WORKINGAGE

Smart Working Environments for All Ages

D2.1 Report about User and Data Requirements

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WP2 – User Centric Design

D2.1 – Report about User and Data Requirements

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Executive Summary

This Deliverable gives an overview of the results and achievements from *Task 2.1: Report about User and Data Requirement.*

The document contains the theoretical background of strain analysis and the planned measurement methods in the WorkingAge project (Section 1).

In Section 2, we derive an ontology from influences towards strain, which is the basis of the following user and data requirements. First, the user requirements are described in Section 2.1. This includes consideration of risk factors from an ergonomic and psychological point of view. Finally, suggestions for the WorkingAge project are derived. Second, the use case requirements are describes in Section 2.2. The three use cases to be considered within the WorkingAge project are discussed in general here. This includes a basic ergonomic analysis of the work tasks regarding to their strain types and a general task description. A concluding summary for the WorkingAge tool finishes this section.

Section 3 then introduces the system concept. The main concept and the components are discussed here. The system requires the communication of several sensors with the WorkingAge tool via a data cloud. Besides its functionality of measuring the working person's condition, the system should be able to, for example, give information about data quality.

This document relates to Task 2.1, and serves as an overall overview about relevant ergonomic concepts, the systematic derivation of system requirements, as well as the system structure. The single aspects will be complemented during the subsequent tasks of Work Package 2.

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1. Data collection

1.1 Stress-Strain Concept

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 (Kirchner, 1986).

The principle idea of the stress-strain concept is based on the analogy to technical mechanics. Stress signifies the entirety of external influences, e.g. forces, which act on a component. Strain signifies the resulting internal tensions within the component (Schlick, Bruder, & Luczak, 2018). 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. Strain is not only a function of stress, but also depends on individual characteristics and abilities (e.g. degree of adaption, qualification) (Kirchner, 1986). An equal amount of stress thus results in various strains for different people (Rohmert, 1984). Some strain can directly be reduced through effective industrial engineering; others can only be taken into consideration by ergonomics workplace design (Schlick et al., 2018).

Rohmert (1984) classifies and 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 (Schlick et al., 2018).

Figure 1: Simple Stress-Strain Concept following Rohmert (1984)

The simple stress-strain concept, which is shown in Figure 1, is based on a simplified understanding of human work. For this reason, the concept of stress and strain in this simple form is therefore suitable especially for the analysis of deterministic work systems.

An extended model is presented in Figure 2, in which stress depends on how and whether the action is performed and on the so-called psychophysiological resistance. Psychophysiological resistance can also be described more vaguely as the "resilience" of the worker (Schlick et al., 2018).

A further differentiation of the relationships between stress, strain and individual characteristics of the working person results in the explicit consideration of the activity of the working person. This *extended stress-strain concept* includes physical and informational, as well as psychological stress and its current and long-term effects (Rohmert, 1984). In addition, the cumulative influence of stress over time is considered, whereby fatigue and damage or compensation due to exercise and habituation are relevant. The performance of the action depends on the stress situation (i.e. the objective circumstances like duration and composition of work) and on the competence to act (the possibilities of the person to fulfil the task). The strain depends on how the action is carried out and on the so-called psycho-physiological resistance. Work-scientific assessment dimensions as well as characteristics of the working person (continuous load, continuous output and continuous load limits) can be precisely anchored in such an extended concept(Schlick et al., 2018).

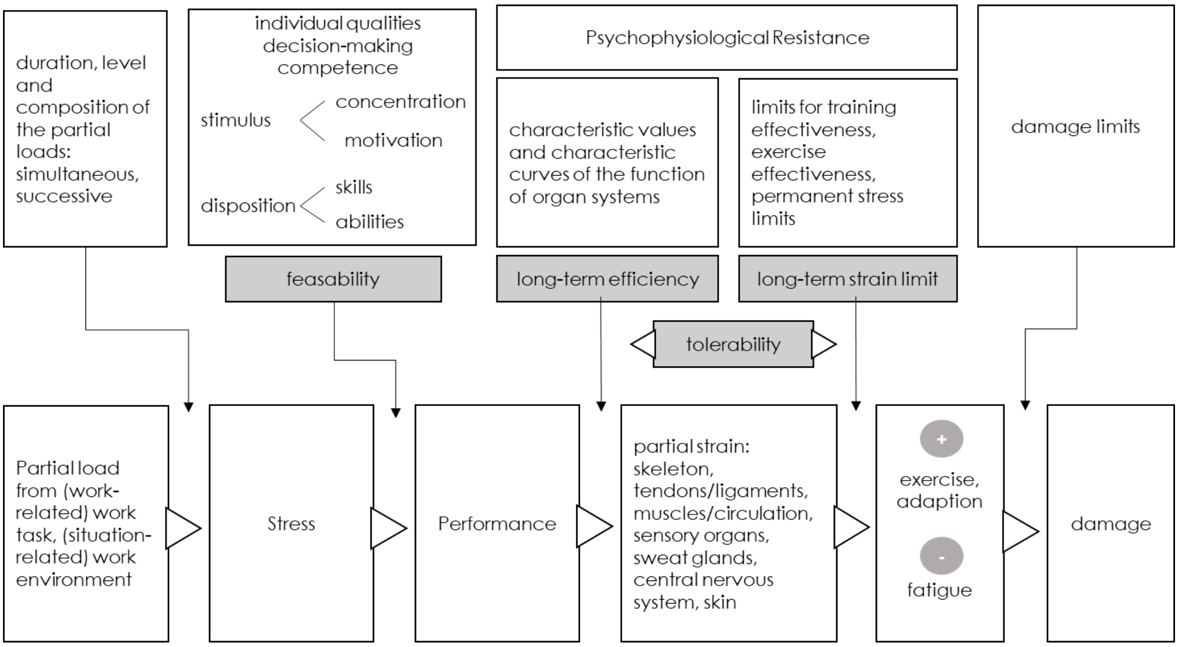


Figure 2: Extended and modified stress-strain concept following Rohmert (1984) (visualisation following Schlick et al., (2018).

1.2 Influences - Stress

Following the extended stress-strain concept (Rohmert, 1984) several external and internal factors can influence the individual performance whilst working. For example, external influences are the working environment (physical, organisational, social) influences, or the task itself (type, duration, frequency, perceptive and cognitive requirements) (Landau, 1978). Internal performance influences for strain can be traced back to individual skills and capabilities. A classification is presented in Luczak (1989). 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.

1.3 Effects - Strain

1.3.1 Physical Strain

Physical strain describes the effects of stress on the muscle and cardiovascular system (Schlick et al., 2018).

Following Kirchner (1986) physical strain can be divided into five different types.

This includes muscle strain, strain of bones, ligaments and tendons, sensory-nervous/humoral strain (hormone release), cardiovascular strain and somatic strain (strain on various internal body organs). Continuative muscle strain can be divided into three different subtypes:

- Heavy dynamic muscle strain describes following Schlick et al. (2018) the use of large muscle groups. Fatigue occurs due to the limited performance capacity of the cardiovascular system. For example, manual transport activities or load handling (lifting, carrying, pushing, pulling loads) belongs to this category.
- One-sided (dynamic) muscle strain describes the use of smaller or locally limited muscle groups. These quickly become tired under high stress, whereby the cardiovascular system does not necessarily have to show noticeable strain reactions (Schlick et al., 2018).
- Finally, static muscle strain occurs during immobile activities, when the muscles are tightened to maintain the body position. This can lead to energetically and physiological problems because it results in an insufficient muscle blood circulation due to the lack of movement. The consequences are much faster muscle fatigue and increasing cardiovascular circulation activity (Schlick et al., 2018).

Reactions through physical exertion manifest themselves in measurable changes in the human body. Therefore, different physiological strain types are measured with the help of different methods. For example, changes of the cardiovascular system can be recorded via heart rate or body temperature. In contract, muscle strain goes along with the measurement of heart rate or electromyography (Kirchner, 1986).

1.3.2 Psychological Strain

As already described, the strain causes not only physical costs but also psychological ones (Rohmert, 1984). Psychological strain is the totality of all detectable influences that have a psychological effect on the working person. Psychological strain can be divided into mental strain and emotional strain. The mental strain corresponds to strain due to processing and implementation of information. Emotional strain predominantly based on performance conditions, such as time pressure, noise, climate or interpersonal relationships (Luczak, 1982).

1.3.2.1 Mental Strain

Mental strain describes the proportion of the total strain that is caused by perception, cognition and action regarding information. Informational strain exists, for example, in monitoring, control and steering activities (Schlick et al., 2018). The mental strain corresponds to the extent of psychophysical activation or arousal during performing the task. In analogy to the physical stress-strain concept, mental strain must be considered in relation to individual abilities and skills as well as task and environmental requirements. While learned individual abilities and skills can reduce mental strain, task and environmental requirements, individual fatigue and damage can increase mental strain. Too high, but also too low mental demands can lead to mistakes in the work process (Figure 3). To ensure a flawless work process it is important to keep mental strain at an reasonable level (Kantowitz & Campbell, 2017). The arousal mechanism, makes it possible to increase available capacity when the task difficulty is increased, for example by adding additional tasks (Schlick et al., 2018).

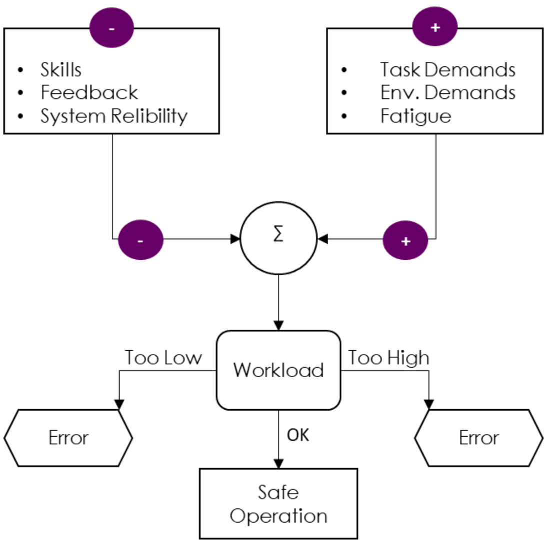


Figure 3: Key factors influencing mental workload (Kantowitz & Campbell, 2017).

Mental strain can further be subdivided into:

- Sensory stain, which describes the use of the human sensory system for recording information by the information input.
- Discriminatory strain, which describes the use of recognition ability and human discrimination.
- Combinatory strain, which describes the use of decision-making ability.
- The information output controllability of human movements and language.

1.3.2.2 Emotional strain

Emotional strain is predominantly based on performance conditions,

such as time pressure, noise, climate or interpersonal relationships, and becomes visible as motivational or affective side effects, e.g. as boredom, fear or helplessness in the work process (Manzey, 1998).

Examples for emotional strain are fatigue and exhaustion or similar conditions like monotony, frustration and psychological saturation (Hacker & Richter, 2013). Emotional strain is related to physical reactions and can therefore be detected by measuring physical parameters, such as the cardiovascular system (Kirchner, 1986). Stress as a form of inner and physical tension represents a special form of emotional strain, which are also associated with physical reactions und therefore, is measurable as physical strain (Kirchner, 1986).

1.4 Measurement Methods

One of the concepts of the project is to improve working 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 stress with the support of an ergonomic tool. In order to achieve this, the users' strain needs to be captured.

