WorkingAge: Smart Working Environments for all Ages.

Vera Rick[1], Gianluca Borghini[2], Julia Czerniak Wilmes[1], Vincenzo Ronca[2], Alessia Vozzi[2], Alexander Mertens[1], Marteyn van Gasteren[3], Carlos Alberto Catalina Ortega[3], Maite Cobo[3], and Fabio Babiloni[2] and Verena Nitsch[1]

[1] IAW – Institute of Industrial Engineering and Ergonomics, RWTH Aachen University, Bergdriesch 27, Aachen, Germany
{v.rick, j.czerniak, a.mertens, v.nitsch }@iaw.rwth-aachen.de

[2] Brainsigns srl,
Lungotevere Michelangelo 9, 00192 Roma, Italy
{vincenzo.ronca, alessia.vozzi, , gianluca.borghini, fabio.babiloni}@brainsigns.com

[3] Instituto Tecnológico de Castilla y León,
López Bravo 70, E-09001 Burgos, Spain
{maite.cobo, marteyn.vangasteren, carlos.catalina}@itcl.es

Abstract. WorkingAge (WA) will use innovative HCI methods to measure the user emotional, cognitive and physical strain. At the same time with the use of Internet of Things (IoTs) sensors will be able to detect environmental conditions. The purpose is to promote healthy habits of users in their working environment and daily living activities in order to improve their working and living conditions. By studying the profile of elderly workers and the working place requirements in three different working environments (Office, Driving and Manufacturing), both profiles (user and environment) will be considered. Information obtained will be used for the creation of interventions that will lead to healthy aging inside and outside the working environment. WA will test and validate an integrated solution that learns the user's behaviour, health data and preferences and naturally interacts with the user through continuous data collection and analysis, with data protection always being a first concern.

Keywords: Emotive, Health, Mental States, Human-Machine-Interaction, Mental Workload, Multi-modal approach, Ontology, Strain, Stress, Worker

1 Introduction

High work intensity, monotonous or complex, working day length, shifts timing, professions prone to burnout and effort-reward imbalance have been found to negatively affect health and well-being outcomes [1]. A health adverse psychosocial work is associated with early retirement and with poor health during retirement [2]. Additionally physical factors like musculoskeletal diseases increase the risk of work disabilities and of productivity loss at work. Exposure to occupational risk factors plays an important role in the aetiology of musculoskeletal diseases. In 2014 there were around 3.2 million non-fatal accidents and 3,793 fatal accidents, and 7.4% of the EU population suffered from one or more work-related health problems [3]. Demographic factors such as ageing and shrinking labour force [4] influence these statistics and lead to poor healthy working conditions, shortage of human resources, loss of knowledge [5] and significant economic and social consequences [6]. But it is not only demographic change that makes it necessary to keep and retain older workers at work. Successful ageing in the workplace must be a priority objective, because age-related changes not only lead to a reduction in working capacity, elderly working persons are characterized though an increasing wisdom and self-development as well as increasing personality and integration into social systems [7]. It is necessary to strike a balance between increasing life expectancy and the associated health changes of ageing in order to enable healthy ageing and working in the long term. Various factors can impede healthy ageing. Since, in the developed countries workplaces have changed due to globalization, use of new information, and communication technology, mental workload is the dominant element in many jobs. If high level of mental workload cumulates and recovery fails, health problems such as chronic stress, depression, or burnout can occur. It appears that mental workload has increased over the last years, more and more often they seem to have a disease value and influence the ability to work. For 20 years, mental stress and disorders have been among the most frequent causes of absence from work due to illness, and the trend is rising in Germany [8], [9]. The tense labour market and rapidly changing demands have forced organizations to be highly flexible, and have resulted in a type of intensified work characterized by time pressure and social interaction. This shift in work strain is not unique to a single country. Economic globalization has contributed to an amalgamation of nationalities, especially in international organizations [10].

