)	Sweden	17
Ergonomic Checklist Method	Influences on the use of observational methods by practitioners when identifying risk factors in physical work.	(Diego-Mas, Poveda-Bautista, & Garzon-Leal, 2015)	Spain	26

Source: Own creation with data collected in databases.

DESCRIPTION OF THE METHODS

MAPFRE Method

This method, also called the method of ergonomic analysis of the workplace, aims to be a simplified ergonomic assessment, in which, from a general analysis of the conditions of the position, it can be addressed deeper and specific studies of the aspects considered as negative. This method carries out a triple evaluation: descriptive, of the work position (machines and materials used, description of the tasks that are carried out).

The valuation of each factor ranges from 1 (very favorable condition) to 5 (an unfavorable condition that needs to be corrected). The second part is the evaluation, where the factors to be considered are established, covering aspects related to the physical environment (noise, temperature, etc.), the physical load (manual lifting of loads, main posture, etc.), nervous load (operations mental and level of attention) and psychological (individual autonomy, cycle repeatability, schedules). The third part is dedicated to correction measures, technical improvements to be made in the analyzed jobs, all showed in Table 2. Because it is a mixed-method, in each one of the factors, an assessment of the conditions by the worker is introduced, also in five qualitative grades: (++) very acceptable, (+) acceptable, (●) neutral, (-) unfavorable, (-) very unfavorable (MAPFRE, 1975).

Table 2. Items considered in the MAPFRE method

Items
Job Position. Equipment. Space Layout.
Static Physical Load
Dynamic Physical Load
Attention Sensory-Motor Coordination
Complexity Content of Work
Autonomy and Decisions
Monotony and Repetitive
Communications and Social Relations
Shifts. Schedules Pause.
Accident Risks
Chemical Contaminants
Noises and Vibrations
Thermal Conditions
Lighting. Chromatic Environment
Radiation. Other Environmental Factors

Source: (MAPFRE, 1975)

Laboratory Method of Economics and Sociology of Work (LEST)

Aims to evaluate the working conditions in the most objective and global way possible, establishing a final diagnosis that indicates whether each of the situations considered in the position is satisfactory, annoying or harmful. It is a global method that considers each aspect of the job in a general way, providing a first assessment that allows establishing if a deeper analysis with specific methods is required.

The objective is, according to the authors, to evaluate the set of factors related to the content of the work that can have an impact both on the health and on the personal life of the workers. Before the application of the method must have considered and resolved the occupational risks related to Health and Safety at Work since they are not contemplated by the method. To determine the diagnosis, the method considers 16 variables grouped into 5 aspects (dimensions): physical environment, physical load, mental load, psychosocial aspects and work time (Diego-Mas et al., 2015).

The evaluation is based on the scores obtained for each of the 16 variables considered, shown in Table 3. The simplified variables are the thermal environment, light environment, noise, vibrations, attention, and complexity.

Evaluate the mental load based on four indicators:

- Time constraint
- Complexity - Speed
- Attention
- Thoroughness (Guelaud et al., 1977).

Table 3. Items considered in the laboratory method of economics and sociology of work (LEST)

Items				
Physical Environment	Physical Load	Mental Load	Psychosocial Aspects	Work Time
Thermal Environment	Static Charge	Time Constraint	Initiative	Working Time
Noise	Dynamic Load	Complexity	Social Status	
Illumination			Communications	
Vibrations			Relationship with the Command	

Source: (Guelaud et al., 1977)

RENAULT Method

It aims to make an assessment from an objective point of view. This method has been made from an industrial experience started in the 1950s by specialists in working conditions and production of the R.N.U.R. (Regie Nationale des Usines Renault (National Director of the Renault Factories)) and is mainly applicable to repetitive short-cycle jobs. It intends to make an assessment from an objective point of view. This method has been compiled from an industrial experience begun in the fifties by specialists working conditions and production of the R.N.U.R. and it is mainly applicable to repetitive, short-cycle jobs, as is the case of assembly lines in automobile manufacturing. For this, the analysis of eight factors that are evaluated through 23 criteria is considered, showed in Table 4, to which are added four other factors related to the Global Conception of the Post (Renault, 1977).