In general, strain can be measured by means of subjective, performance related and physiological indicators. Whereas subjective methods, such as the Nasa-TLX questionnaire (Hart & Staveland, 1988), or the RSME scale (Zijlstra & van Doorn, 1985) and performance indicators, for instance the execution time, mistakes, or number of steps, consist of post-hoc analyses, physiological indicators bear the potential of a near real-time strain assessment.

Following these thoughts, in the WorkingAge project, different sensors to measure situational occurring work strain will be implemented in the developed WA tool. A system has to be developed that covers divers requirements of the following three use cases, by means of the further chosen measurement methods:

- **Office Use Case**, with informational tasks at an HMI, non-standardised task-flow and mainly sitting body posture;
- **Production Use Case**, with more standardised informational tasks at an HMI and often standing body posture;
- **Driving Use Case**, with informational reactive tasks without an HMI, highly influenced by constantly changing working environment and suddenly arising critical situations.

Therefore, a multitude of different sensors will be implemented in the WA system. Each method will briefly be described in the following paragraph.

1.4.1 Individual Data

- **Electrocardiogram (ECG)**

Electrocardiogram (ECG) represents electrical activity of human heart. In the absence of any outside influences spontaneous and periodic activation of the pacemaker cells within the *Sinoatrial* (SA) node determines the intrinsic *Heart*

Rate (HR), and action potentials from the SA node spread throughout the atria to the *Atrioventricular* (AV) node. The AV node provides a propagation delay that allows for complete atrial depolarization before action potentials propagate through the bundle of His, Purkinje fibers, and ultimately throughout the ventricles. Modulation of this inherent HR is accomplished by *Autonomic Nervous System* (ANS) innervations, the intrinsic cardiac nervous system, reflexes, respiration, and humeral inputs. Traditionally the ANS was thought to be the only nervous system directly associated with HR modulating capabilities. However, recent evidence has shown that there is an *Intrinsic Cardiac Network* (ICN) capable of mediating intracardiac reflexes. In addition to the classically described parasympathetic postganglionic neurons, the ICN includes sensor neurons, interneurons, and catecholaminergic neurons (De Jong, Maj Marla J & Randall, 2005). "Thus, neural control of HR is likely a function of both the intrinsic cardiac and autonomic nervous system" (De Jong, Maj Marla J & Randall, 2005). The ECG signal can be measured by electrodes placed on human body, like on the chest or wrist. The main problem of digitalized signal is interference with other noisy signals like power supply network (e.g. 50 Hz frequency) and breathing muscle artefacts. HR can be detected from ECG signal by the detection of the distance between QRS weave complexes. Another interesting measure is the fluctuation of HR over time (Ramshur, 2010). *Heart Rate Variability* (HRV) measures HR fluctuations over time and reflects the autonomic balance, i.e. whether it is the *Sympathetic Nervous System* (SNS) or the *Parasympathetic Nervous System* (PNS) that is dominating. Spectral analysis in the frequency domain enables a separation between vagal (PNS related) and sympathetic cardiac control to be made. Stress usually causes a decrease in HRV. Also, a decrease in HRV, in particular the 0.1 Hz component, is associated with increased mental effort (Mulder, 1992). The higher frequency components (HF, 0.15-0.4 Hz) are mainly related to respiratory influences and solely controlled by PNS. There is also a low frequency component (LF, 0.04-0.15 Hz) and a very low frequency component (VLF, ≤0.04 Hz), which are controlled by both SNS and PNS. Some studies have also analysed the LF/HF ratio and observed that an increase is associated with mental stress (Sloan et al., 1994).

- **ELECTROENCEPHALOGRAM (EEG)**

The *Electroencephalogram* (EEG) comes from the summation of synchronously postsynaptic potentials. The frequency of oscillation depends on the intrinsic membrane properties, on the membrane potential of the individual neurons, and on the strength of the synaptic interactions. Bursts of oscillatory activity may constitute a mechanism by which the brain can regulate changes of state in selected neuronal networks and change the route of information (da Silva, 1996). EEG is usually registered by means of electrodes placed on the brain scalp. Knowledge of exact positions of electrodes is very important for both interpretation of a single recording as well as comparison of results, hence the need for standardization. The traditional 10–20 electrode system (Jasper, 1958) states positions of 19 EEG electrodes (and two electrodes placed on earlobes A1/A2) related to specific anatomic landmarks, such that 10 – 20% of the distance between them is used as the electrode interval. The first part of derivation's name indexes the array's row—from the front of head: Fp, F, C, P, and O. The second part is formed from numbers *even* on the left and *odd* on the right side, in the centre ''z'' or ''*0*''. The necessity of artefact rejections is very important. Artefacts are recorded signals that are non-cerebral in origin. They may be divided into one of two categories depending on their origin: *physiological* artefacts or *non-physiological artefacts*. Physiological artefacts can stem from muscle or heart activity (EMG, ECG), eye movement (EOG), external electromagnetic field, poor electrode contact, subject's movement. Non-physiological artefacts arise from two main sources: external electrical interference (power lines or electrical equipment), and internal electrical malfunctioning of the recording system (electrodes, cables, amplifier). Artefacts may be avoided, rejected or removed from the EEG dataset. Artefacts avoidance involves asking users to avoid blinking or moving their body during the experiments. This approach is very simple, because it does not require any computation, as brain signals are assumed to have no artefacts. However, this assumption is not feasible in operational environments, since some artefacts, eye and body movements, are not easily avoidable. Artefact rejection approaches suggest discarding the epochs contaminated by the artefacts. Manual artefact rejection is an option to remove artefacts in brain signals, and experts could identify and eliminate all artefact-contaminated EEG epochs. The main disadvantage in using manual rejection is that it requires intensive human labor, so this approach is not suitable for real-time evaluations. In the EEG, the following frequency rhythms are considered characteristics for its analysis: *Delta* (0.5 – 4 (Hz)), *Theta* (4 – 8 (Hz)), *Alpha* (8 – 12 (Hz)), *Beta* (12 – 30 (Hz)), and *Gamma* (above 30 (Hz)). During a cognitive process, the electrical activity of neurons populations of a specific cortical area is synchronized or desynchronized, causing a measurable increasing or decreasing of that brain specific rhythm over specific brain areas (Borghini, Aricò, Di Flumeri, & Babiloni, 2017).

- **ELECTROMYOGRAPHY (EMG)**

Besides basic physiological and biomechanical studies, electromyography has established as an evaluation tool for applied research and interactions of the human body to industrial products and work conditions (Konrad, 2006). The use in ergonomic research enables information about muscle activity and muscle fatigue by which derivations about the physical workload and the ergonomic conditions of workplaces can be made. Due to their non-invasive character, in most cases surface electrodes are used. Besides the benefit of easy handling, their main limitation is that only surface muscles can be detected (Konrad, 2006). Various studies proved that there are limit values for muscle strain. Exceeding these limits results in damage to the musculoskeletal system (Björkstén & Jonsson, 1977; Kroemer, 1989; Rohmert, 1962). An EMG measurement can therefore provide information about muscle activity and detect an overload.

- **GALVANIC SKIN RESPONSE (GSR)**

Electrodermal activity measured by *Galvanic Skin Response* (GSR) is a well-accepted indicator of reticular activation and, therefore, of emotion and cognition. A transient increase in skin conductance is proportional to sweat secretion. When an individual is under mental stress, sweat gland activity is activated and increases skin conductance. Since the sweat glands are also controlled by the *Sympathetic Nervous System* (SNS), skin conductance acts as an indicator for sympathetic activation due to the stress reaction (Sequeira, Hot, Silvert, & Delplanque, 2009). In particular, there are two major components for GSR analysis. *Skin Conductance Level* (SCL – tonic component) is a slowly changing part of the GSR signal, and it can be computed as the mean value of skin conductance over a window of data. A fast changing part of the GSR signal is called *Skin Conductance Response* (SCR – phasic component), which occurs in relation to a single stimulus. He showed that slowly changing SCL and SCR aroused by specific stimulus are sensitive and valid indicators for the course of a stress reaction. Setz et al. (2010) demonstrated the discriminative power of GSR in distinguishing stress caused by a cognitive load and psychosocial stress by using a wearable GSR device in an office environment. In addition, the SCL peak height and the SCR peak rate carry information about the stress level of a person (Sun et al., 2012). With respect to all biomarkers related to stress, information available from the GSR shows the highest correlation with the level of stress experienced by the subject (Sun et al., 2012).

- **Gesture Recognition**

Originally, gesture recognition was meant to be implemented as an interface to the WA system. However, analysis of a subject's movements of arms, may give information on the worker's strain too. Hence it is included in this section. (Note that body pose recognition also measures the arm, but is unlikely to provide enough resolution for this purpose.)

Gesture recognition is becoming an essential component of human computer interaction (HCI) and home automation. Even commercial gesture recognition systems, such as Microsoft Kinect (Shotton et al., 2013) have been successfully implemented without the need of dedicated controllers. Most common sensing techniques for gesture recognition include Infra-Red (IR) sensors and wearable devices. Despite the popularity of wearable devices, radio frequency (RF) signals were leveraged to achieve gesture recognition in a device-free manner, meaning that the user does not need to carry any devices and the system performance is invariant with lighting conditions. Examples of RF-based systems are WiSee (Pu, Gupta, Gollakota, & Patel, 2013) and WiTrack (Adib, Kabelac, Katabi, & Miller, 2014). The drawback of such software defined radios (SDRs) platforms is their high cost for large-scale usage. Other RF sensing techniques are Passive Infra-Red (PIR) (Weekly et al., 2014), Bluetooth (Zou, Chen, Jiang, Xie, & Spanos, 2017) and RFID (Weekly et al., 2014), which require either deploying dedicated infrastructure or the active cooperation of users, the wide availability of WiFi access and WiFi-enabled internet of things (IoT). Thus, these technologies have become quite popular for indoor environments. Due to the recent development of WiFi Network Interface Card (NIC), Channel State Information (CSI) has also become a possibility. Several CSI-based recognition systems have been recently proposed e.g. (Virmani & Shahzad, 2017), (He, Wu, Zou, & Ming, 2015), however only CSI amplitude measurements collected from laptops with the use of external WiFi NIC are exploited for gesture recognition and tedious de-noising and feature selection procedures are required. Nevertheless, promising solutions to overcome those barriers are being developed, using off-the shelf WiFi-enabled IoT devices (Zou et al., 2018).

- **Facial Expression**

Facial expression is the primary nonverbal component for human beings to regulate their interactions (Ekman, 1997). There are two main approaches for facial expression measurement: message and sign judgement (Juslin, Scherer, Harrigan, & Rosenthal, 2005). Message judgement aims to directly decode the meaning conveyed by a facial display (such as being happy, angry or sad), while sign judgement aims to study the physical signal used to transmit the message instead (such as raised cheeks or depressed lips) (Martinez, Valstar, Michel, Jiang, & Pantic, 2017). Ekman (2003) proposed that a specific set of facial expressions accurately communicated six basic emotions (i.e. happy, surprise, fear, disgust, anger and sad). These six basic emotions are most commonly studied and represent the main message-judgement approach. The most common descriptors used in sign-judgement approaches are those specified by the Facial Action Coding System (FACS), which is a taxonomy of human facial expressions (Friesen & Ekman, 1978) in the form of Action Units (e.g., smile, eyebrow raise). Since any facial expression results from the activation of a set of facial muscles, every possible facial expression can be comprehensively described as a combination of Action Units (AUs) – e.g., happiness can be described as a combination of pulling the lip corners up (AU 12) and raising the cheeks (AU 6).