Strain is an essential aspect for assessing the effects of work on the working person and it plays an important role in the assessment of human work; therefore, the reduction of strain is often an essential goal in work structure [11]. In context of ergonomics, stress describes the external characteristics of a work situation that influences the working person. These include, for example, physical and organisational working conditions. Strain, on the other hand, describes the reactions of the working person to these conditions. Some external factors, which represent stress, are the same for all people, the respective impact, the strain on the individual, can be different and change while ageing. Strain is the individual reaction to stress [12]. Rohmert [12] differentiates between physical and psychological strain. Physical strain describes the effects of stress on the muscle and cardiovascular system. Strain reactions resulting from physical exertion manifest themselves in measurable changes of the human body, for example changes of the cardiovascular system can be recorded or subjectively evaluated via physiological parameters such as heart rate, respiratory rate, respiratory volume, blood pressure, body temperature, etc. In contrast psychological stress is the entirety of all detectable influences that have a psychological effect on the working person [13]. Mental strain is one factor of psychological strain that describes the portion of total strain induced by perception, cognition and action. Mental strain occurs during cognitive work and is dependent on interaction of internal and external factors. External factors are specified by characteristics of the technical system, e.g. task requirements, design of graphical user interface etc. Internal factors are specified by the individual characteristics. The increasing strain of a person while processing information causes the change of physiological variables. The following figure illustrates further subdivisions between physical and psychological strain (Fig. 1) [14].

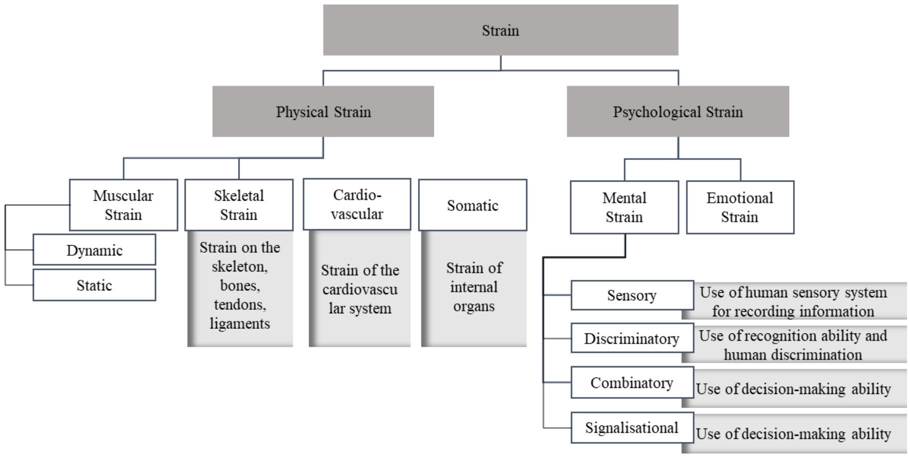

Fig. 1. Further subdivisions between physical and psychological strain [11].

Following this concept several external and internal factors can influence the individual performance whilst working [12]. According to his research, individual performance is dependent on constitutional, dispositional, and adaptational characteristics, as well as the level of individual qualification and competence. In this regard, constitutional characteristics are unchangeable during lifecycle, e.g. gender, physique, race, genes; whereas adaptational characteristics can directly and very fast be influenced, such as strain, fatigue, mood, motivation, or concentration. Dispositional characteristics on the other hand, are changeable, but cannot willingly be influenced, for instance age, weight, or health. The last category, qualification and competence, contains characteristics that are influenceable by means of long-term processes, e.g. skills, capabilities, experience, knowledge or education.

Conventional risk assessment techniques provide the assessment of risk related to the workplace, i.e. for the general collective of individuals that may be working at a particular workplace (applying statistical approaches when needed), and valuated through a long period of time. The innovative approach of the WA project allows the adoption of immediate corrective measures, maintaining the risk permanently under control and empowering the worker in the application of preventive measures. In fact, the WorkingAge-Tool (WA-Tool) will use various sensors to determine the employee's current status in terms of mental workload, stress, emotional states, working conditions and environmental influences in order to permanent maintenance of risks behind the safe level and produce healthier workers and longer work lives.

