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IMPROVING QUALITY OF WORK LIFE THROUGH ELECTROPHYSIOLOGY: AN IDEA ACCEPTED BY INDUSTRY

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Abstract: *Quality of Work Life (QWL) and Occupational Health and Safety (OHS) are two interconnected and important human needs. Modern industry shows a clear will for improving QWL and OHS, nevertheless, existent automatization and technological advances may negatively influence employees' wellbeing and result as triggers to their health deterioration. Subjective measures of employees workload can help, however, the lack of objectivity may be an issue. Improvement of working life needs objective measures. There is technology for measuring objectively employees' psychophysiology, but is considered to interfere with the flexibility needed for performing working tasks. Today electrophysiological methods require minimal dimensions, are wireless connected, allow movement and are proved to be useful in capturing psychophysical wellbeing. This study shows that the industry is ready to accept electrophysiological measures for monitoring and improving the employees' wellbeing.*

Keywords: *QWL, OHS, electrophysiology*

1. Introduction

It is not easy to define Quality of Work Life (QWL), but it is understandable that it is important to workers' well-being as well as to the organizational environment and indirectly to the rest of society. QWL views the organizational environment under the spectrum of a wide range of needs of their employees' wellbeing in the workplace that can lead to career advancement (Cascio, 2000; Sirgy *et al.*, 2001). QWL describes employee's satisfaction in seven major needs: (a) Health and safety needs, (b) Economic and family needs, (c) Social needs, (d) Esteem needs, (e) Actualization needs, (f) Knowledge needs and (g) Aesthetic needs (Sirgy *et al.*, 2001). Kalleberg (1977) for defining QWL specified three main sets of concepts: job rewards, work values and job satisfaction. Howard (1983) stated that QWL was both a goal and a continuous process for achieving it. In fact Maslow hierarchy of needs emphasized on the importance of understanding one's individual needs which he categorized into physiological, safety, belongingness and love, esteem, and self-actualization needs. The lowest level needs of the hierarchy must be satisfied in order to proceed to the next level. Rethinam and Ismail (2008) mentioned that QWL has similarity with Maslow's hierarchy of needs. Accordingly, the meaning of QWL is tightly

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connected to Safety. Safety is the condition of being protected from or unlikely to cause danger, harm or injury. The term Safety in the workplace may be related to disastrous fatal accidents, but also to occupational problems and generally to workers' health, so the latest years it is used the term Occupational Health and Safety (OHS), according to the EEC Directive 89/391/EEC – OHS. The relation between QWL and OHS is evident in Work studies. Work environment studies have shown that physical and social work environment did affect employees wellbeing (Cummings and Malloy, 1977; Lawler and Hall, 1970; Sheppard and Herrick, 1972; Simmons and Mares, 1985; Susman, 1976). Bagtasos (2011) stated that QWL encompassed the characteristics of the work and the work environment influences employees' work lives. Major attendance should be given to work environmental conditions, because they affect job performance (Gnanayudam and Dharmasiri, 2007). However, industries face difficulty in attaining high quality and productivity in their manufacturing, and in parallel having good working conditions for their workers at low cost, so that they can compete in the global market (Sen, 1984; 1998). Differences in employment relations influence individuals' attitudes and behaviours as well as the quality of their jobs (Kalleberg, *et al.*, 2000). Besides, it is understandable that, in the nowadays automatic industrial environment, where most of the operations are sustained by advance technology, cognitive activity is influential and intrinsically connected to safety. Moreover, psychological and social factors may affect and get influenced by OHS and QWL as a vicious-circle-effect. Eklund (1995) showed that tasks that are ergonomically poorly designed have more quality deficiencies. Seems logical that the common basis for improving OHS and accordingly QWL is optimization of ergonomics. Layer *et al*. (2009) show that human performance in manufacturing environments depends on the operators' cognitive demands and the perceived QWL and this relationship is related to the operator's manufacturing tasks and sometimes to the time of exposure for performing these tasks.