Table 4. Items considered in the RENAULT method

Items							
Security	Physical Environment	Physical Load	Mental Load	Autonomy	Independent Work Relationships	Repeatability	Contented of The Work
	Thermal Environment	Main Posture	Mental Operations	Individual Autonomy	Dependents of Work	Repeatability of The Cycle.	Potential
	Sound Environment	Work Effort	Level of Attention	Group Autonomy			Responsibility
	Artificial Lighting	Work Posture					Interest of Work
	Vibrations	Effort					
	Industrial Hygiene	Maintenance Posture					
	The Appearance of the Position						

Source: (Renault, 1977)

Subjective Fatigue Symptoms Test (SFST)

The Subjective Fatigue Symptoms Test (SFST) was developed by the Industrial Fatigue Research Committee of the Industrial Health Association of Japan (Yoshitake, 1978), and it is composed of 30 items showed in Table 5, that explore the presence of symptoms of fatigue. Originally, the SFST classified the items into three groups: physical, mental, and neurosensory (Saito, 1970). However, (Saito, Kogi, & Kashiwagi, 1970) subjected the instrument to factorial validity obtaining three factors: drowsiness and heaviness, projection of physical discomfort, and difficulty concentrating. Yoshitake, (1978) related the first factor with undifferentiated work, the second with physical work and the third with mental work. Additionally, Yoshitake proposed the qualification of the test through the percentage of affirmative answers. In addition, it determined that, if a person answers affirmatively to 6 of the 10 questions of one of the analyzed dimensions, it can be considered that this dimension presents as a symptom of fatigue.

ARBAN Method

It is a method for the ergonomic analysis of work, which includes work situations that involve very different postures and body loads. The idea of the method is that all the phases of the analysis process that imply a specific knowledge about ergonomics are taken by the film crew and a computer routine. All the tasks that the researcher must carry out in the analysis process are designed in such a way that they appear as evident using systematic common sense.

The ARBAN analysis method contains four steps: 1. Recording of the workplace situation in video or film. 2. Coding of the posture and the situation of the load in a series of “frozen” situations very close. 3. Computerization. 4. Evaluation of the results. When evaluating the film, the human body is regarded as a conglomerate of functional units, based on the logical coordinated sequence of movements achieved by most human beings while working.

Table 5. Items considered in the subjective fatigue symptoms test (SFST)

Items		
Group A (General)	**Group B (Mental)**	**Group C (Physical)**
1. Feel heavy in the head	1. Find difficulty in thinking	1. Have a headache
2. Feel tired in the whole body	2. Become weary while talking	2. Feel stiff in the shoulder
3. Feel tired in the legs	3. Become nervous	3. Feel pain in the waist
4. Give a yawn	4. Unable to concentrate attention	4. Feel constrained in breathing
5. Feel the brain hot or muddled	5. Unable to have an interest in thinking	5. Feel thirsty
6. Become drowsy	6. Become apt to forgot things	6. Have a husky voice
7. Feel strained in the eyes	7. Lack of self-confidence	7. Have dizziness
8. Become rigid or clumsy in motion	8. Anxious about things	8. Have a spasm of the eyelids
9. Feel unsteady while standing	9. Unable to straighten up in a posture	9. Have a tremor in the limbs
10. Want to lie down	10. Lack of patience	10. Feel ill

Source: (Yoshitake, 1978)

The intervals between the analyzed frames depend on the properties of the work situation and dividing the cycle time into 100-200 equal time intervals is often enough for simple tasks. It provides a representative sample of the working postures throughout the job and allows a quick evaluation procedure. However, the intervals should normally not exceed a few seconds, to avoid loss of information. This method is used to offer a simple and easily handled procedure with a broad field of application. Such methods normally contain two sources of error - the man and the system and is designed to enable both man and machine to do what they can best accomplish, thus reducing the risk of error. Even persons with limited knowledge of ergonomics will be able to use the method after a few hours of training.