2 Methods

One of the concepts of the WA project is to improve work by developing a tool that helps the user to feel more comfortable in different working environments, and to decrease the strain whilst working by lowering physical and mental workload and stress. In order to achieve this, the users' strain needs to be estimated. In general, strain can be measured by means of subjective, performance related and physiological indicators. Whereas subjective methods, such as the NASA-TLX questionnaire [15], or the RSME scale [16] and performance indicators (e.g. execution time, errors), consist of post hoc analyses, physiological indicators have the potential for timely strain assessment. In order to provide timely and objective feedback, the WA-Tool will be developed by using different kinds of sensors. **Fehler! Verweisquelle konnte nicht gefunden werden.** shows which measurement methods and sensor will be employed within the WA-Tool. Furthermore, the algorithms at the basis of the WA-Tool are capable of provide coaching depending on each specific working situation. This reasoning engine will offer a set of operations on the defined ontology's axioms and rules, providing recommendations on working habits, physical activities and social relations. Such algorithms will make use of hybrid models mixing a-priori knowledge (i.e. ontology) with machine-learning methodologies (i.e. Deep Neural Networks).

Table 1. Measurement of mental workload, stress, emotional and physical strain.

	Psychological Strain						*Physical Strain*							
	mental	sensory	discriminatory	combinatory	signalisational	emotional	muscular	dynamic	static	skeletal	sensory-nervous	cardiovascular	somatic	*Environmental Conditions*
Electrocardiogram	o					o	●	●	o	o	o	●		
Electromyography							●		o					
Skin Conductance	o					●			o			o		
Electroencephalogram	●	o	o	●		o						o		
Electrooculogram											o			
Facial expression						o								
Voice Recognition						o								
Gesture recognition						o		o						
Pupil diameter	o	o	o	o		o								
Body Posture							o		o	o				
Eye-Movement	o													
Noise														●
Thermohygrometric														●
Light														●
Location														●

● – direct Indicator; o – indirect Indicator

2.1 Requirements for the WorkingAge System

Since strain, as the individual reaction to mental workload and stress, is very much dependent on several internal and external influences, an overview about possible influences is mandatory. In Fig. 2, a *Data Ontology* that shows all influences as a whole is presented, based on findings of the prior paragraph. The WA project focuses on elderly users above 50 years of age. This user group is characterised through an increasing wisdom and self-development as well as increasing personality and integration into social systems. However, there is been a decrease in cognitive, perception and biological systems [7]. The main changes in mental and physical conditions around the age of 50 years are changes in visual perception (e.g. color perception, visual acuity), auditory perception (auditory acuity, frequency), perception of vibration, cognition (e.g. working memory, learning, reaction) and the mobility of upper limbs [17]. From this, different requirements for the WA-Tool can be determined. First of all, it must meet the measurement requirements, primarily the desired parameters (measuring physical and mental strain and recording environmental variables). Furthermore, an important requirement is the usability in varying work environments. Finally, it must meet the requirements of elderly users in particular, i.e. in terms of operation, handling and type of feedback.