In automatic industrial environment, Quality is intrinsically connected with advance technology, but this is not directly related to QWL. Automation demands cognitive activity, which is influential and intrinsically connected to safety. Technological systems in modern society are becoming more and more complex mainly due to the various phases of manufacturing products that require different systems, job operations and processes (Michalos *et al*., 2010; Mirer, 2011), with high level of automation and human-machine interfaces (Hassam and Mahamad, 2012). Ulin and Keyserling (2004) noticed that automotive industry although one of the most technologically advanced has a high incidence of musculoskeletal disorders. Additionally, Kvarnström (1997) also observed that the implementation of high technological assembly lines resulted in more complicated manual operations. Moreover, the presence of repetitive task is one of the most relevant safety issues (Spallek *et al*., 2010). We return to the concern that achieving high product quality and productivity is not always in parallel amelioration with good working conditions specially when the workload factor may not be thoroughly understood. Moreover, cognitive factors like mental fatigue and stress most of the times are not directly detected, even if they influence the performance of operational tasks; consequentially, these factors may cause economic loss, accidents, injuries and even death.

2. Methods of capturing workers' workload

One of the major health and safety issues in working environment is the workload in terms of cognitive and/or physical working task. Workload is negatively related to OHS influencing both physical and psychological health (Fournier *et al.*, 2011). Workload also known as work demand (Laschinger *et al.*, 2001) is a major negatively related QWL factor (Cordes and Dougherty, 1993; Houkes *et al.*, 2003). It sounds logic that if we measure and control workload factors then we can improve both OHS and QWL.

De Waard (1996) suggested that task-demand usually refers to the intrinsic features of the task while task-load describes the subjective impact on the operator. Therefore, measuring workload would necessarily require taking into account factors characterising the task and those describing how the operator is engaged with it.

Oerlemans and Bakker (2013) outlined two research methods, the Experience Sampling Method and the Day reconstruction Method for studying changes in momentary Subjective Wellbeing in everyday working life. There are other proposed methods for accessing to workers' wellbeing as Workload Assessment Technique (SWAT), Workload Profile (WP) and NASA-Task Load Index (TLX) (Hart *et al.*, 1984; Hart *et al.*, 1986; Hart, 2006; Rubio *et al.*, 2004), which are methods for obtaining workload estimates, but are based on subjective ratings. Nevertheless, latest research studies demonstrate that we can have objective workload measures (Buettner *et al.*, 2015; Gevins and Smith, 2003; Just *et al.*, 2003; Parasuraman, 2003; 2011; Parasuraman and Wilson, 2008) with the help of neurophysiological tools. The Electrophysiological tools of today can be used outside the laboratory, because of the advances of Wireless connections technology. Some researchers have even developed special monitoring systems for extreme environments (Mundt *et al.*, 2005). An important advantage of electrophysiological measures is that they can record the biodata continuously and the technology today can even offer a real time evaluation (Wilson and Russel, 2003).

3. Proposal of Electrophysiology

We propose Electrodermal activity (EDA), Electroencephalography (EEG) and Oximeter pulse recording for the purpose to capture operators' psychophysiology during their working tasks. These selected methods provide tools which are wireless connected, allow continuous recording, their dimensions are small allowing movement and flexibility and they are relatively inexpensive.

3.1 Electroencephalogram

Novel and state-of-the-art lightweight wireless EEG system (SMARTING, made by mBrainTrain LLC), which confirmed the ability of the device to obtain reliable, artefact-free recordings. The signal strength, judged by visual inspection of known eye-blink signatures and clearly visible alpha activity. The mBrainTrain company recently provided a research tool for neurofeedback testing paradigms.

Figure 1. mBrainTrain, montage of EEG system

Figure 1 shows "SMARTING" while being prepared for recording. This solution uses gel-based electrodes produced by proven, Easycap company offering high-quality recordings mainly due to low impedance. This system features 24 EEG channels with 24 bit resolution. The real-time data transmission is achieved using the Bluetooth 2.1 EDR which is able to communicate with a PC or Android based phones/tablets. In addition, electrode impedance information is continuously sent, together with the gyroscope readings. Several workload studies have reported the utility and efficacy of EEG in the field.