The computer calculates the figures for total ergonomic tension throughout the body, as well as in different parts of the body separately, shown in Table 6. They are presented as 'Ergonomic tension/time curves', where heavy load situations occur as curve peaks. The work cycle can also be divided into different tasks, where the stress and duration patterns can be compared. The integral of the curves are calculated for the comparison of a single figure of different tasks, as well as different work situations. The results of the analysis make it possible to identify critical phases of the studied work and to compare different working conditions. The method allows the analyzer to work in a correct ergonomic sequence so that his efforts produce the best result. Subtasks that do not require the comprehension of the human brain or exceed its capabilities are handled by technical equipment such as video and computers (P. Holzmann, 1982).

Global Load Scale (GLS)

It was proposed by Vidulich, Field & Tsang (1987) for the evaluation of the mental load experienced by individuals. GLS is a bipolar scale from 0 to 100, with intervals of 5 units, where the 0 represents a very low mental load and 100 very high mental load. This scale has been used, for example, in the study by Zeitlin, (1995) whose objective was to evaluate the mental load associated with driving a car under different situations (urban or rural environment) and combinations of additional tasks. In Table 7, it shows two rating scale techniques employing an absolute magnitude estimation method were compared to a relative judgment method for assessing subjective workload. The absolute estimation techniques used was a unidimensional Overall Workload scale and the other was the multidimensional NASA-Task Load Index technique. The techniques were used to assess the subjective workload of various single and dual tracking conditions. Thomas Saaty's Analytic Hierarchy Process was the unidimensional relative judgment method used. The validity of the techniques of this method was defined as their ability to detect

Table 6. Items considered in the ARBAN method

Items
Head - neck
Right shoulder - arm
Left shoulder - arm
Trunk – back
Right leg
Left leg

Source: (P. Holzmann, 1982)

the same phenomena observed in the tracking performance. Reliability is assessed by calculating test-retest. The Saaty Analytic Hierarchy Process was found to be superior in validity and reliability using this method. These findings suggest that the relative judgment method would be an effective addition to the currently available subjective workload assessment techniques. An equally used evaluation modality is that of binary comparisons, a method that essentially consists of comparing two to two the mental load associated with the tasks that make up a certain activity, so that for each task it can be calculated in a matrix double entry the load index resulting from the average of the times that people attribute a greater value with respect to the other tasks considered (Vidulich et al., 1987).

NASA- TLX (Task Load Index)

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, showed in Table 8 who 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 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). 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.

Table 7. Scores considered in the global load scale (GLS)

Scores
Overall Workload Scale – OW
Nasa-Task Load Index (TLX)
Saaty's Analytic Hierarchy Process

Source: (Vidulich et al., 1987)

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 (Archer & Nogare, 2001).

Joyce Method

It is a method for the ergonomic evaluation of jobs, whose objective is to eliminate or minimize the causes of Damage due to Accumulated Trauma (DTA's) related to work. The method allows identifying the jobs that present or are susceptible to present problems of this type, as well as to determine the associated risk to be able to initiate actions that resolve them. It consists of five steps, shown in Table 9.

Table 8. Items considered in the NASA- TLX (Task Load Index)

Items	
Subscales	**Subscales for rating**
Mental Demand	Mental Demand: How much mental and perceptual activity was required? Was the task easy or demanding, simple or complex?
Physical Demand	Physical Demand: How much physical activity was required? Was the task easy or demanding, slack or strenuous?
Temporal Demand	Temporal Demand: How much time pressure did you feel due to the pace at which the tasks or task elements occurred? Was the pace slow or rapid?
Performance	Overall Performance: How successful were you in performing the task? How satisfied were you with your performance?
Effort	Effort: How hard did you have to work (mentally and physically) to accomplish your level of performance?
Frustration	Frustration Level: How irritated, stressed, and annoyed versus content, relaxed, and complacent did you feel during the task?