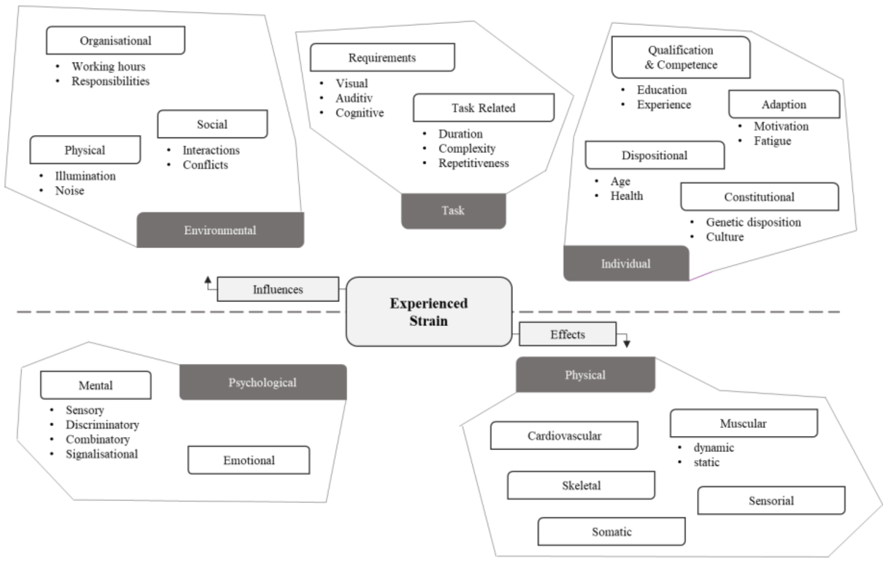

Fig. 2. WorkingAge Data Ontology.

2.2 Procedure

In order to build the WA-Tool on active user engagement, the project will interact with three different environments. A workplace *in-production*, characterised by movements being carried out, and information to be perceived and reacted to, *in-vehicle* workplace consisting of reactive work elements as the driver has to perceive their environment, to assess the current traffic situation, and respectively react by making decisions and adjusting their own driving operation, and finally *in-office* workplace where basically the work consists of the utilization of profession specific methods, problem solving, implementing strategies, and deciding by the usage of computer programs.

3 Concept of the WorkingAge System

The WA-Tool concept offers the first direction, when defining the system architecture. In the following, basic software and hardware components are described, their interplay, as well as the functionality of the system, regarding the processing of the measured data.

3.1 Components and Functionality

An important facet of the WA project is the availability of the user model data analysis and advanced functionalities as a cloud service rather than as standalone software. To meet the requirements, the WA system will be designed as a modular, mobile system, with autonomous sensor components, at best wireless capable sensors. Particular attention will be paid to always acting within the framework of the European GDPR. As a minimum, the following components are planned within the WA project (Fig. 3). Since various sensors will be used to collect the worker's data, a Central Processing Unit (CPU) cloud solution will be employed to process all the data. The WA-Tool calculates the overall worker's strain-level by combining all the available information and considering risk assessment according to Occupational Safety regulations. The overall strain value is further calculated on the basis of the sensor data, and builds the basis for further health evaluation and the definition of system feedback. Additionally, a prioritisation algorithm will be developed to evaluate the data on the basis of their accuracy.

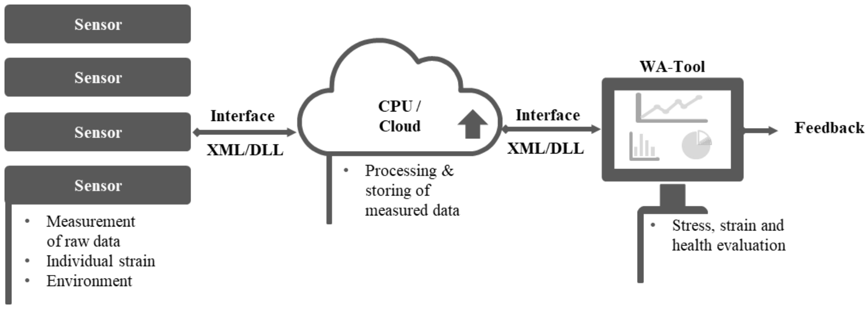

Fig. 3. System structure and concept of the component interaction of the WA project.

4 Objectives and Perspectives

The working environments today differ considerably from that of ten years ago. In this new environments, where pressure on workers and employers is high, health costs are rising and chronic diseases and safety are new threats, health promotion and protection measures could have a significant long-term impact and potentially save economical resources. The duration of a person's ability to work is influenced by several factors, of which health is the greatest risk to early retirement [18]. In addition, work is an important factor for health. Individual health practices are shaped by our work cultures and values. The workplace is organically linked to the home and physical communities in which workplaces exist. There is no clear dividing line between "work-related" and "non-work-related" injuries [19]. This is where the WA project takes action. It will support a better understanding of well-being at work and the factors that can inhibit or improve long-term employment, as well as supporting health-promoting properties that are also applied in everyday life. The WA-Tool will support employees in their daily work with recommendations, risk avoidance and reminders, which they can also use in everyday life.