The six basic emotions theory has been widely used for automatic analysis of facial expressions but has received criticism because basic emotions cannot explain the full range of facial expressions in naturalistic settings. Therefore, a number of researchers advocate the use of dimensional description of human affect (Gunes, Schuller, Pantic, & Cowie, 2011), based on the hypothesis that each affective state represents a bipolar entity being part of the same continuum. The proposed polars are arousal (relaxed vs. aroused) and valence (pleasant vs. unpleasant). The current trend in the field is to move away from analysing static frames of posed and laboratory data to analysing non-basic affective states acquired in naturalistic settings (e.g., neutral, boredom, engagement, confusion, frustration, anxiety, distress/stress) in a continuous manner (Gunes & Schuller, 2013).

Automating the analysis of facial signals has been proven to be beneficial for various applications (e.g., human-computer and human-robot interaction, gaming and entertainment, personalised virtual assistants, pain analysis, assistive technologies for therapy etc.). Previously, the detection of facial expressions was mainly based on first obtaining facial landmarks and then applying feature extraction algorithms (e.g. local binary patterns (LBP), Gabor, SIFT) to conduct machine analysis of facial signals (Sariyanidi, Gunes, & Cavallaro, 2015). Nowadays, there is a trend towards deep learning. Deep convolutional neural network (CNN) have been applied to affect recognition problems across multiple modalities and led to improved performance (Rouast, Adam, & Chiong, 2019).

- **VOICE ANALYSIS**

Several studies investigate the issue of characterizing human behaviours through vocal expressions; such studies rely on prosodic elements that transmit essential information about the speaker's attitude, emotion, intention, context, gender, age, and physical condition (Asawa, Verma, & Agrawal, 2012). Information conveyed by the paralinguistic channel, in particular prosody, is useful for many research fields where the study of the rhythmic and international properties of speech is required (Ng, Leung, Lee, Ma, & Li, 2010). The ability to guess the emotional state of the speaker is particularly interesting for Conversational Agents, as could allow them to select the more appropriate reaction to the user's requests, making the conversation more natural and thus improving the effectiveness of the system (Moridis & Economides, 2012; Pleva et al., 2011). In particular, we focus on the following prosodic characteristics (Pinker & Prince, 1994): intonation, loudness, duration, pauses, timbre, and rhythm.
Finally, emotions can be detected analysing the text generated by transcribing the voice (i.e., using an Automatic Speech Recognition – ASR tool); in particular, it seems that combining voice and text provides the best accuracy in recognizing emotions (Origgi, 2018).

- **ELECTROOCULOGRAM (EOG)**

It is a common experience that when a particular task involves the use of visual attention, the subject becomes more concentrated and decreases the time spent with the eye closed for blinking, i.e., their blink frequency decreases (Borghini et al., 2017; Borghini, Astolfi, Vecchiato, Mattia, & Babiloni, 2014). Researchers have investigated whether such phenomena could lead to valid indications about the mental workload for tasks requiring high visual attention, such as car driving. As a result, eye blink data has been collected in highly realistic settings of driving. Different parameters characterising the blink, such as the Blink Rate (BR), the Blink Duration (BD), and the Blink Latency (BL) have been analysed and used as workload measures in a series of studies (Eggemeier et al., 1990; Kramer, 1991; Stein, 1992; Wilson, 1993; Wilson & Fisher, 1991). Results in the literature suggested that both the blink rate and blink duration decrease with increases in task demands, and they have been found to significantly decrease during high load segments of missions (Wilson & Fisher, 1991). In addition, the blink rate has been found to be sensitive and capable of differentiating among mission types (Wilson, 1982) and it was found that it could also distinguish fatigue in pilots and non-flying co-pilots of military aircraft (Stern, Boyer, & Schroeder, 1994). Blink patterns can be used to provide information about the subjects' response to different stimuli and thus Situation Awareness (SA), and the latency measure has been found to increase with memory demands (Eggemeier et al., 1990). Blink rate and duration could be also measures of workload (Carmody, 1994; Kramer, 1991). Wilson and Fisher (1991) have demonstrated the advantage of using both HR and eye blink data in the analyses of pilots' mental workload. Fewer and shorter blinks have been associated with increased workload, in tasks such as city driving, reading and aircraft weapon delivery (Brookings & Wilson, 1994; Krebs, Wingert, & Cunningham, 1997).

- **Eye Movement**

The observation behaviour (instrument scan, point of regard) of the working person may contain information about the recording and temporal processing of information. The analysis of the fixation point is based on the assumption that the human being, in the case of fixation of an information-bearing object actually draws his attention to it and the contained information further processed (Schlick et al., 2018).

Different eye movements can be distinguished (cited following Schlick et al., 2018):

1. Smooth pursuit eye-movements, which are controlled completely autonomously (involuntarily). Only movements of the body and movements of the eye object can trigger such eye movements.
2. Saccades are fast, erratic movements to focus the gaze on an object. By increasing mental stress, the field of vision is reduced (Williams, 1982). An increase in mental stress leads to a reduction in saccade range (May, Kennedy, Williams, Dunlap, & Brannan, 1990; Meyer-Delius & Lackner, 1983).
3. The fixation duration is the time during which the eye does not change its gaze. In the case of tasks that predominantly require central processes, an extension of the fixation time is an indication of increasing strain. With perceptive tasks, on the other hand, shorter fixation times are to be expected with increasing task difficulty (Grandt, 2004; Meyer-Delius, Kriesel, & Johnson, 1981).
4. The frequency with which a gaze object is fixed as well as the sequence of fixations on different objects can provide information about which perception strategy is present during the information search or whether the visual environment is scanned rather randomly, i.e. without a meaning-dependent distribution of fixations (Ellis & Smith, 1985). Due to the complexity of the scanning patterns, mental strain due to time pressure can be evaluated and spontaneous cognitive abstraction processes can be identified in human-machine interaction (Schlick, Winkelholz, Motz, & Luczak, 2006).

- **Pupil Diameter**

Changes of the pupil diameter serve the regulation of the incidence of light controlled by the iris. A constriction occurs by a ring muscle layer, an extension by a radially arranged muscle layer. Both muscle layers consist of smooth musculature and are part of the autonomic nervous system. By means of the parasympathetic nervous system, the ring muscle and thus pupillary constriction is influenced (Schlick et al., 2018). An increase of the sympathetic tonus on the other hand leads to dilation of the pupil (Bartels, 1991). The pupil reaction triggered by task processing has already been examined in many studies in the past decades (e.g. by (Boff & Lincoln, 1988; Kahneman & Beatty, 1966). The investigations come to the following agreement that, at higher mental stress leads to a larger pupil diameter. Kramer (1991) and Manzey (1998) limit, however, that this indicator is globally sensitive to mental strain, but only has low diagnosticity, because it equally consists of perceptive, cognitive and reactive aspects of the information processing process. Grandt (2004) also comes to the conclusion, that the pupil diameter of other oculomotoric Indicators related to validity and, accordingly, also diagnosticity is inferior (cited following Schlick et al., 2018).

- **Body Posture**

The effect of awkward body postures in musculoskeletal disorders (MDS) has been a field of study in numerous researches (Herzog, Beharic, Beharic, & Buchmeister, 2015), confirming the risk produced by inadequate postures and repetitions. In order to objectivize the postural analysis, several methods have been created being three of the most commonly used RULA (McAtamney & Nigel Corlett, 1993), REBA (Hignett & McAtamney, 2000), OWAS (Mattila M, 1993). The assessment of awkward body postures risk can be done through self-report, direct measurement and/or external observation. Self-report has a high subjective component, direct measurement usually implies wearing devices that influence the postural behaviour and external observation depends on the input information collected. (Plantard et al., 2017) solve some of these issues by transforming the joints coordinates captured by a Kinect device into RULA assessment. However, the use of Kinect has some limitations as the workplace distance range, or the influence of occlusions. Some of these technical limitations are being solved through deep learning approaches even using 2D RGB images (Rogez, Weinzaepfel, & Schmid, 2019).

- **Vibration**

According to the description of action, regular occupational exposure to vibrating tools and environments can produce injuries, medical conditions or discomfort. Whole body vibrations are produced in workplaces such as planes, the deck of a ship, the vicinity of presses or heavy machinery, platforms that receive vibration of the structure, etc. Hand-arm system is analysed in jobs with frequent use of non-manual tools i.e. pneumatic hammers, pneumatic tools for stapling, etc. For these measures standard ISO 2631 on Mechanical vibration and shock, Evaluation of human exposure to whole-body vibration will be considered.

1.4.1.1 Summary

Table 1 gives an overview about the WorkingAge measurement methods in relation to mental, emotional and physical strain.

Table 1. *Measurement of mental, emotional and physical strain with the WorkingAge tool, adapted and extended following Kirchner (1986)*

X direct indicator O indirect indicator	Electrocardiogram (ECG)	Electromyography (EMG)	Galvanic skin response (GSR)	Electroencephalogram (EEG)	Electrooculogram (EOG)	Facial expression	Voice Analysis	Gesture recognition	Pupil diameter (PD)	Body Posture	Eye-Movement
psychological strain								o			
• mental	o		o	x					o		o
sensory				o	o				o		
discriminatory			o	o					o		
combinatory			o	x					o		
• emotional	o		x	o		o	o	o	o		
physical strain								o			
• muscular	o	x								o	
dynamic	x	x						o			
static	o	x	o							o	
cardiovascular	x		o	o							
• skeletal	o	o								o	

1.4.2 Environmental Data

- **NOISE**

According to the World Health Organisation (WHO) a healthy continuous noise level has a maximum of 55dB during days and 50dB during nights. However, 65% of Europeans living in major urban areas are exposed to daytime noise greater than 55dB (Jarosińska et al., 2018). Environmental noise coming from traffic jam, manufacturing machines, talking people in the office, etc. can increase the level of stress and strain (van Kempen & Babisch, 2012; Westman & Walters, 1981). Noise as unwanted sounds (car horn, breaking glass, screaming) can dramatically elicit stress in the body for a short period and prepares the body into a fight-or-flight mode. Emotional state which elicits prominently to noise is annoyance, which in long term, can cause effects on blood pressure elevation, headaches, anxiety, productivity, health… (Åhrlin & Öhrström, 1978). Moreover, noise exposure during sleep will affect sleep performance which may reduce the quality of life during days. Further, Gary and Johnson found that office noise causes motivational deficits as well as musculoskeletal disorder (Evans & Johnson, 2000). In WA, we measure noise level, existence of human speech (through Voice Activity Detection), abrupt changes in acoustics (indicates sudden events such as broken glass, car horn), and some statistics of these measures (max, average, min, …). These measures will be extracted through audEERING's tool, openSMILE, which performs audio processing and classification.

- **Thermohygrometric, CO_2 and Other Pollutants**

For the thermohygrometric conditions, the current regulations (Workplaces Directive and its application guides) and the complementary regulations so as the Fanger method will be considered. Wearable temperature & humidity meters can be used for this purpose.

For Thermohygrometric, CO_2 and other pollutants, sensors from advisory board member Senseair will be included in the WorkingAge system.