Source: (Hart & Staveland, 1988)

Table 9. Items considered to the Joyce method

Items
Data collection
Data evaluation
Problem prioritization
Solution design
Validation

Source: (Joyce Institute Training Design Team, 1992)

The risk estimation is done with the checklist during the data collection and its evaluation, the possible results of this estimation are jobs of low, medium or high risk, which facilitates the prioritization of problems. Once the evaluation list is applied, a list of possible situations that could cause damage to workers' health is made. This method is very complete to detect potentially risky jobs in developing DTA's, but it does not detect physical fatigue or metabolic expense which are important processes in the ergonomic evaluation and the worker's involvement is only done if a detailed analysis is necessary (Joyce Institute Training Design Team, 1992).

Swedish Occupational Fatigue Inventory (SOFI)

Swedish Occupational Fatigue Inventory (SOFI) is an instrument composed of 25 items (expressions) showed in Table 10, that evaluates five dimensions of fatigue: lack of energy, physical fatigue, physical discomfort, lack of motivation, and drowsiness, all of them related to physiological, cognitive, motor, and emotional responses.

According to Ahsberg, Garnberale, & Kjellberg (1997), the underlying structure of the instrument corresponds to a new qualitative and quantitative description of the physical (physical exertion and physical discomfort) and mental (lack of motivation and sleepiness) dimensions of perceived fatigue. Together with these, the factor ''lack of energy'' corresponds to a fatigue dimension with both physical and mental characteristics.

The subject must respond to the extent to which these expressions describe how he usually feels at the end of his workday using a scale of the analogous visual type of 11 response points, where 0 is interpreted as "nothing at all" and 10 as "in a high degree". The first version of this instrument was made in Sweden by Ahsberg et al., (1997) and was subsequently revised by Ahsberg, (2000) using confirmatory factorial analysis, and the number of expressions in each dimension was reduced to four (the questionnaire finally consisted of 15 elements). Previously, in accordance with the information from earlier research, two of the original expressions had been replaced by new ones. Finally, the response scale was changed to one with seven points (González Gutiérrez, Jiménez, Hernández, & López, 2005).

OWL Method

It was developed to evaluate the level of general workload (OWL) by introducing sets of variables and application of the hierarchical analysis process (AHP) to estimate the external workload imposed on

Table 10. Factors and items considered in the Swedish occupational fatigue inventory (SOFI)

	Factors of fatigue				
	Lack of energy	**Physical exertion**	**Physical discomfort**	**Lack of motivation**	**Sleepiness**
Items	Overworked	Sweaty	Tense muscles	Uninterested	Sleepy
	Worn out	Breathing heavily	Stiff joints	Passive	Falling asleep
	Exhausted	Palpitations	Numbness	Listless	Drowsy
	Spent	Warm	Hurting	Indifferent	Yawning
	Drained	Out of breath	Aching	Lack of involvement	Lazy

Source: (Ahsberg et al., 1997)

a human operator in systems man-machine. The number of factors considered as potential sources of occupational workload is seemingly limitless. For this, a five-point linguistic variable set scale was constructed, and their hierarchical prioritization procedures were set up (weight of load: 'very light,' 'light,' 'medium,' 'heavy,' 'very heavy,'). Whether the source of an imposed workload is physical or mental in an industrial environment, it may influence an operator's health, performance, or productivity. of the task and the workplace variables (e.g., physical job demand, environmental, postural, and mental demand workloads) which can capture the operator's perception of a workload are introduced as a value of variables.

It must be pointed out that some factors (i.e., task and workplace variables) might be sources of workloads for some individuals but not for others. These differences can arise from various individual characteristics of a physical, mental, attitudinal, or emotional nature. Individual differences in such characteristics might be reflected, for example, in everyone's differences in capacities to adjust or adapt to different external conditions. In addition, a person's perception of his or her own ability to deal with specific job requirements and its external features could cause some people to experience workload but not others.