3.2 Electrodermal activity

Electrodermal activity (EDA) is the property of the skin to change its electric conductance in response to the sweat secretion phenomena. The system is related to sympathetic nervous system and can be used in order to control the cognitive system functionality. The EDA is used since decades by psychologists and other related professionals demonstrating that can discriminate with success emotional arousals (Bouscein, 2012). In the field of work studies. For EDA purposes measures, University of Kragujevac has developed an Electrodermal activity measuring device, for exosomatic recording, using direct current. The device can be seen on Figure 2. The specifications of EDA device are the following: sampling frequency is 40 samples/sec., measurement range for skin conductivity is 0-120uS, wireless operation with Bluetooth 2.4GHz, Class 2 (10 m range) used for real-time monitoring on PC. Overall dimensions: 50x40x10 mm. The electrodes used are Biopac-EL507. Electrodes specifications: Ag/AgCl contact (11 mm diameter), electrolyte wet liquid gel of 0.5% chloride salt, size 27 mm wide x 36 mm long x 1.5 mm thick. The raw EDA signal contains two main components, the Phasic and the Tonic. We can extrapolate from Phasic rapid changes the Skin Conductance Responses (SCRs). Each SCR contains features useful for further analysis, as shown in the Figure 3.

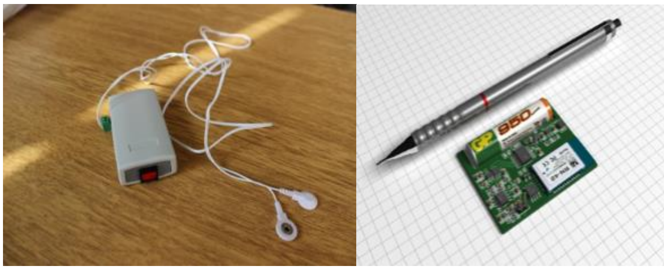

Figure 2. EDA device.

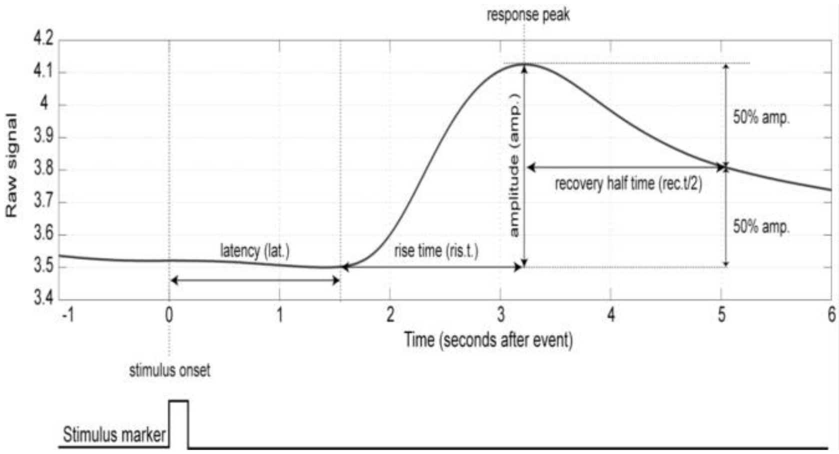

Figure 3. Raw signal with SCR components that can be used for quantitative

3.3 Oximeter pulse

Oximeter pulse. Measures what percentages of blood (hemoglobin) is loaded with oxygen. The system is based on the fact that oxygenated hemoglobin absorbs more infrared light and allows more red light to pass through. Deoxygenated hemoglobin allows more infrared light to pass through and absorbs more red light. It is not invasive and it is used since decades by physicians for various purposes that demand knowledge of level of oxygen percentages. In our case, it is an excellent tool for measuring oxygen levels and relate them with fatigue (Bundele and Banerjee, 2009). We will use: Acc U Rate (R) Handheld Continuous Pulse Monitor/ Pulse Oximeter.

4. The programme proposed

The proposal of electrophysiology recording during working tasks was made to the safety officers of the industrial plants of five international manufacturing companies. Three of the companies are situated in the area of Central Serbia and two in North Greece, respectively we will name the companies as A, B, C, D, E. In Serbia the Company A has approximately 3500 employees, the Company B 380 and Company C more than 150. The companies D and E, in Greece have less than 100 employees each. To all the companies we introduced the electrophysiological methods to their Safety, Quality, Human Resources managers or representatives and to a selected number of the staff. After an initial short presentation regarding EEG, EDA and oximeter pulse, we proposed a programme to the companies, as shown synoptically on Table 1. The proposal consists in recording the operators' psychophysiology two times during their working tasks, at the first 20min and the last 20min of their working day, in order to compare how the working hours influenced their psychophysiology. Although there is technology for continuing long term measuring, we consider that at the initial phase of our programme there is no need for 8 hours of recording. The operators selected for participating to the programme represent the levels of physical, and/or cognitive working tasks. The aim should be comparison with international standards of risk limits after particular working tasks. The pushing/pulling industrial cart task will be compared with the ISO 11228-2:2007 psychophysical tables. More precisely, we propose to determine the handle height, the distance and frequency of pushed/pull actions, the characteristics of workers population, as the standard suggests and additionally to record electrophysiological measures. The participants after their tasks will have to answer the Checklist Individual Strength CIS questionnaire (Fig. 4) about their fatigue level, overall workload, and mental effort. At the end a comparison between their answers and the psychophysiological measures will be done.