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References

[1] J. Siegrist *et al.*, “The measurement of effort--reward imbalance at work: European comparisons,” *Soc. Sci. Med.*, vol. 58, no. 8, pp. 1483–1499, 2004.

[2] J. Siegrist and M. Wahrendorf, “Quality of work, health, and retirement,” *Lancet*, vol. 374, no. 9705, pp. 1872–1873, 2009.

[3] Eurostat, “Accidents at work statistics,” 2016. [Online]. Available: http://ec.europa.eu/eurostat/statisticsexplained/index.php/Accidents_at_work_statistics.

[4] D. Kooij, A. de Lange, P. Jansen, and J. Dikkers, “Older workers’ motivation to continue to work: Five meanings of age: A conceptual review,” *J. Manag. Psychol.*, vol. 23, no. 4, pp. 364–394, 2008.

[5] T. J. Calo, “Talent management in the era of the aging workforce: The critical role of knowledge transfer,” *Public Pers. Manage.*, vol. 37, no. 4, pp. 403–416, 2008.

[6] M. D. Fitzpatrick and T. J. Moore, “The mortality effects of retirement: Evidence from Social Security eligibility at age 62,” *J. Public Econ.*, vol. 157, pp. 121–137, 2018.

[7] J. M. Munnichsm, *Evaluation and Intervention: Research on Aging: Proceedings of a Symposium of EBSSRS Held at Nijmegen in August 1988*. Department of Social Gerontology, University of Nijmegen, Nijmegen, 1989.

[8] B. J. Burchill *et al.*, “Job insecurity and work intensification: Flexibility and the changing boundaries of work,” *York Joseph Rowntree Found.*, 1999.

[9] T. Z. Livia Ryl, Anke-Christine Saß, “Gesundheit in Deutschland - die wichtigsten Entwicklungen,” Berlin, 2015.

[10] OECD, “The employment of foreigners: outlook and issues in OECD countries,” *OECD Employ. Outlook 2001*, 2001.

[11] J.-H. Kirchner, “Belastungen und Beanspruchungen—Einige begriffliche Klärungen zum Belastungs-Beanspruchungs-Konzept,” in *Arbeitsorganisation und Neue Technologien*, Springer, 1986, pp. 553–569.

[12] W. Rohmert, “Das Belastungs-Beanspruchungs-Konzept,” *Z. Arbeitswiss.*, vol. 38, no. 4, pp. 193–200, 1984.

[13] C. Schlick, R. Bruder, and H. Luczak, *Arbeitswissenschaft*. Springer-Verlag, 2018.

[14] H. Luczak, “Belastung, Beanspruchung und Erholungszeit bei informatorisch-mentaler Arbeit,” *Bremerhaven Wirtschaftsverlag NW*, 1982.

[15] S. G. Hart and others, “Development of NASA-TLX: Results of empirical and theoretical research.” inP. A. Hancock and N. Meshkati (eds.), Human Mental Workload.” North-Holland, 1988.

[16] F. R. H. Zijlstra and L. Van Doorn, “The construction of a scale to measure subjective effort,” *Delft, Netherlands*, vol. 43, 1985.

[17] A. Mertens, “Altersgerechte Gestaltung von Mensch-Maschine-Schnittstelle zur ergonomischen Interaktion mit telemedizinischen Systemen und Dienstleistungen,” RWTH Aachen University, 2014.

[18] B. L. Oortwijn W, Nelissen E, Adamini S, van den Heuvel S, Geuskens G, “Social determinants state of the art reviews - Health of people of working age - Summary Report,” Luxembourg, 2011.

[19] L. Punnett, M. Cherniack, R. Henning, T. Morse, P. Faghri, and C.-N. R. Team, “A conceptual framework for integrating workplace health promotion and occupational ergonomics programs,” *Public Health Rep.*, vol. 124, no. 4_suppl1, pp. 16–25, 2009.