The task and workplace variables (e.g., physical, environmental, postural, and mental job demand workloads), showed in Table 11, which can obtain the operator's perception of the workload are selected as workload factors and the AHP technique is used to collect different weights. Since there exist various perceptions and responses to a workload by different individuals, the analytic hierarchy process (AHP) is introduced to collect different weighting factors. It organizes basic rationality by breaking down a problem into its smaller constituent parts and then guides subjects through a series of pairwise comparison judgments to express the relative strength or intensity of impact on a subject's workload in the hierarchy. This approach calculates the ratio of the subjective judgment from each type of workload and weighs each workload based on the impact on the subject's perception. Finally, OWL is calculated using a computer-assisted system to determine the level of overall workload impinged on an operator. The OWL was implemented in an actual industrial environment from a physiological and epidemiological viewpoint to determine the validity of the model (Jung & Jung, 2001).

Multivariate Workload Assessment (MWE)

The multivariate workload assessment, which integrates physiological parameters and one subjective parameter through Principal Components Analysis (PCA), was proposed to characterize task-specific

Table 11. Items considered in the OWL method

Items			
Physical job demand	Environment factors	Postural Discomfort	Mental Job Demand
Weight	Working Climate	Standing	
Frequency	Light	Stooping	
Duration	Noise	Squatting	
Distance	Vibration	Twisting	
	Exposure to Chemicals		

Source: (Jung & Jung, 2001)

responses and individual differences in response patterns to mental tasks (Miyake, 2001). With the aim of integrating in the workload measurement parameters with different origin in a single index, the multivariate workload assessment (MWE) allows to mix physiological parameters, showed in Table 12 (heart rate variability, changes in the sanguine pressure of the fingers of the hands and the perspiration) with subjective parameters (mental demands, temporary demand and global effort) by means of the technique of PCA.

This method employs three subscales: mental demand, temporal demand, and effort out of six subscales in the NASA-Task Load Index were used as subjective scores. These parameters were standardized within each participant and then combined. It was possible to assess workload using this method from two different aspects, i.e. physiological and subjective, simultaneously. As a result of this combination, a workload index with a range of 0 to 1 is obtained (Miyake, 2001).

Fatigue Assessment Scale (FAS)

The Fatigue Assessment Scale (FAS) is a method designed to assess the total fatigue using 10 items showed in Table 13, which is divided into two dimensions: physical fatigue and mental fatigue. The final score of the total fatigue is obtained by adding the values of the 10 items included in the questionnaire. In the same way, the physical and mental fatigue score is obtained.

A five-point Likert scale is used. An answer to every question must be given, even if the person does not have any complaints. Where 1 means “never”, 2 “sometimes”, 3 “regularly”, 4 “almost always” and 5 “always”. Scores on question 4 and 10 should be recorded (1=5, 2=4, 3=3, 4=2, 5=1). Subsequently, the total FAS score can be calculated by adding the scores on all questions (recorded scores for questions 4 and 10). The total score ranges from 10 to 50. A total FAS score < 22 indicates no fatigue, a score ≥ 22 indicates fatigue. All online versions of the FAS calculate the FAS scores automatically: a total score, as well as mental and physical score, will be provided (Michielsen, H. J., De Vries, J., & Van Heck, 2003)

Table 12. Items considered in the multivariate workload assessment (MWE)

Items
Heat rate variability
Finger plethysmography amplitude
Perspiration
Mental demand
Temporal demand
Effort

Source: (Miyake, 2001)

Table 13. Items considered in the fatigue assessment scale (FAS)

Items
1. I am bothered by fatigue
2. I get tired very quickly
3. I don’t do much during the day
4. I have enough energy for everyday life
5. Physically, I feel exhausted
6. I have problems to start things
7. I have problems to think clearly
8. I feel no desire to do anything
9. Mentally, I feel exhausted
10. When I am doing something, I can concentrate quite well