Table 1. The psychophysiology monitoring programme proposed

Task	Time of 1st recording	Time of 2nd recording	Measure
Pushing/Pulling industrial cart	20 min	20 min	EEG, EDA, oximeter
Video Data terminal Operator	20 min	20 min	EEG, EDA, oximeter
Health Safety specialist	20 min	20 min	EEG, EDA, oximeter

1.	I feel tired.	**yes, that is true**								**no, that is not true**
2.	I feel very active.	**yes, that is true**								**no, that is not true**
3.	Thinking requires effort.	**yes, that is true**								**no, that is not true**
4.	Physically I feel exhausted.	**yes, that is true**								**no, that is not true**
5.	I feel like doing lots of nice things.	**yes, that is true**								**no, that is not true**
6.	I feel fit.	**yes, that is true**								**no, that is not true**
7.	I am physically very active.	**yes, that is true**								**no, that is not true**
8.	When I am doing something, I can keep my thoughts on it.	**yes, that is true**								**no, that is not true**
9.	I feel powerless.	**yes, that is true**								**no, that is not true**
10.	I am physically not very active.	**yes, that is true**								**no, that is not true**
11.	I find it easy to focus my mind.	**yes, that is true**								**no, that is not true**
12.	I am rested.	**yes, that is true**								**no, that is not true**
13.	It takes a lot of effort to concentrate on things.	**yes, that is true**								**no, that is not true**
14.	Physically I feel I am in bad form.	**yes, that is true**								**no, that is not true**
15.	I have a lot of plans.	**yes, that is true**								**no, that is not true**
16.	I tire easily.	**yes, that is true**								**no, that is not true**
17.	My level of physical activity is low.	**yes, that is true**								**no, that is not true**
18.	I don't feel like doing anything.	**yes, that is true**								**no, that is not true**
19.	My thoughts easily wander.	**yes, that is true**								**no, that is not true**
20.	Physically I feel I am in an excellent condition.	**yes, that is true**								**no, that is not true**

Figure 4. The CIS questionnaire.

The aim is to create new indexes of risk. For the strictly cognitive demanding tasks, we suggest the same CIS questionnaire and the same recording plan, without the relation of a standard. The CIS questionnaire has demonstrated its validity in capturing workers' fatigue limits (Bültmann *et al.*, 2000). Each question is scored on a 7-point Likert scale (from "yes, that is true to "no, that is not true"). The total score is the sum of all items (range 20–140). The four subscales are Subjective Fatigue (8 questions), Concentration (5 questions), Motivation (4 questions), and Physical Activity (3 questions). The selection of CIS questionnaire was based on its simplicity and its questions. At this phase of the psychophysiology programme the CIS questionnaire is addressed only to English speaking operators.

5. Questionnaires for asking permission

The above electrophysiological are non-invasive methods, but cannot be used without the clear employees' permission. Moreover these methods may result in adding discomfort to a worker's task. After the presentation, we distributed a questionnaire to the employees who attended our presentation, asking them to answer questions regarding our proposal and their opinion about if these tools can or not help them improving their QWL.

Table 2. Operators' answers of Company A, Company B and Company C.

		Do you want to improve your QWL		**Do you want to try EEG, EDA and Oximeter**		
Company A	**Nº operators**	**YES**	**NO**	**YES**	**NO**	**Maybe**
Safety engineer	1	1		1		
EHS specialist	3	3		3		
Worker	9	7	2	3	6	
Video Data Terminal Operator	5	5		5		
Company B						
EHS specialist	2	2		2		
Safety engineer	1	1				1
Workers	10	6	4	5	4	1
Company C						
Safety Engineer	2	2		2		
Maintenance Engineer	1		1	1		
Internship student	2	2		2		
Worker	5	2	3	2	3	

Table 3. Operators' answers of Company D and Company E.