- **Light**

It has long been known that light and lighting have an impact on health and well-being (Wurtman, 1975) and bad lighting has been associated with a range of ill-health effects, both physical and mental, such as eye strain, headaches, fatigue, stress, and anxiety. The effects of lighting, its quality, lighting technologies and daylight on workers have been the subject of a vast number of studies featuring an equally large number of scopes and approaches (Bauer t al., 2018; Borisuit, Linhart, Scartezzini, & Münch, 2015; Kralikova & Wessely, 2018; Wright et al., 2013). In order to assess the conditions of a workplace, lighting is, therefore, a key factor. Since light is electromagnetic radiation, and the human eye is sensitive to a certain electromagnetic radiation spectrum range known as visible light, it can be quantified and measured in terms of luminous intensity (candela), luminous flux (lumen) and illuminance (lux) among others. Occupational risks prevention standards usually use illuminance as the base quality measure of lighting. The WA tool will make use of semiconductor-based light sensors to measure the intensity of light as visible by the human eye (illuminance) to determine the lighting conditions of the monitored workplaces.

- **User Location**

The location is not used as any other WA measurement to determine the state of the WA device user; it is only used to provide information about the localization of the WA user anywhere. In case the user's health state requires immediate attention, the emergency services can be warned with the exact localization of the WA user. We could also imagine that the user location could also be used after an incident to gain more understanding on how and why the incident happened. Some correlations between the places the WA user went and the incident he got might for instance be found.

The WA user needs to be localized anywhere and GNSS (Global Navigation Satellite Systems) is the only global positioning method currently existing, i.e. the only positioning technology that can compute the user position anywhere on the planet. Therefore, GNSS seems to be a logical choice to obtain the position of the WA user. GNSS regroups all the satellite navigation constellations such as the American GPS, the European GALILEO, the Russian GLONASS and the Chinese BEIDOU. A GNSS receiver can track all these constellations at the same time and compute an accurate position based on measurements coming from all these systems together. In ideal conditions (open-sky), the GNSS receiver can reach a position accuracy of about 1 meter. However, GNSS is a technology based on satellite signals, so satellites need to be in view of the receiver for it to compute a position. Thus, in urban environments, the receiver can see less GNSS satellites and thus the GNSS position accuracy can drop down to 10 or even 100 meters in worst cases. In indoor environments, the receiver will not be able to track any satellite and therefore it will not be able to compute a position.

Wifi positioning or UWB positioning provide a useful backup when GNSS is not available, typically in dense urban environment (urban canyons) and in indoor conditions. These technologies can be used to estimate the location of a device within the Wifi or UWB communication ranges using the knowledge of the radio wave emitter location and an estimation of the range from the (UWB or Wifi) emitting device to the user. The difference between the two technologies is related to the type of radio wave that is transmitted and to the way the emitter-to-transmitter range is computed.

The Wifi technology is already widespread, most of the building are currently equipped with Wifi routers and thus, it does not need extra infrastructure to be installed. On the contrary, the UWB technology requires the installation of specific transmitters but this technology will allow a more accurate computation of the range than the Wifi signals:

- Wifi: 5 to 10m accuracy with 100m range.
- UWB: 0.1 to 0.5m accuracy with 10m range.

The type of indoor technology that will be used within the scope of this project is currently unknown. It will depend on the requirements that the WA device will have to fulfil.

2 Data Requirements

Since strain, as the individual reaction to stress, is very much dependent on several internal and external influences, an overview about possible influences is mandatory. In the following we present a data ontology that shows all influences as a whole, based on findings of the prior paragraph (Figure 4). The scheme will serve as a basis for further selection of use case relevant data.

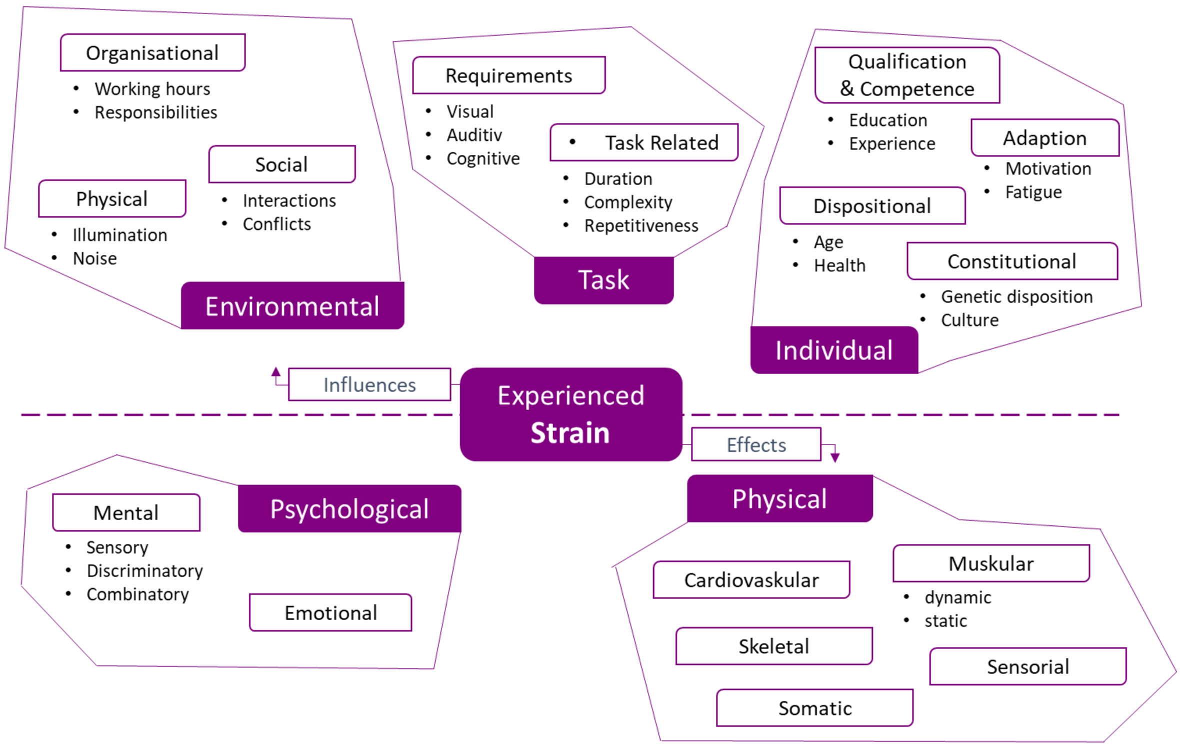


Figure 4: Data Ontology.

2.1 Risk Factors and User Requirements

2.1.1 Introduction

WorkingAge developments will be tested in three different workplaces:

- Driving Use Case
- Office Use Case
- Production Use Case

The aim is to test the developments created to measure factors of risk and early effects in humans, with the objective of providing guidance and advice when needed. The main innovation of WorkingAge compared to the conventional method for risk assessment is that it provides an immediate and continuous assessment of risk for a particular person.

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.

This new approach allows the adoption of immediate corrective measures, maintaining the risk permanently under control and empowering the worker in the application of preventive measures. The permanent maintenance of risk behind the safe level will produce healthier workers and longer work lives.

2.1.2 Risk Factors and Effects Considered in Defining User Requirements

2.1.2.1 Overview

WorkingAge focus on the ergonomics and psychosocial risks, it is not part of the WorkingAge scope to analyse safety risks (e.g. risk of electric contact) or risks derived to exposure to contamination of the environment or exposure to any kind of radiation or fields. Therefore, WorkingAge will be a powerful tool to prevent the most spread work-related diseases.

All influences described in Figure 4 will be taken into account by measuring parameters related to the risk factors (or work situations) that require a risk assessment in the workplaces. These factors are extracted from Annex 1A of the Document issued by the European Commission "Guidance on risk assessment at work" (Directive 89/391/EEC). This guidance was developed in order to help Member States and management and labour to fulfil the risk assessment duties laid down in Framework Directive 89/391/EEC.

According to the "Guidance on risk assessment at work" document as well as other sources and usual practice of safety professionals, the hazards covered in risks assessments are usually classified in groups listed below. In the following, an overview of the risks is given before they are discussed further:

- **Risk of Accident**
  This group includes all factors that may produce an accident, like falls or contact with electricity. The consequences of these risks are occupational accidents.
- **Environmental Physical risks**

  This group includes noise, vibrations, extreme thermo-hygrometric conditions, Illumination, radiation (ionizing and not ionizing). The consequences of these risks are occupational diseases.
- **Environmental Chemical and Biological Risks**

  This group includes exposure to substances or biological organisms that may have effects on human health. The consequences of these risks are occupational or work-related diseases.
- **Ergonomic Risks**

  This group includes as main factors: static postures, dynamic load, load handling, repetitive movements. The consequences of these risks are occupational or work-related diseases.
- **Psychosocial Factors of Risks**

  This group includes all factors related to the cognitive design of tasks, organization of work, social aspects of work. The consequences of these factors of risk are commonly stress, but also other health symptoms like anxiety, depression, burn-out syndrome, addictions and others. There are also some risks named "psychosocial risks" that are not considered here (e.g. violence, harassment, contractual insecurity, work-family conflict). Emotional issues were not considered in the project, but could be reconsidered now, as some effects could be measured.

For the purpose of WorkingAge, only some of the above risk factors have been considered.

2.1.2.2 Analysis of the Risks and Effects Considered in WorkingAge

The risks considered and their possible measureable effects are:

- **Environmental Physical Risks**

  Only those that can be measured with simple devices like mobile phones, PC devices or similar, i.e. noise, vibration, thermo-hygrometric conditions and illumination. The possible measureable effects could be visual fatigue, emotional responses (e.g. in case of too much environmental noise, to be confirmed by partners)

- **Ergonomic Risk**

  Those that can be measured by means of the technologies provided by WorkingAge partners, e.g. body posture.

- **Psychosocial Factors of Risk**

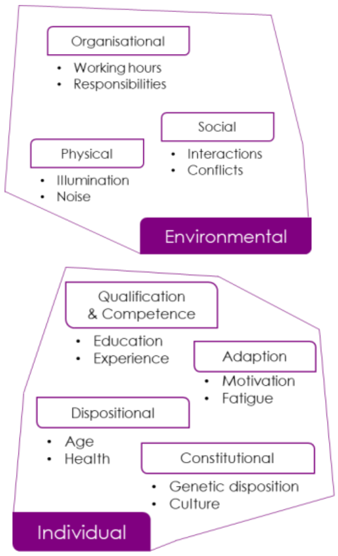
  Those that can be measured directly or through its effects on the individual by means of technologies provided by WorkingAge partners, e.g. mental strain.

The use of questionnaires has been considered as complementary tool where appropriate for the determination of the risk or the effects on the individuals.

2.1.2.3 Environmental Physical Risks (Usually Considered also Ergonomic Risks)

The factors considered are:

- **Exposure to Noise**
  Risk level and communication interference level
- **Exposure to Vibrations**
  Full body seated, full body standing, hand-arm.
- **Thermo-Hygrometric Conditions**



Individual contribution to risk is included in the methodology for risk evaluation

- **Age**
  Age is taken into account in the methodology applied to calculate risk
- **Gender**
  Gender is taken into account when appropriate in the methodology applied to calculate risk (thermo-hygrometric conditions)
- **Specific Individual Situations**
  Individuals with specific situations or pertaining to a vulnerable group are not considered (e.g. pregnant women, disabled persons, especially sensible persons to some risk like persons treated with drugs that may influence in hearing conditions).
- **Genetic Disposition**
  We are not aware of the existence of genetic tests that allow foreseeing the tendency of an individual to develop the same health effects related to noise, vibrations or thermo-hygrometric conditions.

