

The Assessment of Mental Load of Air Traffic Controllers Based on Psychophysiological Indicators

Raluca Maria Iordache^{1,*}, and *Viorica Petreanu*²

¹The National Research and Development Institute of Occupational Safety and Health (INCDPM) - "Alexandru Darabont" Bucharest, Romania

²The National Research and Development Institute of Occupational Safety and Health (INCDPM) - "Alexandru Darabont" Bucharest, Romania

Abstract. The article presents a part of a broader study on identifying and monitoring occupational risks, early detection of signs and symptoms of reversible impairment of physical and mental health of staff, decrease in work capacity and the occurrence of deficient, risky behavior in working practices, as a result of intense neuropsychological or physical professional effort. The results of the study aimed at highlighting: professional effort factors experienced by the trial subjects; occupational risk factors that cannot be avoided and which, due to the nature of the workload and the conditions for completing it, can in time lead to reduced work capacity, premature wear and tear, work-related illnesses and risky behaviors in the workplace, with serious consequences for the safety and health of employees and / or other people; measures to prevent and reduce identified work and stress factors, in order to ensure health and safety at work, optimal use of human resources and maintenance of work capacity throughout the professional life. The results can be implemented in the actions taken to ensure occupational health and safety regulations and to monitor employees' health conditions and their work capacity in accordance with the legislation in force.

1 Introduction

At present, the number of people who travel to all corners of the earth for different reasons has increased considerably. This has also led to a continuous increase in air traffic, given the advantages of this type of transport: fast, hence time saving, safety, comfort, etc.

There have been and there are still technical, technological and organizational actions being taken for the development of Air Traffic Management (ATM) to ensure both increased safety and economic and financial efficiency of this type of traffic [1]. Over time, the European Organization for the Safety of Air Navigation - EUROCONTROL - which Romania

* Corresponding author: iorraluca@yahoo.com

joined in 1996, has implemented a whole range of measures to make ATM more efficient. A few examples are: gradually introducing automated and computerized systems [2]; standardizing and harmonizing air traffic control (ATC) practices across the different states; establishing flexible airspace, etc. [3-4]. The above are among the objectives aimed at continuously improving the information network, the technical systems, the airspace flexibility, the human resource management, including the studies focused on safety and health conditions for air traffic controllers [5- 6].

1.1. Mental (neuropsychological) effort assessment:

Work activities consist of a combination of tasks performed with certain technical equipment, in a particular work environment, having specific authority and characteristics, in a certain organizational structure. Each of these factors is likely to exert an influence on the effort involved in work-related activities.

Work-related load (professional effort) depends on the requirements of the (professional) task and the individual capacities of the person carrying out the task. It represents the degree of mobilization of the employee, the percentage of their work capacity invested in carrying out the task and it depends not only on the nature and characteristics of the task but also on the characteristics of the technical equipment, the nature and characteristics of the factors of the work environment, their health, their personal and even extra-professional factors [7- 10].

The employee's exertion is the effort they feel they need to make depending on the level of their capacities. The biological cost - the individual load will be different depending on the ratio between the professional and personal capacities and will be reflected in different levels of demand on the body, on its various systems, functions, physical and psychophysiological capacities.

Since the professional load represents a multidimensional concept of the individual biological cost invested in an activity and at the same time it depends on professional, extra-professional and personal factors, its analysis and evaluation must also be multidimensional and multifactorial [9-10].

In this respect, depending on the specific nature of the task (characteristics, levels involved, etc.), it is necessary to use several evaluation techniques, so that their complementary results can be correlated to allow an assessment as close to reality as possible [11].

Techniques, indicators, and quotas cannot be limiting and fixed, they can and must be optimized by adapting them to the purpose of use, the activity under consideration, the conditions required to carry out that activity and the assessments undertaken (including the available time). These techniques, indicators, and quotas can also be used: to diagnose dysfunctions and their causes, which would lead to psychophysiological sub-or overloading of the individual; to check the effectiveness of business optimization solutions; to develop criteria for their optimization (in its various components).

Mental (neuropsychological) load is, in itself, one of the most important and most frequently responsible factors for causing fatigue in work activity.

Unlike physical effort which appears to be more objective and easier to measure [12], the neuropsychological effort can only be assessed indirectly using different categories of indicators, such as:

- indicators of workload;
- indicators of human performance when carrying out the workload (both quantitative and qualitative);
- psychophysiological indicators (pointing out the pressure exerted on different capacities: cognitive, psychomotor, etc.);

- assessments of the employees' subjective feeling of effort, of the physical and mental state at the beginning, during and at the end of the activity, and even of the state experienced after leaving work (as a reflection of the professional effort consequences on the extraprofessional time).

The quantitative or qualitative characteristics of these parameters are influenced by the interaction of the various professional factors during the completion of the work task: specific technical equipment, specific physical and psychosocial environment and complying with specific behavioral rules (technical, technological, organizational, health and safety).