		Do you want to improve your QWL		Do you want to try EEG, EDA and Oximeter		
Company D	**N° operators**	**YES**	**NO**	**YES**	**NO**	**Maybe**
EHS specialist	2	2		2		
HR manager	1	0	1			1
Worker	4	2	2	2		2
Company E						
Safety manager	1	1				1
Worker	7	4	3	3	3	1

The Table 2 shows the answers from the employees A, B, C, and Table 3 from the employees of the D and E companies respectively. From the company A, 18 employees attended our presentation, among them one was Safety engineer, three were EHS specialists, five were employees working on computer with cognitive demands tasks and nine workers with mainly physical load tasks. From the company B, 13 employees attended our presentation, among them one Safety engineer, two EHS specialists, and ten workers. From the Company C, 10 employees attended our presentation, 2 were Safety engineers, 1 Maintenance engineer, 2 Engineering post graduate students during their internship and 5 manual operators. It is important to underline that all the employees in Serbia were in the range of age 36±13 years old, more precisely the Safety engineers and the EHS specialists were in the range of age 35±5 with experience of 3-6 years in the field of Industrial Safety. From the companies in Greece, at Company D, 6 employees attended our presentation 2 were Occupational Health and Safety Specialists, 1 Human Resources manager and 4 workers for manual handling operations. From the Company E, 8 persons attended, one was Safety manager and 7 manual handling operators. The average age of the employees questioned at the D and E Greek companies is 42±5 years old.

6. Results

From the company A, all 18 employees answered the questionnaire, only 2 workers do not want to improve their QWL, 6 workers do not want to be measured with electrophysiological tools during their working tasks, while all higher level of employees (EHS specialists and employees with computer-based tasks) answered positively either for improving the QWL and ready to be tested with psychophysiological methods.

From the company B, 13 employees answered our questionnaire, 4 express that there is no need to improve their QWL, and the same 4 do not want to be tested with electrophysiology methods during their working tasks. 7 employees answered positively and 2 maybe on the question if they want to use electrophysiology. From the Company C, 2 Safety engineers answered that they want to improve their QWL and are willing to try electrophysiological methods, 2 postgraduate Engineering students want to try electrophysiology and improve their QWL, 2 of the workers in manual handling operations answered that they want to try electrophysiology and improve their QWL while 3 answered that they don't want to improve their QWL and not willing to try electrophysiology. 1 Maintenance Engineer does not want to improve his QWL, but he is willing to try electrophysiology.