2.1.2.4 Ergonomic Factors Related to the Task

Individual contribution to risk is included in every methodology selected for risk evaluation. The aspects considered are:

- Age
- Gender
- Anthropometrics of the individual
- Specific conditions. We recommend not to examine persons in special situations or in connection with a vulnerable group (e.g. pregnant women, disabled persons, particularly sensitive persons with a certain risk such as persons with musculoskeletal disorders and others who can be defined in the design of the experience).
- Genetic disposition. Some genetics analyses allow determining the predisposition of individuals to musculoskeletal injuries, the type of injuries as well as recovery time. However, these analyses are not within in the scope of WorkingAge and their costs not included in the budget.

2.1.2.5 Psychosocial Factors

The usual factors considered in the psychosocial assessment are:

- **Related to the Organization (Company):**
  Communication, , participation in the decision making process, changes in organization, insufficient staff, leadership, organizational equity, professional career development, ambiguity or conflict in roles

- **Related to Interpersonal Relationships**
  Relationship with supervisors, with peers, with staff, social support

- **Related to the Organization of Work**
  Task assignment, working day, rotation of shifts, number of hours of work

- **Related to Development of Tasks**
  Autonomy/control, rhythm, work overload or insufficient work load

- **Related to the Contents of the Task (or Task Demands)**
  Cognitive demands, emotional demands (to consider), monotony and repetitiveness (low variation of the task), short cycles of work, fragmented work (too frequent interruptions), non-sense tasks, level of

use of own skills, frequent changes, conflict between demands, feed-back, frequent interaction with customers (internal or external)

Based on the difficulties that could arise from some of the factors described above and with the aim of simplifying the development of tools as well, we suggest to take into account only the factors related to the task and its performance, and let aside other factors related to the organization (company) itself, interpersonal relationships and other factors alien to the task.

It means that the workplaces selected should present neutral conditions regarding the three first groups of factors (company issues, interpersonal relationships and organization of work), i.e. the existing conditions should be optimal (e.g. to discard the influence of family-work conflicts, select workplaces and workers without this problem).

On the other hand, for some risks it may be easier to measure early effects on the individual instead of measuring the parameter that define and characterize every factor of risk. The main effects to measure will be:

- Early symptoms of physical pain or discomfort (is it possible by direct measurement? e.g. by capturing specific movements of the body to rearrange posture or similar)
- Early symptoms of some MDS (e.g. carpal tunnel syndrome, tendinitis…)
- Variation in cardiac frequency related to energy consumption of the body
- Visual fatigue (e.g. by measuring blinking)
- Mental fatigue (e.g. by measuring EEG)

The parameters that will be measured must be confirmed by the partners in charge of measurements (UCAM, EXO, RWTH, ITCL, AUD and BS).

2.1.2.6 Other Practical Considerations when Selecting Workplaces for the Tests

The workplaces selected for the tests need to provide adequate conditions for the installation of equipment and devices. Moreover, workers participating in the text will be asked to use some wearables during the performance of the tests.

We need to take into account:

- There is sufficient space in the entourage of the workplaces where cameras will be installed to capture data
- Use of wearables. The workplaces and tasks selected for the tests must be performed by workers wearing wearables without interference in the normal development of the task
- Possible interference in the data collection. The existence of other sources of signals in the workplaces must not interfere with the data collection system and vice-versa
- Additional space needed for the team collecting data (when appropriate)

2.1.2.7 Suggestions

It could be a good measure to separate data collection for different parameters of risk. This would help in the process of obtaining conclusions and relationship between factors. For example, identifying workplaces where only some risk factors are predominant and the rest of them can be considered low.

On the other hand, we can consider that the other two workplaces (office and driving use case) provide opportunities for the analysis of few specific factors (e.g. both allow to measure the detection of static postures). Having this into account, we could select in industry workplaces with some factors of risk that are not present in the other two.

Following this criteria, we suggest to identify:

- Workplaces with risk related to repetitive movements
- Workplaces with load handling/high muscular effort demand
- Workplaces with high psychosocial demands of different kinds. Some ideas could be: an assembly line workplace to measure response to factors like monotony, rhythm, etc.; a workplace of a machine operator (if possible, a workplace where the worker is in constant control of several machines); a workplace with collaborative robots.

Factors like illumination, background noise (or high level of noise) and thermo-hygrometric conditions should be also measured, as they can influence the response to other risks, (e.g. a high level of background noise interfering communications may produce irritation and higher responses to psychosocial factors of risks). Vibrations will be considered in the driver use case tests, so this factor can be obviate here.

2.1.3 User Requirements

2.1.3.1 Characteristics of User Target Group

The WorkingAge project focuses on elderly users above 50 years of age. This user group is characterized though 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 (Buck & Reif, 1997; Munnichsm, 1989) (Figure 5).

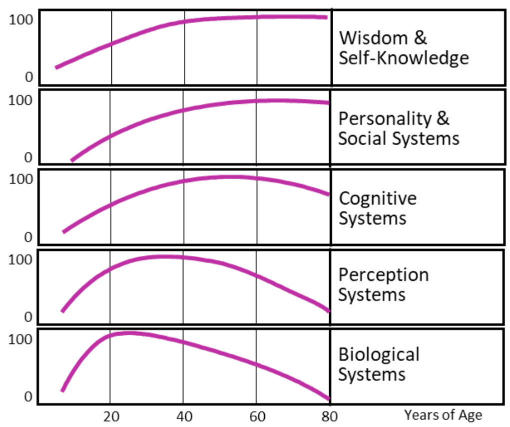


Figure 5: Age-related changes.

This leads to the following assumptions regarding the WorkingAge tool. The WorkingAge users are mainly characterised by changes in capabilities due to aging processes of information processing, which therefore lead to limitations in perception, cognition and action. In addition this kind of users are likely to have high working experience, but lower affinity towards computerized devices, resulting in difficulties in utilizing modern automated machines that come with complex HMIs. All these characteristics may lead to a higher mental strain during task execution. Therefore, the focus of implementation of the WorkingAge tool should lie on information processing together with technical support, dependent on specific use case requirements (

Table 2).

Table 2. *Target User Characteristics*

Elderly (>50 Years of Age)
Changes in Physical and Psychological Conditions • Perception • Cognition • Action
High Experience Lower affinity to modern computerized devices

With age, several changes in physical conditions occur that are central influencing working situations since information processing capabilities are different due to changes in perception, cognition and action. The main changes in 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 (Mertens, 2014).

2.1.3.2 Requirements Regarding Target Users

Different requirements are necessary depending on whether and how the system interact with the working person. Age-related changes have to be considered, when designing the system. The following enumeration takes up some of these age-related changes, which must be taken into account, especially in the case of older users:

- **Visual Perception**
  Due to the visual changes towards a deterioration of almost all visual functions, particular attention should be paid to font sizes, lighting conditions and colour schemes.
- **Auditory Perception**
  Due to the auditory changes towards hearing loss and declining speech comprehension, attention should be paid to clear acoustic sounds and cues.
- **Perception of Vibration**
  The ability to perceive high-frequency vibrations is reduced with increasing age, this should be taken into account when using vibrations (e.g. as indicators).
- **Cognition**
  Elderly people show an increased susceptibility to interference in the case of stimulus flooding and distraction, a reduced performance in speed-related tasks and a reduced reaction speed. This should be taken into account when developing a system.

2.2 Use Case Requirements

2.2.1 Introduction

The categorisation of work systems is difficult due to the enormous diversity of human work. Probably the most common structuring of forms of work system is based on the differentiation between mental and physical work, also head and hand work called. Usually this means that one of the aspects outweighs the other. Based on this, two form of human work are distinguished, which are called informational and energetic work (Schlick et al., 2018).

The energetic part of work activities usually involves the use of skeletal muscles so that forces can be generated and movements can be performed. The working possibilities of a muscle can be divided into two basic forms, which are presented in Table 3. In view of the manifold manifestations of predominantly non-physical forms of work, it has not yet been possible to create a logical-stringent subdivision with a high degree of abstraction similar to muscle work. Taking into account considerations regarding the observability and measurability of state variables, the classical psychophysiological approach of structuring non-physical work is used; differentiate three types of informational work.

Table 3. *Differentiation of Work Types (Schlick et al., 2018)*

Energetic-Effectorial Work	Static Muscle Work	Only one force (e.g. lifted load, dead weight of limbs) is kept in balance (isometric contraction).
	Dynamic Muscle Work	Individual muscles alternately tense and relax (e.g. lifting a load, turning a crank)

INFORMATIONAL-MENTAL WORK	EARLY PROCESSES (SENSORY)	Information recording, perception of a stimuli by means of the receptors (sense organs), including pre-processing
	CENTAL PROCESSES (DISCRIMINATORY & COMBINATORY	Recognize the signal meaning, identify the essential syntactic, semantic and pragmatic features and decide between alternative actions, and link with memory contents
	LATE PROCESSES (SENSU-MOTOR, VERBAL)	Motor regulation and output, e.g. through speech, gesture or other actions

From this, following Rohmert (1983) five ideal-typical mixed forms of work can be differentiated (Table 4):

Table 4. *Different forms of work as a combination of the basic types of energetic and informational work*

Energetic Work				**Informational Work**
MECHANICAL	**MOTOR**	**REACTIVE**	**COMBINATORY**	**CREATIVE**
Release forces	Perform Movements	Reaction and action	combine information	generate knowledge

The possibilities for classifying work systems described here are used in the following section to classify the use cases in WorkingAge in order to be able to determine the strain following Kirchner (1986).

2.2.2 Methodology

2.2.2.1 Classification of WorkingAge Use Cases

Using three exemplary work systems - production, driver and office workplaces - a corresponding user-centred system will be developed, which generates appropriate feedback and recommendations for the target group based on the recorded data. The following Figure 6 illustrates the forms of work following Rohmert and Rutenfranz (1983) for the WorkingAge use cases. The classification is based on typical work tasks.

Office work mainly consists of tasks including the combination of information, further relevant requirements are conclusion and deduction, as well as to generate knowledge. These characteristics are, for example, relevant when applying strategies and methods or when solving problems and making decisions. This leads to the conclusion that the office workplace contains combinative and creative work.

In contrast, the production use case combines elements of informational-mental and energetic-effectorial work. Working on and with machines leads to a higher use of physical and motoric activity. Depending on the concrete work task, both forms of energetic-effectorial work can occur here, i.e. both dynamic and static muscle work is conceivable. Nevertheless, this workplace also contains parts of informational work, which involves absorbing information and reacting to it. This leads to the conclusion that the office workplace contains reactive and combinative work as well as motor and mechanical work.

The driver´s use case again contains parts of information-mental work as well as energetic-effectorial work. An important part of the driver's workplace consists of driving the car, with which the perception of the environment, in particular the recognition of the traffic situation and the subsequent adaptation of the driving style walk along. This results in a large proportion of reactive work for the driver's workplace. However, driving a car also involves physical work, which leads to a motor component.

After classifying the WorkingAge use cases into informational and energetic work tasks, the resulting strain can be derived. As already described, Kirchner (1986) distinguishes between physical and psychological strain, which, again can be further subdivided. The following figure represents the classification of the use cases regarding informational-metal work and energetic-effectorial work and the resulting strain following Kirchner (1986).