Source: (Michielsen, H. J., De Vries, J., & Van Heck, 2003)

Used in conjunction with other techniques of inquiry, FAS is valuable for the study of the physical and cognitive demands of different types of work processes. This method is now available in more than 15 languages. FAS is quick and easy to complete and not time-consuming. It is also helpful for physicians and other health care workers in the follow-up of their patients in addition to the regular functional tests such as lung function tests. The FAS has proven to be a valid questionnaire to assess fatigue in patients with ILD, but also in many other patients with chronic diseases and it was used few times for industrial use (Cano-Climent, Oliver-Roig, Cabrero-García, de Vries, & Richart-Martínez, 2017).

The Scale of Recovery for Exhaustion of Occupational Fatigue (OFER)

The Occupational Fatigue Exhaustion Recovery Scale (OFER) is a method designed to assess the recovery that a worker requires after their activities, it was developed by Winwood, Winefield, Dawson, & Lushington (2005) in the Netherlands. The 20-item scale showed in Table 14, has been developed and validated using data from three study populations specifically to measure work-related fatigue and possesses robust, gender-bias free psychometric characteristics. The three subscales identify and distinguish between chronic work-related fatigue traits, acute end-of-shift states, and effective fatigue recovery between shifts and analyze fatigue in 3 dimensions (called fatigue states): Chronic Fatigue (CF), acute fatigue (AF), and recovery between work shifts (RT).

The rating scale used in this method is Likert type from 0 to 6, where 0 is “strongly disagree”, 1 is “disagree”, 2 “little disagree”, 3 “no opinion (neutral)”, 4 ” bit of agreement “, 5” agree “and 6” totally agree.” This scale is suggested as a potentially valuable new tool for use in work-related fatigue research (Winwood et al., 2005).

The Scale of Estimated Fatigue-Energy Points (SEFEP)

The Scale of Estimated Fatigue-Energy points (SEFEP) allows relating fatigue with the energy that a worker uses when performing a specific task (Juárez-García, 2007). Whose methodology of application requires the evaluation at the beginning and at the end of the working day; an estimated point (average) is obtained from the objective and subjective items, shown in Table 15.

SEFEP contains 10 levels of punctuation and its interpretation is inverse to the Borg scale (0-10) (Borg, 1985). Consider the score of 10 as the best on the scale, that is, it is interpreted as extremely strong, animated and full of energy and level 1 is interpreted as extremely exhausted and exhausted. As concurrent criteria, several objectives and subjective indicators were used (Juárez-García, 2007).

NERPA Method

It is a novel method for the ergonomic postural evaluation method, fit for product-process design, which was developed with the help of a digital human model together with a 3D CAD tool. NERPA is widely used in the aeronautic and automotive industries. The power of 3D visualization and the possibility of studying the actual assembly sequence in a virtual environment can allow the functional performance of the parts to be addressed. NERPA works as a modified version of the method of rapid evaluation of upper extremities (RULA), showed in Table 16, this tool was developed for use in typical industrial manual assembly tasks in the automotive industry. The effectiveness of RULA and NERPA was compared by a real manufacturing process.

Table 14. Items considered in the fatigue assessment scale (FAS)

Items
1. "I use a lot of my spare time recovering from work"
2. "I often feel at the end of my rope with my work"
3. "I often dread waking up to another day of my work"
4. "I often wonder how long I can keep going at my work"
5. "I feel most of the time I'm living to work"
6. "My head feels dull/heavy a lot of the time"
7. "I often feel exhausted at work"
8. "Too much is expected of me at my work"
9. "My working life takes all my energy from me"
10. "I feel exhausted all the time"
11. "I usually have lots of energy to give my family or friends"
12. "I wish I had more 'get up and go' generally"
13. "I have the energy for my hobbies/relaxing activities in my spare time"
14. "I have plenty of reserve energy when I need it"
15. "I can't recover my energy completely between work shifts"
16. "I fully rested at the start of each workday/shift"
17. "Worrying about work issues makes it hard to relax at home"
18. "I usually recover my energy within a few hours of getting home from work"
19. "I usually feel fully relaxed by the time I go to bed"
20. "I don't get enough time between work shifts to recovery my energy fully"