A number of researchers [7-8] described the mental (neuropsychological) load as related to central processing, focusing in particular on visual, auditory, cognitive and psychomotor resources. Thus, specialists believe that all work tasks can be "broken down" into the following components:

- visual and auditory components relating to external stimuli to which the employee is exposed;
- the cognitive component, which refers to the level of information processing required by the task;
- the psychomotor component, which describes the physical effort required by the task.

Using from the conclusions of the studies carried out up to the present time and taking into account the provisions of ISO 10075 - 3/2004 - "Ergonomic principles regarding the effort in mental activity. Principles and requirements for methods of measuring and assessing the effort in mental activity" [17], objectifying and measuring of mental effort in work activity can be achieved through the following categories of indicators and techniques:

- Indicators and techniques for analyzing and assessing workload demands, aimed at evaluating some of its objective parameters: time requirements; complexity; cognitive requirements, etc.
- Indicators and techniques for subjective assessment: scales for assessing the subjective feeling of effort, of individual physical and mental state during the activity, at the end of it, and after leaving work during the extraprofessional time (as a prolonged effect of carrying out a work task).

Performance indicators and techniques that enable neuropsychological effort indicators to be obtained through performance or behavioral elements (changing the way a task is carried out depending on the level of effort required). Psychophysiological indicators and techniques for assessing the dynamics of psychophysiological and biochemical parameters required by completing the workload over a period of time.

2 Materials and methods

The present research used a complex, ergonomic methodology that has aimed at exploring the following:

- analysis of ATC work related activities (from a technical-organizational and psychophysiological perspective) and the conditions for their completion (environmental factors, ergonomics of job positions, organizational factors, etc.);
- assessment of professional effort, cognitive and psychomotor skills;
- assessment of psychological stress and psychosocial risk factors;
- the assessment of the labor capacity index;
- identification of the risk factors and the demand on the body as well as the response of the body to the effects of the professional risk factors as experienced by the trial subjects, response which reflects in the subjects physical and mental health,
- recommendations on reducing risk and exertion factors and managing stress at work, using as methods:

- the study of technical and technological workplace specifications (made available by the beneficiary), job descriptions, tasks, files for identifying professional risks;
- the analysis of the activities carried out (workload, working regime, conditions of completion);
- the analysis of the results of regular medical examinations;
- the analysis of the results when assessing risk levels / workplace / activity;
- the analysis of the results of measuring / assessing certain risk factors;
- the establishment and assessment of indicators for staff neuropsychological demands involved in performing work-related tasks at different times of shift work (starting and finishing the shift), characteristics for neuropsychological professional effort. [15]

Of the techniques and indicators used in the neuropsychological (mental) effort assessment in this study, we are going to present the results of the use of psychophysiological techniques and indicators. Evaluation through psychophysiological parameters was performed by recording the levels of psychophysiological (cognitive and psychomotor) capacities at the beginning and end of the work shift. The gross data obtained were recorded and processed statistically in order to highlight the main trends and their statistical significance. The psychophysiological capabilities which were evaluated had been divided into two main categories: cognitive (sensory-receptive, memory, focus) and psychomotor.

In regards to the cognitive capabilities, the focus has been on a number of psychological functions / mechanisms which, according to studies, allow the assessment of neuropsychological effort by analyzing the different performance levels of employees when carrying out a certain task. Also, based on the study of these psychological functions / mechanisms, we can observe occurrence of fatigue caused by the neuropsychological effort required by the workload.

Among the cognitive capacities explored in the study, we would like to mention the following:

- Perceptual abilities (especially the peripheral perceptual field, mostly affected by high effort / fatigue caused by effort) [16]
- Attention, as a psychophysiological process of orientation, concentration and selective enhancement of psychological and psycho-behavioral functions and activities. The focus was mainly on certain dimensions of attention, namely concentration and distributed attention.

Concentration is a specific attribute of attention and it refers to the depth of mental processing, the depth of analysis of the selected stimulus (element / operation of the workload).

Moments of deep concentration are manifested at the cortical level through strong stimulation accompanied by consecutive inhibition of neighboring areas. For this reason, it is expected that following periods of intense focus the concentration will decline, performances will decrease and fatigue will occur.

Distributed attention refers to its ability of simultaneously supporting two or more different activities.

- Memory, as a psychological mechanism for coding, storing and retrieving information.

In relation to this psychological process, special focus was placed in particular on work memory involved in instant solving of work tasks, and also on some memory sequences (such as the storage, recognition and updating of information) [13-14].

In relation to this first category of capabilities, two types of research equipment have been used: one focused on perceptual capacities and concentrated attention and another one focused on work memory (information update) and distributed attention. The above research equipment calculates the percentages of individual performance, corresponding to a certain level of development (very good, good, medium, poor, very poor).