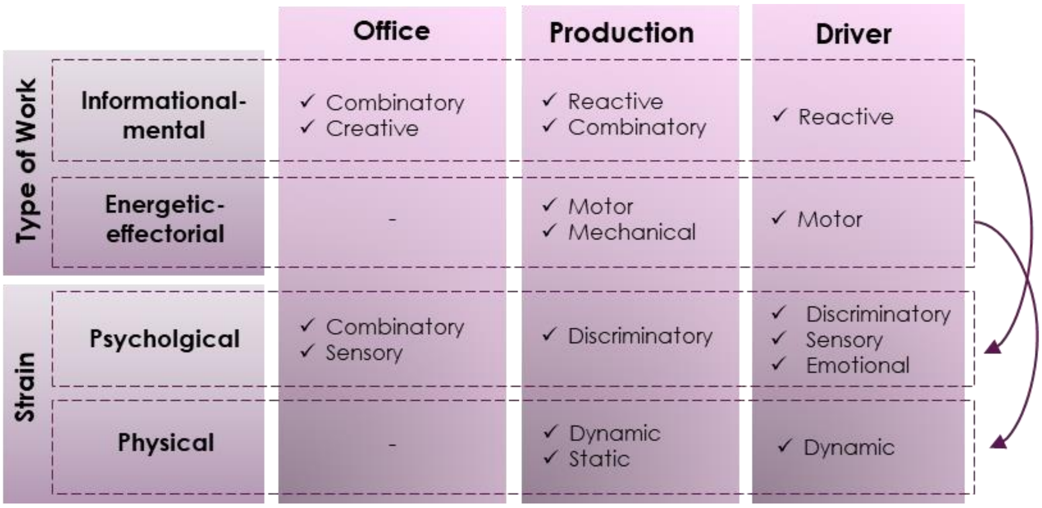


Figure 6: Classification of the WorkingAge use cases.

The following section describes the use cases (production, driver, office) with regard to their requirements for the WA system. At this point a general analysis is conducted, from which overall use case requirements will be derived. A further more detailed use case analysis will be part of Task 2.4 and content of Deliverable 2.4.

The analysis of use cases is conducted using two different methods. For the description of the workplaces in general, we will follow the structure of the Ergonomic Task Analysis (Rohmert & Landau, 1979). A general description of the tasks will be given and visualised by means of UML diagrams.

Following the main aspects of the AET analysis, in the following we describe the workplaces and derive general requirements regarding the WA tool. We focus on overarching points, which distinguish the use cases.

2.2.2.2 Environment Analysis

The analysis of the Environment will be conducted following the AET approach (Table 5).The "*Ergonomic Task Analysis*" (AET) is a condition-related survey. The procedure aims at solving problems of work conditions and the determination of requirements. The AET classifies stress-types and stress-kinds, classifies stress levels, and stress duration using time or frequency classifications. The analysis is divided into the analysis of the work system (work objects, equipment and work environment, including physical/chemical environment, organization, remuneration and social interaction), the task analysis and the requirements analysis (Schlick et al., 2018) (

Table 5). By means of the AET analysis, relevant stressors of the work environment and task requirements can be detected.

Table 5. *Structure of the AET*

System	Work Objects
	Equipment
	Physical, organisational and social environment
Task	Types of Objects
Requirements	Information intake
	Information processing
	Information Output and Action

2.2.2.3 Task Analysis

For a generic analysis of the work tasks, Unified Modelling Language (UML) will be considered. UML diagrams have been developed in order to obtain a representation of the work tasks and task relationships within the work system. UML is a graphical modelling language for the specification, construction and documentation of software parts or other systems. It contains different types of diagrams that can be used depending on the context. One of these diagrams are the so-called use-case diagrams, which belongs to behavioural-diagram. Behaviour-diagrams give the opportunity to model the behaviour of a system from different points of view. With the use-case-diagram, the representation of the functionality of a system from the user's point of view is possible. It allows showing the limits of the system or the context of the use cases. It also enables the representation of the relationships between use cases and so-called actors, which interact with the displayed system in the form of users or external systems.

2.2.3 Office Use Case

2.2.3.1 General Environment Analysis

The work object of office work is information, which has to be processed by the worker. Information is combined and knowledge is generated. Basically the work consists of the utilization of profession specific methods, problem solving, implementing strategies, and deciding. The work is characterised by the usage of Computer programs, as well as mostly visual and auditory information input and output (e.g. reading, writing, verbal communication). Figure 7 shows an exemplary office workplace, which usually is equipped with a desk, chair, computer, monitors, keyboard, mouse, and a telephone. Usually the work is done in a sitting position. Ergonomic requirements regarding monitor workplaces can for example be derived from the European Standard EN ISO 9421.

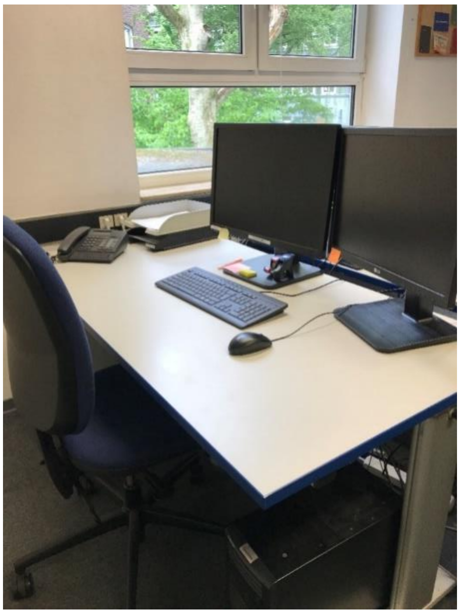


Figure 7: Example for Office Workplace (picture: RWTH)

Relevant physical environment influences are limited to indoor aspects, such as illumination, which can ergonomically be designed by recommendations of European standards. Other physical conditions, such as climate, mechanical vibrations, noise exposure, surface temperatures, dirty/wet environment, weather conditions, etc. do only play a minor role for this work place.

From an organisational point of view, office work is typically characterised by regulated working hours, in which flexible working time models are possible. Usually, there is no shift work model.

2.2.3.2 General Task Description

The work task contains changing contents, the dominant tasks is of informational character by means of working with a computer, including organisational and structuring contents, for example the planning and coordination of appointments. In addition, there is plenty of time dedicated to reading and writing texts, such as applications, invoices and e-mails. This also includes a social component, which involves coordination and contact with colleagues, supervisors and customers (Figure 8).

Strain shows up in the office use particularly in mental strain range by perception, cognition and action regarding information processing. Such an information strain exists, for example, in monitoring, controlling and steering activities.

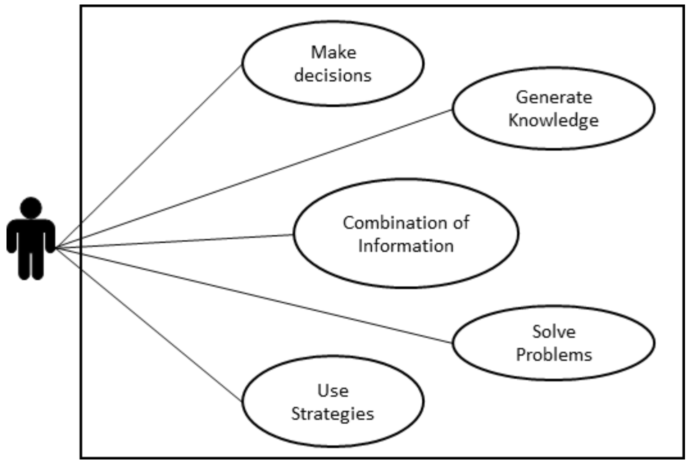


Figure 8: UML figure representation of the main points of the office use case.

2.2.4 Production Use Case

2.2.4.1 General Environment Analysis

The work object of production work is to conduct movements, e.g. for handling material and to perceive information and react to them, e.g. when interacting with machines.

Figure 9 shows an exemplary production workplace, which can be equipped with machines, or work equipment to assemble different pieces. Usually the work is done in a standing position. As the figure shows, depending on the working area, working postures exist where parts of the body have to be bended or twisted might be considered.

Ergonomic requirements regarding body postures can for example be derived from the European Standard EN ISO 1005.

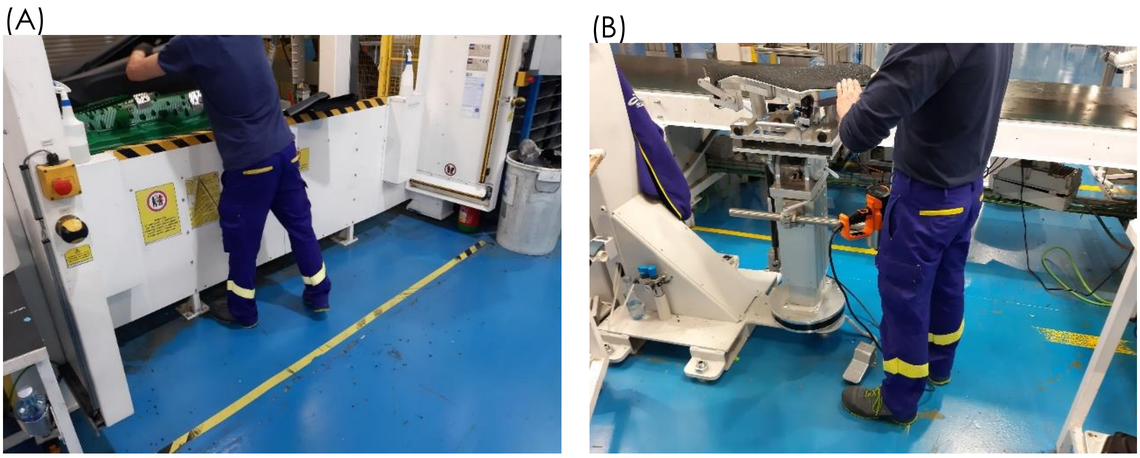


Figure 9: Examples for Production Workplaces; (A) Welding work-position: Assembly + machine feed (B) Manual dress work-position: Manual dress of pieces (pictures: Grupo Antolín).

Concerning production halls, physical environment influences are much more important, than in the office use case, since the worker is exposed to varying illumination, or climate conditions, or to surface temperatures of materials, mechanical machine vibrations, noise, dirty and wet environment, chemicals (e.g. cooling fluid).

Form an organisational point of view; this is often accompanied by shift work, which involves night- and weekend work, and sometime seasonal influences, depending on the product. Technicians usually do not have management responsibility or personnel authority. Social interaction takes place with supervisors and colleagues.

2.2.4.2 General Task Description

Production work in general can consist of a wide variety of tasks. Depending on the task, a completely different working system is possible and the associated use and processing of different materials and machines may be necessary.

The workstation includes the work with machine tools or assembly equipment, which includes various aspects, such as cognitive/physical exhausting work or very monotonous work (e.g. assembly line).

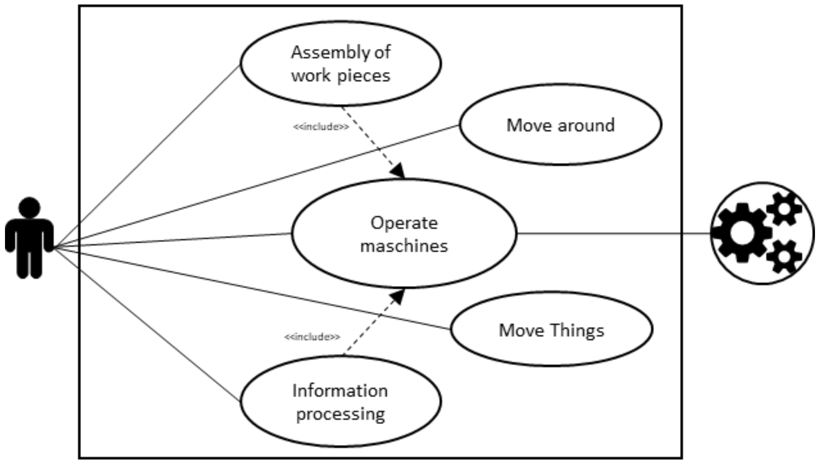


Figure 10: UML figure representation of the main points of the production use case.