Source: (Winwood et al., 2005)

Table 15. Items considered in the scale of estimated fatigue-energy points (SEFEP)

Items	
Objective	**Subjective**
Simple visual	Yoshitake's fatigue scale
Auditory	Maslach's MBI-GS emotional exhaustion sub-scale
Discriminatory time reaction tests	
Precision	
Speed of psychomotor performance test	

Source: (Juárez-García, 2007)

Table 16. Items considered in the NERPA method

Items
Stature
Eye height
Mid-shoulder height
Elbow height
Wrist height

Source: (Sanchez-Lite A, Garcia M, Domingo R, 2013)

The NERPA method, which modifies the evaluation of some joint ranges while maintaining the same evaluation structure as the RULA method, presents significant differences with respect to RULA. For the working conditions in which it was used, this method can detect positions with ergonomic risk and is more sensitive to the detection of an ergonomic improvement than the RULA method. The two methods lead to significantly different results. Under the methodological concept presented in this document, other ergonomic risk factors could be added to the NERPA method, which would allow the development of a general risk assessment methodology for industrial production within the framework of risk prevention (Sanchez-Lite A, Garcia M, Domingo R, 2013).

Combined Cognitive and Physical Assessment (CCPA)

It has a proactive and analytical approach to assess the imbalances in the interaction between the human being and the artifact. The CCPA methodology is based on the methods of cognitive assessment and predictive analysis of human errors. These methods have been further developed into four new methods: enhanced cognitive assessment, predictive use error analysis, predictive ergonomic error analysis, and generic task specification.

In addition to the changes that avoid the weaknesses and deficiencies identified in the original methods, the most important aspect of the CCPA methodology is that it deals with cognitive and physical ergonomics together. The objective of CCPA is to predict presumed discrepancies in the interaction of the human-machine, such as physical and mental workload, use of errors, usability problems and ergonomic errors, using a process that supports the cognitive processes of the evaluators. The purpose of examining the problems of physical and cognitive usability and errors of use in this interaction is to achieve a more comprehensive global assessment. In addition, this results in a more cost-effective evaluation of what would be the case if separate methods of cognitive and physical ergonomic assessment were used. CCPA also has a deep theoretical base in both areas.

CCPA is a task-based methodology that uses a structured and systematic questioning process to look for imbalances at each step of the interaction, as well as at a more general level of the system, showed in Table 17. The methodology was developed during work on product development projects in the industry and the academic world, where it was judged that existing evaluation methods did not provide enough information on interaction problems. The research was driven by problems and was conducted as action research. During and after development, CCPA and its methods were used in a series of evaluations in which the methodology predicted, identified and presented supposed imbalances in a structured manner. The strength of CCPA is that its development was iterative and based on reality, as well as on a solid theoretical basis.

The greatest strength of CCPA is the structured and systematic search for imbalances and the integration of cognitive and physical factors. The main weakness of CCPA is that it is more cumbersome and complicated to learn and use than the original methods, as well as compared to other individual HFE methods. However, CCPA generates a more complete result, which is presented in clear descriptions, than in the case of other methods. CCPA also contributes to consensus and knowledge transfer in the evaluation group in a product development project. To conclude, this thesis has resulted in a methodology to predict, identify and present presumed differences in the interaction between the human being and the artifact. However, more work is needed to evaluate the reliability of the methodology and to develop computer aids to simplify its use (Bligárd & Osvalder, 2014).

Ergonomic Checklist Method

Developed by the International Labor Office & International Association of Ergonomics (1991), the ergonomic risk checklist is a tool whose main objective is to contribute to a systematic application of ergonomic principles. It was developed with the purpose of offering practical and low-cost solutions to ergonomic problems, particularly for small and medium enterprises. It aims to improve working conditions in a simple way, through the improvement of safety, health, and efficiency. It is a particularly suitable tool to carry out a basic level assessment (or initial risk identification) prior to the advanced level assessment.