Also, due to the fact that the stimuli registered by the device come from both areas of the perceptual field (central and peripheral), we were able to notice a certain level of mental exertion based on the differences between the number of inaccurate perceptions, especially in the peripheral perceptions field, between the start and finish of the work shift.

In the case of psychomotor skills, the aim was to investigate the complex (discriminative) response time to visual and auditory stimuli, which involves the simple reaction time as well as the mental processing (through concentrated attention, discrimination, choice among the different presented stimuli, etc.).

In relation to this second category of capacities, the results take the form of reaction times and the number of correct reactions or errors (wrong reactions, omissions, delays or anticipations). The two cognitive and psychomotor levels were analyzed using two research machines: EM - 05.74 digital tachistoscope and EM - 05.58 K complex psychomotricity conflictograph (both manufactured by Struktura Co. - Hungary).

2.1 Participants

20 air traffic controllers. Average age: 40.3 years (SD = 3.5), average work experience: 15.8 years (SD = 6.8).

3 RESULTS

Taking into account the special features of the activity that was analyzed, the neuropsychological (mental) effort was evaluated using psychophysiological parameters, by recording the values of cognitive capacities (sensory-receptive and complex) as well as complex psychomotor capacities at the start and at the end of the work shift.

On the cognitive level (sensory - receptive and complex), in relation to the overall general levels, all subjects recorded high (above average) levels of cognitive capacities (sensory - receptive and complex).

In relation to the perceptual and concentrated attention analysis, the results allowed certain correlations, some of which were statistically significant, based on correlation matrices and the Pearson coefficient (r), as shown in the Table 1 below.

Table 1. Cognitive indicators (attention): difference start – end of work shift

	Performance day shift start
Performance day shift finish	0,83 p = 0,09
	Performance night shift start
Performance night shift finish	0,92 p = 0,003*

*significant for $p < 0.05$

It can thus be established that the performance achieved at the end of the day shift is lower than at the start of the shift, although the difference is not significant from a statistical point of view. As for the night shift, there were strong, statistically significant correlations between the start and the finish of the shift, as a level of overall performance.

The indicators of professional fatigue accumulated during day and night shift are not limited to general performance, but rather to the level of concentrated attention in relation to

perceived stimuli, as well as to the capacity of perception of the stimuli from the central area and especially from the peripheral area of the perceptual field (Table 2).

Table 2. Cognitive indicators (perception): difference start – end of work shift

Start day shift	
Finish day shift	
Central stimuli	-0.67 (p=0.5)
Peripheral stimuli	2.585 (p=0.02)*

Start night shift	
Finish night shift	
Central stimuli	2.497 (p=0.79)
Peripheral stimuli	-0.09 (p=0.379)

*significant for p<0.05

These elements may indicate a more intense exertion during the day shift, due to specific conditions to complete the workload, higher number of supervised aircraft, causing fatigue that may be related to the peripheral area of the perceptual field.

We believe that the higher decrease in general performance at the end of the night shift compared to the day shift is not so much due to mental exertion during night shift, but rather to psychophysiological changes due to variations in individual biorhythms.

In regards to the analysis of work memory (information update), some relatively strong correlations were found, as shown in the Table 3 below.

Table 3. Cognitive indicators (memory): difference start – end of work shift

	Performance at the start of day shift
Performance at the end of day shift	0,81 p = 0,015*
	Performance at the start of night shift
Performance at the end of night shift	0,75 p = 0,034*

*significant for p<0.05

It can be noticed that for both day shift and night shift, the performance at the end of the shift is lower than at the start of the shift.

This result is due to impairment of the memory capacity level after performing a neuropsychological demanding activity. On a psychomotor level, ATC results indicate that 100% of subjects have medium and higher levels of psychomotor capacity.

There is also a greater number of stimuli errors and omissions, between starting and leaving work.

Day shift		t	p
	Number of errors	0.840	0.407
	Omissions	0.941	0.354

Night shift		t	p
	Number of errors	1.116	0.278
	Omissions	0.261	0.796

4 Discussion

The indicators of professional fatigue accumulated during day shift and night shift activities are not limited to general performance, but rather to the changes in the level of focused attention in relation to perceived stimuli, as well as to the capacity of perception of stimuli in the area central and, in particular, in the peripheral area of the perceptual field.

These elements may indicate a more intense exertion during the day shift, due to specific conditions to complete the workload, higher number of supervised aircraft, causing fatigue that was related to the peripheral area of the perceptual field (the most sensitive to mental fatigue).

We believe that higher decrease in general performance at the end of the night shift compared to the day shift are not so much due to mental exertion during night shift, but rather to psychophysiological changes due to variations in individual biorhythms.

In conclusion, in the case of complex discriminative reaction times, relevant to the assessment of mental effort based on psychophysiological indicators, we have demonstrated the presence of this effort as well as of the fatigue following the completion of the workload.

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