2.2.5 Driving Use Case

2.2.5.1 General Workplace Description

The driving workplace is exemplary shown in Figure 11. This work mainly consists of reactive work elements. The driver has to perceive their environment, has to assess the current traffic situation, and respectively react by making decisions and adjusting their own driving operation. This requires constant concentration. The work object therefore, is to drive. Information input is usually visual (see street, traffic, other road users) or auditory (hear driving noises, horns, etc.). The workplace is a vehicle, equipped with a steering wheel, pedals, a seat and a coupling, with regard to the human-machine-interaction of the main task. The work is done in a sitting position. In general, the driver's space is limited to the vehicle dimensions.

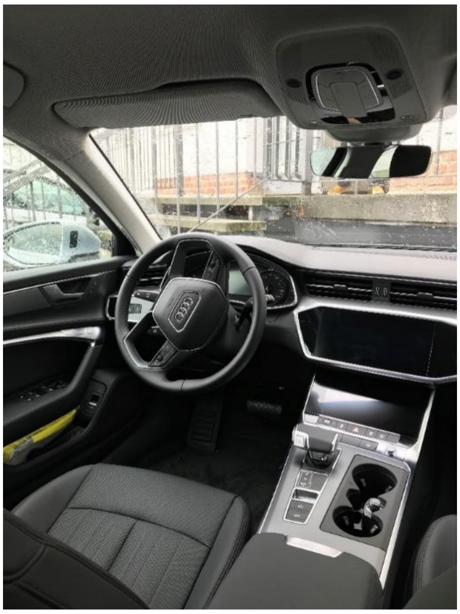


Figure 11: Example for Driving Workplace (picture: RWTH).

2.2.5.2 General Task Description

The vehicle driving workstation includes first the driving of the vehicle. This includes the responsibility for oneself and other road users, the recognition of environmental conditions and the appropriate conclusions for one's own driving style. In addition, the interaction with customers and other road users takes place.

Depending on the weather conditions, the amount of traffic and road conditions, different reactions have to take place. At the same time, the correct way must be determined and the contact with customers maintained. This goes hand in hand with a high level of responsibility for personal injury. The work task always remains the constant adaptation to new conditions.

The work requires a driving license and a work-related training. The work task involves a one-sided muscle load, because the posture rarely changes. The work involves few social interactions with colleagues, rather these with customers. Strain is recognisable particularly in mental strain due to processing and implementation of information.

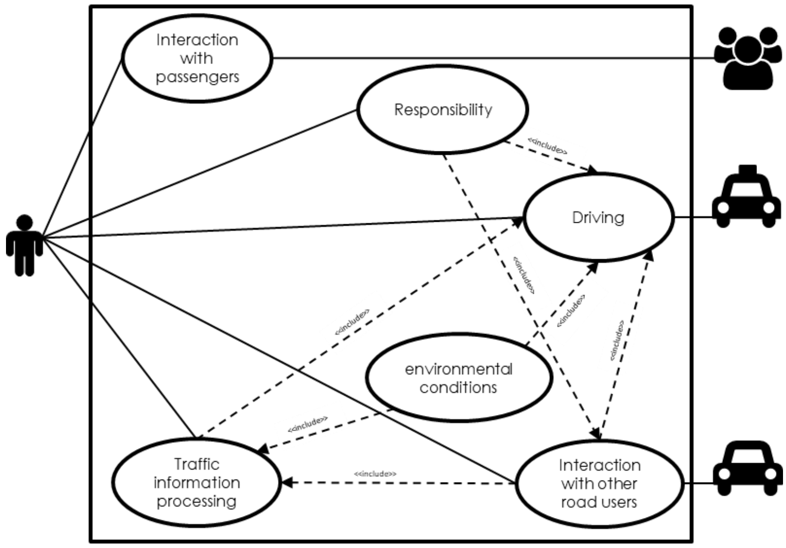


Figure 12: UML figure representation of the main points of the vehicle driving use case.

2.3 Summary of Requirements for the WA Tool

With regard to the prior sections, we now summarise requirements for the WA tool. Requirements here are still on a basic level, formulated as general aspects to be further specified, when developing the system architecture.

- **General Requirements:**
  - System should work autonomously, for example no external power source should be necessary
  - Best value for money
  - Mobile solution in order to serve all use cases
  - Small devices regarding shipping in order to conduct pilots in different countries
  - Since the use cases have different requirements, we would need a modular system, with independent sensor components, which do not necessarily have to be used at the same time (only sensors that are relevant for occurring strain in a specific use case)

- **Functional Requirements:**
  - System, able to measure mental and physical strain indicators, and external influences
    - Discriminatory & combinatory strain and emotional strain (stress, e.g. for ambulance drivers)
    - Body postures as indicator for muscular strain
    - External influences (stressors), e.g. illumination
  - Concerning especially wireless sensors, and the risk of connection loss, the system should provide information about the quality of the signals
  - Definition of system reaction, when strain is captured (Task 2.6), e.g.:
    - Stress,- strain & health evaluation

        - HCI (only information output about status, support function, recommendations)
        - Changes in work organisation (job rotation, brakes)
        - Other

- **User Requirements:**
    - If interaction with the system is foreseen, the WA tool should consider age-related changes in
        - Perception
        - Cognition
        - Action

- **Use Case requirements:**
    - Specifications of office use case:
        - Little limitations regarding weight and contact, because measurement equipment does not have to be worn and location is constant.
    - Specifications of production use case:
        - Sensors should not interfere the workflow, contactless and light sensors, if possible should be preferred.
        - Minimal effort for implementation of measurement system before task is conducted should be considered.
        - Sensors should not hinder someone when physical location is changed. Recommendation would be wireless sensors.
        - When using wireless sensory, data quality has to be assessed and a high level has to be ensured
    - Specifications of driving use case:
        - Due to little space in the vehicle, small sensors are necessary
        - Sensors have to be attachable/placeable to/in the cockpit of the car, suitability for this use case have to be clarified
        - Due to quick reactions of the driver to changing traffic situations, high data processing frequency is required
        - Additional external battery

- **Data Processing Requirements:**
    - Common data format has to be defined (e.g. XML, DLL)
    - Data protocol has to be defined (e.g. TCP/IP)
    - Interface/s [applications] (sensors – cloud – WA tool)
    - Data from sensors have to be prioritized by an algorithm (location – interface application/cloud/WA tool)
    - To make data processing easy, raw data has to be evaluated and translated into a code language by each sensor module – (location – interface application/cloud/WA tool)
    - Consistent processing frequency

3 System Concept

3.1 Introduction

The system concept offers the first direction, when defining the system architecture. In the following, we describe necessary software and hardware components, their interplay, as well as the functionality of the system, regarding the processing of the measured data.

3.2 Components

An important facet of WorkingAge is the availability of the user model data analysis and advanced functionalities as a cloud service rather than as standalone software. Different software and hardware components have to be implemented, to guarantee smooth and anonymous data processing, with regard to the multitude of data received by many different sensors.

Minimum requirements for such a system are the following components:

- Central Processing Unit (CPU) as a cloud solution
- Various sensors to collect the data at the working person and the workplace
- Interfaces between these components (possible software applications)
- WA tool
- Prioritisation algorithm & code languages to standardise different data types/format

Figure 13 gives an overview about the required components and the data processing structure. The definition of the system feedback is content of Task 6.2. The definition of interfaces and data format depends on the chosen technologies.

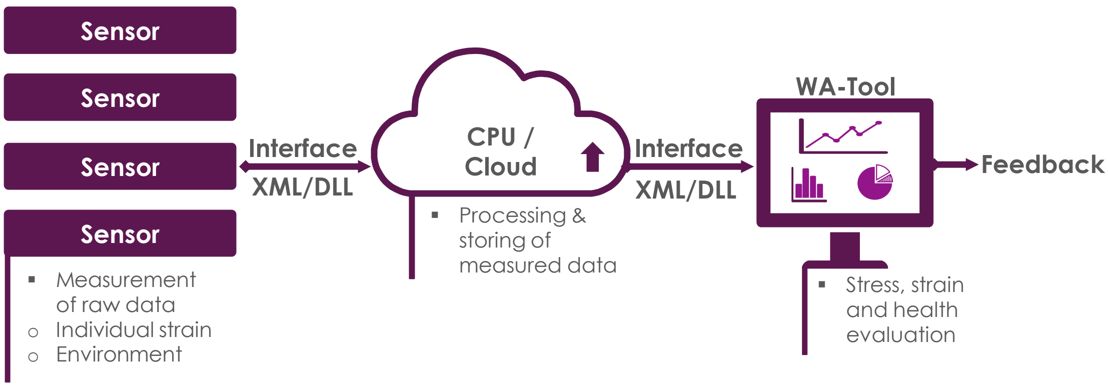


Figure 13: System structure and concept of the component interaction.

3.3 Functionality of the system

In this excerpt, we describe the functionality concerning the data processing.

It is necessary to filter and standardize the data so that they can be merged and processed within the WorkingAge tool.

The developed software will contain at least the following contents, regarding the measured data:

- **Data Type:** Information about the type of data collected (e.g. EEG, EKG, etc.).
- **Strain Value:** Individual strain value, which is measured with one of the used methods.
- **Accuracy:** Value used to assess the accuracy of the collected data and the determined strain value.

The WorkingAge tool calculates the overall strain-level, based on the single strain values of each measurement method by prioritising the best measured value, considering risk assessment according to Occupational Safety regulations. It has to be defined, if this prioritisation takes place within the Cloud or within the WorkingAge tool. The overall strain value is further calculated on the basis of this sensor data, and builds the basis for further health evaluation and the definition of system feedback. Figure 14 schematically shows data processing features of the system.

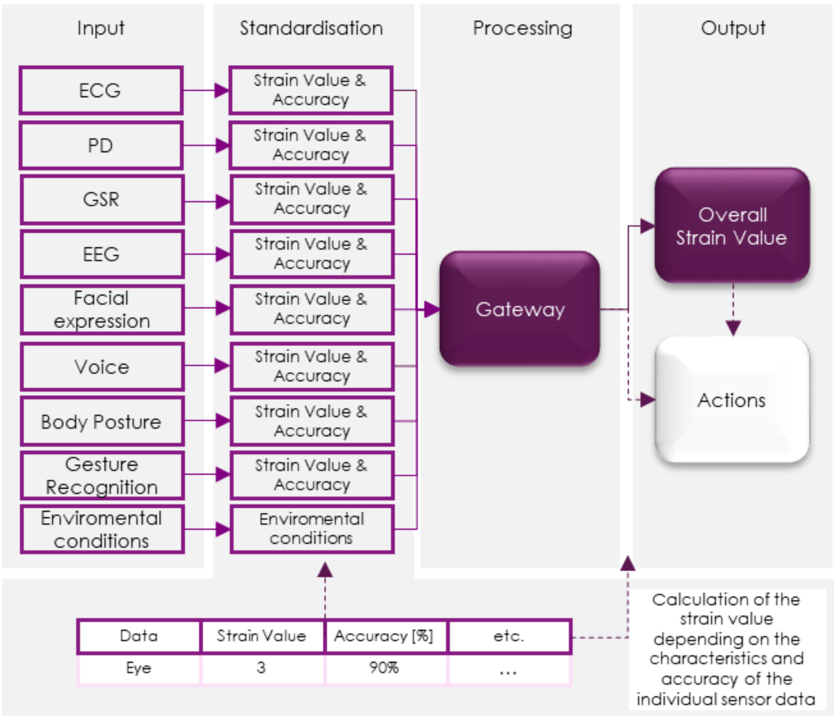


Figure 14: Data processing features of the WA system.