Table 17. Items considered in the combined cognitive and physical assessment (CCPA)

Items			
Task Demands	Automation Levels	Mental Workload	Physical Workload
Task Type (TT)	Power (P)	Mental Processing Type (MPT)	Force Resources (FR)
Task Category (TC)	Data Collection (DC)	Attention Resources (AR)	Fine Motor Resources (MR)
Performance/Accuracy (P/A)	Data Analysis (DA)	Memory Resources (R)	Speed Resources (SR)
Time Pressure (TP)	Decision Making (DM)	Processing Resources (PrR)	Body Loads (BL)
Performance Shaping Factors (PSF)	Control (CO)	Frustration and Stress (FS)	Body Contact (BC)
Frustration	Execution (EX)	Superimposed Mental Activities (SMA)	
	Supervision (S)		

Source: (Bligárd & Osvalder, 2014)

Table 18. Items considered in the ergonomic checklist method

Grouped Items
Material Handling and Storage
Manual tools
Safety of Production Machinery
Drawing of the Workstation
Illumination
Locals
Environmental risks
Hygienic and Local Rest Services
Individual Protection Equipment
Organization of Work

Source: (Diego-Mas et al., 2015)

The ergonomic checklist performs an analysis of ten different areas in which ergonomics influence working conditions. In Table 18, it shows the grouped items who contains from 10 to 20 checkpoints. In its entirety, the list consists of 128 points. Each checkpoint indicates an action. Options and some additional indications are given for each of the actions. In this way, there is the possibility to select the checkpoints that are applicable to a specific workplace and use the action proposals as an adapted checklist.

The way of using the list is as follows:

- Define the work area that will be inspected. In the case of a small company, it can be the entire work area.
- Know the most important characteristics and factors of the workplace that will be analyzed, such as, for example, the different products and processes that are carried out, the number of workers, shifts, breaks, overtime and any problems or incident that may exist in the workplace.

- Use the checklist to select and apply the checkpoints that are relevant in the workplace.
- Read each item carefully to know how to apply it, in case of doubt, ask the bosses or employees.
- Organize a discussion group using the user-specific checklist as a reference material. A group of people can examine the workplace to conduct a field study.
- Mark at each checkpoint, in the section "Do you propose any action?", A "YES", if the checkpoint is being met. If you think it should be fulfilled and it is not, mark a "NO". Use the Observations section if you wish to add any suggestions or locations.
- Once finished, re-analyze the items marked "NO". Select those whose improvements seem more important and mark them as a priority.

During the group discussion, existing information on "preventive actions" and "recommendations" could be useful as additional information to the selected checkpoints. In addition, good working practices and conditions should also be specified, where they are observed (Diego-Mas et al., 2015).

CONCLUSION

Through the review, using the information gathered in the research conducted in the databases, it was possible to conclude that there are combined evaluation methods most used than others because of the wide variety of tasks and the ease of obtaining results of the evaluation of tasks, where some methods quickly allow the accomplishment of the evaluations of the tasks. With the 17 methods explained in this research, it was found the three most used evaluations methods: NASA- TLX (Task Load Index), Subjective Fatigue Symptoms Test (SFST) and Fatigue Assessment Scale (FAS) with 9034, 267 and 204 citations respectively.

There are ergonomic evaluation methods that work differently from one another, some work with questionnaires, others with factors captured from observation or measurement of data, all have the goal to make an accurate assessment. Some methods work quickly, and others work slower, as there are some that in the evaluation does not consider more important items. Where a better evaluation is facilitated using physical load factors, mental load factors and other factors like ambient factors, which over time has been validated in different investigations.

According to this, it is recommendable to determine criteria to do a proper evaluation, using and compare the different methods considering the evaluated task and factors available against criteria for suitability and application of different ergonomic methods to do an accurate evaluation.

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