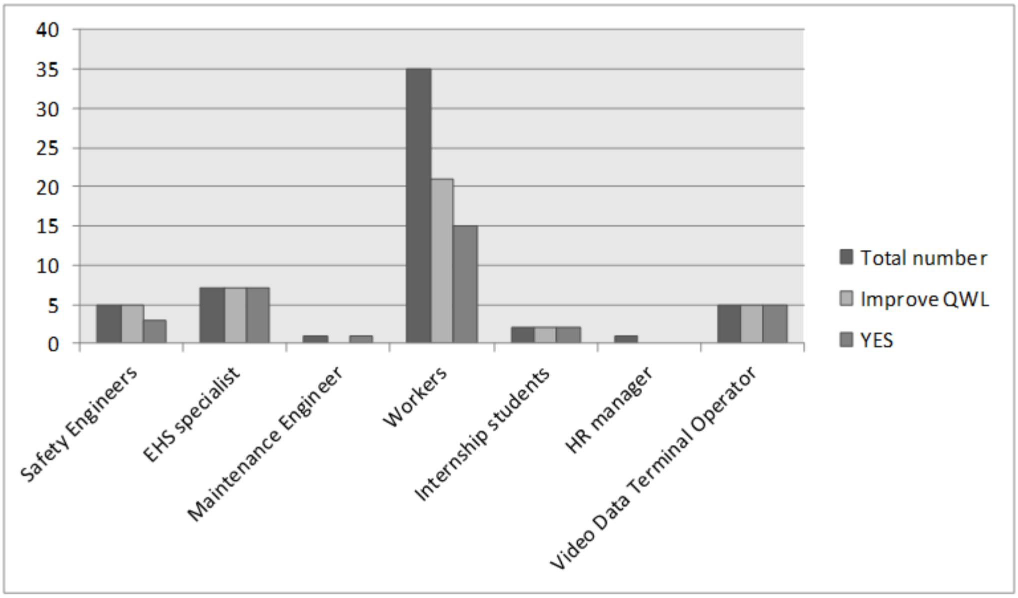

Figure 4. The number of the employees from all the companies divided on their profession. Total number: the number of the professionals of each category asked. Improve QWL: the number of those who asked they want to improve QWL. YES: the number of the professionals that answered positively on electrophysiology monitor programme.

From the companies in Greece, the EHS specialists of the Company D answered that they want to improve their QWL and the accept to try electrophysiology, the HR manager does not want to improve his QWL but maybe he will try electrophysiology. Two manual handling operators who want to improve their QWL want also to try electrophysiology and the other 2 who don't feel the need for improving their QWL but maybe they will try electrophysiology. From the Company E the Safety manager wants to improve the QWL through electrophysiology, 3 of the workers do not feel the need for improving their QWL but 4 want to among them 3 will try electrophysiology but one answered maybe. It is important to underlie that all employees from the two companies who attended our presentation answered the questionnaire. The Tables 2 and 3 show the results in details and the Figure 4 shows the operators from all companies divided in professionals, the number of those who have answered positive on improving their QWL and their positive opinion on implementation of electrophysiology.

7. Discussion

Measuring workload, job satisfaction, and accordingly QWL and their relation to EHS remains a qualitative approach. Many studies deepen in measuring objectively the relation between safety and cognitive factors through electrophysiology, but even though these studies are successful, electrophysiology remains in the domain of high risk sectors as flight pilots and drivers (Miyake *et al.*, 2009). Electrophysiology could have many useful applications in industry beyond high risk environments. A study by Léger *et al*. (2014) demonstrates the importance of EDA and other neuro-physiology methods to cognitive absorption during enactive training and their relation to training outcome. Another study by Yoshino *et al*. (2007) investigated the possibility of recording automatically dangerous situations provided an algorithm containing EDA and Heart rate parameters.

Job quality has been a concern of researchers and policy-makers for a long period of time, recently among other factors employees' wellbeing is of crucial importance for defining Job Quality (Warhurst and Knox, 2013). Moreover, selected studies show that productivity is found to be related directly to OHS (De Greef and Van de Broek, 2004).

On the results of the questionnaires we can also derive on some other conclusions. In total 21 professionals from all the companies, all with tertiary education title answered the questionnaire and 17 of them accept the electrophysiology programme. One surprising result is that the Maintenance Engineer although does not feel the need for improving his QWL wants to implement electrophysiology. This fact may be explained by the personal interest to check if electrophysiology can help for the overall improvement of working conditions in the manufacturing working environment. We consider very positive the fact that 100% of the EHS specialists answered positively on QWL and on electrophysiology.

Until now it seemed that the only factors that influence negatively the use of electrophysiological methods for working environment optimization, was the lack of appropriate technology, that permits flexibility and movement because of the eventual discomfort that may create to employees. This work demonstrates that the employees of all levels are ready to improve their QWL through psychophysiological modern and wireless connected sensors. Nevertheless some limitations should be noticed. Although the industrial environment seems to accept the novel measures, this does not provide necessarily implementation or adaptation of their working tasks. It is up to the organization, once the measures are taken, to change or transform the working conditions. Moreover the permission was addressed to a small number of operators, although they are in key positions, we cannot be sure that this monitoring programme can be accepted by all the operators. We can conclude though that the managers asked acted positively to the idea of psychophysiological monitoring as tool for improvement of QWL and OHS. Another limitation is the English CIS questionnaire. This is only the initial phase of this programme and we will provide to all the international companies the same questionnaire. It is important to underline that a number of foreigner operators work in the companies of Serbian and Greek territory and the main language is English.

The objective measures provided by this proposal cannot improve other factors that contribute to QWL as autonomy and job security (Gallie, 2003; 2007). This study is not aiming to substitute self-reports, but to add physiology measures for better understanding the employees during a task according to de Waard and Lewis-Evans (2014) suggestions.

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