4 Conclusion

This deliverable defines the data and user requirements for the WorkingAge system. Requirements have been defined based on the theoretical background of the stress-strain concept, by analysing three different use cases covering a broad range of workplaces: office, production, driving. The theoretical introduction provided the basis for determining the user and data requirements. Five requirement dimensions were identified:

- General requirements,
- Functional requirements,
- User requirements,
- Use case requirements and
- Data processing requirements.

Specific requirements with regard to user and the use cases have been described. This includes consideration of risk factors from an ergonomic and psychological point of view and a general description of the work task regarding.

To meet the requirements of all use cases, the WA tool should be designed as a modular, mobile system, with autonomous sensor components. Wireless sensors will be preferred, with regards to the driving use case. Concerning the target user group, age-related changes in information processing have to be taken into account, when developing a HMI (human-machine-interface). In general, the system should be designed after the best value for money concept, concerning the acquisition of sensors.

Moreover, the document offers a first impression of the system concept, including system components, data processing, and system features. The WA system can be described as a tool that shall improves working experience and the work-life balance. Whist working, the working person faces various stressors, leading to individual experienced mental and physical strain. For this reason, the system will be capturing the working persons' strain via physiological and physical indicators, in a first step. This information will further be evaluated by means of the system. Therefore, the system requires the interaction of different components, such as sensors, interfaces, data collection, a central processing unit, and the WA tool itself, which is an interface. Within this document, we provide a general idea of this concept and the system's functions, but do not determine specific devices or data formats, etc.

This document and its derived requirements are the starting point for further developing the concrete system architecture. A more detailed analysis of the measurement components and user data will be provided in Deliverable 2.2.

5 Reference List

Adib, F., Kabelac, Z., Katabi, D., & Miller, R. C. (2014). 3d tracking via body radio reflections. In USENIX Association (Ed.), *11th USENIX Symposium on Networked Systems Design and Implementation* (pp. 317–325). The Usenix Magazine.

Åhrlin, U., & Öhrström (1978). Medical effects of environmental noise on humans. *Journal of Sound and Vibration, 59*(1), 79–87.

Asawa, K., Verma, V., & Agrawal, A. (2012). Recognition of vocal emotions from acoustic profile. In K. Gopalan (Ed.), *Proceedings of the International Conference on Advances in Computing, Communications and Informatics* (p. 710). [Place of publication not identified]: ACM.

Bartels, H. (1991). *Physiologie: Lehrbuch und Atlas.* München: Urban & [u.] Schwarzenberg.

Bauer, M., Glenn, T., Monteith, S., Gottlieb, J. F., Ritter, P. S., Geddes, J., & Whybrow, P. C. (2018). The potential influence of LED lighting on mental illness. *The world journal of biological psychiatry : the official journal of the World Federation of Societies of Biological Psychiatry, 19*(1), 59–73.

Björkstén, M., & Jonsson, B. (1977). Endurance limit of force in long-term intermittent static contractions. *Scandinavian journal of work, environment & health, 3*(1), 23–27.

Boff, K. R., & Lincoln, J. E. (1988). *User's Guide Engineering Data Compendium Human Perception and Performance.* Harry G Armstrong Aerospace Medical Research Lab Wright-Patterson AFB OH.

Borghini, G., Aricò, P., Di Flumeri, G., & Babiloni, F. (2017). *Industrial Neuroscience in Aviation: Evaluation of Mental States in Aviation Personnel. Biosystems & Biorobotics: Vol. 18.* Cham, s.l.: Springer International Publishing.

Borghini, G., Astolfi, L., Vecchiato, G., Mattia, D., & Babiloni, F. (2014). Measuring neurophysiological signals in aircraft pilots and car drivers for the assessment of mental workload, fatigue and drowsiness. *Neuroscience and biobehavioral reviews, 44*, 58–75.

Borisuit, A., Linhart, F., Scartezzini, J.-L., & Münch, M. (2015). Effects of realistic office daylighting and electric lighting conditions on visual comfort, alertness and mood. *Lighting Research & Technology, 47*(2), 192–209.

Brookings, J. B., & Wilson, J. F. (1994). Personality and family-environment predictors of self-reported eating attitudes and behaviors. *Journal of personality assessment, 63*(2), 313–326.

Buck, H., & Reif, A. (1997). Innovative industrielle Produktion bei veränderten Altersstrukturen. In *Perspektiven der alternden Arbeitsgesellschaft, in: Forum Demographie und Politik* (Vol. 9, pp. 159–181).

Carmody, M. A. (1994). *Current Issues in the Measurement of Military Aircrew Performance: A Consideration of the Relationship Between Available Metrics and Operational Concerns* (NAVAL AIR WARFARE CENTER AIRCRAFT DIV WARMINSTER PA AIR VEHICLE AND CREW SYST EMS TECHNOLOGY DEPT No. NAWCADWAR-94139-60), from https://apps.dtic.mil/dtic/tr/fulltext/u2/a292539.pdf.

da Silva, F. H. L. (1996). The Generation of Electric and Magnetic Signals of the Brain by Local Networks. In R. Greger & U. Windhorst (Eds.), *Comprehensive human physiology. From cellular mechanisms to integration* (pp. 509–531). [Place of publication not identified]: Springer.

De Jong, Maj Marla J, & Randall, D. C. (2005). Heart rate variability analysis in the assessment of autonomic function in heart failure. *Journal of Cardiovascular Nursing, 20*(3), 186–195.

Eggemeier, F. T., Biers, D. W., Wickens, C. D., Andre, A. D., Vreuls, D., Billman, E. R., & Schueren, J. (1990). *Performance assessment and workload evaluation systems: Analysis of candidate measures.* Technical Report No. HSD-TR-90-023, Brooks Air Force Base, TX: Armstrong …

Ekman, P. (1997). *What the Face Reveals: Basic and Applied studies of Spontaneous Expression Using the Facial Action Coding System (FACS). Series in affective science.* Oxford: Oxford University Press.

Ekman, P. (2003). Darwin, Deception, and Facial Expression. *Annals of the New York Academy of Sciences, 1000*(1), 205–221.

Ellis, S. R., & Smith, J. D. (1985). Patterns of Statistical Dependency in Visual Scanning. In R. Groner (Ed.), *Proceedings of the twenty-third International Congress of Psychology: Vol. 9. Eye movements and human information processing.* Amsterdam: North-Holland.

Directive 89/391/EEC.

Evans, G. W., & Johnson, D. (2000). Stress and open-office noise. *The Journal of applied psychology, 85*(5), 779–783.

Friesen, E., & Ekman, P. (1978). Facial action coding system: a technique for the measurement of facial movement. *Palo Alto, 3*.

Grandt, M. (2004). *Zur Erfassung und Bewertung der mentalen Beanspruchung mittels psychophysiologischer Messverfahren.* Dissertation, Universität Wuppertal, Wuppertal.

Gunes, H., & Schuller, B. (2013). Categorical and dimensional affect analysis in continuous input: Current trends and future directions. *Image and Vision Computing, 31*(2), 120–136.

Gunes, H., Schuller, B., Pantic, M., & Cowie, R. (2011). Emotion representation, analysis and synthesis in continuous space: A survey. In *Automatic Face & Gesture Recognition and Workshops (FG 2011), 2011 IEEE International Conference on. Date, 21-25 March 2011* (pp. 827–834). [Piscataway, N.J.]: [IEEE].

Hacker, W., & Richter, P. (2013). *Psychische Fehlbeanspruchung: Psychische Ermüdung, Monotonie, Sättigung und Stress* (Vol. 2): Springer-Verlag.

Hart, S. G., & Staveland, L. E. (1988). Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research. In P. A. Hancock & N. Meshkati (Eds.), *Human Mental Workload. Advances in Psychology* (pp. 139–183). Amsterdam: Elsevier.

He, W., Wu, K., Zou, Y., & Ming, Z. (2015). Wig: Wifi-based gesture recognition system. In ICCCN (Ed.), *The 24th International Conference on Computer Communication and Networks* (pp. 1–7).

Herzog, N. V., Beharic, R. V., Beharic, A., & Buchmeister, B. (2015). Ergonomic Analysis and Simulation in Department of Ophthalmology. *Procedia Manufacturing, 3*, 128–135.

Hignett, S., & McAtamney, L. (2000). Rapid Entire Body Assessment (REBA). *Applied Ergonomics, 31*(2), 201–205.

Jarosińska, D., Héroux, M.-È., Wilkhu, P., Creswick, J., Verbeek, J., Wothge, J., & Paunović, E. (2018). Development of the WHO Environmental Noise Guidelines for the European Region: An Introduction. *International journal of environmental research and public health, 15*(4).

Jasper, H. (1958). Report of the committee on methods of clinical examination in electroencephalography. *Electroencephalography and Clinical Neurophysiology, 10*(2), 370–375.

Juslin, P. N., Scherer, K. R., Harrigan, J., & Rosenthal, R. (2005). *The new handbook of methods in nonverbal behavior research. Series in affective science*. Oxford: Oxford University Press.

Kahneman, D., & Beatty, J. (1966). Pupil diameter and load on memory. *Science, 154*(3756), 1583–1585.

Kantowitz, B. H., & Campbell, J. L. (2017). Pilot Workload and Flightdeck Automation. In M. Mouloua (Ed.), *Automation and Human Performance. Theory and Applications*. London: Taylor and Francis.

Kirchner, J.-H. (1986). Belastungen und Beanspruchungen—Einige begriffliche Klärungen zum Belastungs-Beanspruchungs-Konzept. In *Arbeitsorganisation und Neue Technologien* (pp. 553–569). Springer.

Konrad, P. (2006). The ABC of EMG. *A practical introduction to kinesiological electromyography, 1*.

Kralikova, R., & Wessely, E. (2018). Lighting Quality, Productivity and Human Health. In B. Katalinic (Ed.), *DAAAM Proceedings: Vol. 1. Proceedings of the 29th International DAAAM Symposium 2018* (pp. 59–65). DAAAM International Vienna.

Kramer, A. F. (1991). Physiological metrics of mental workload: A review of recent progress. *Multiple-task performance*, 279–328.

Krebs, M. J., Wingert, J. W., & Cunningham, T. (1997). *Exploration of an oculometer-based model of pilot workload*. Minnesota: National Aeronautics and Space Administration.

Kroemer, K. H. (1989). Cumulative trauma disorders: their recognition and ergonomics measures to avoid them. *Applied Ergonomics, 20*(4), 274–280.

Landau, K. (1978). *Das arbeitswissenschaftliche Erhebungsverfahren zur Tätigkeitsanalyse - AET*. @Darmstadt, Techn. Hochsch., Diss., 1978.

Luczak, H. (1982). Belastung, Beanspruchung und Erholungszeit bei informatorisch-mentaler Arbeit. *Bremerhaven: Wirtschaftsverlag NW*.

Luczak, H. (1989). Wesen menschlicher Leistung. *Arbeitsgestaltung in Produktion und Verwaltung. Wirtschaftsverlag Bachem, Köln*, 39–64.

Manzey, D. (1998). Psychophysiologie mentaler beanspruchung. *Ergebnisse und Anwendungen der psychophysiologie. Enzyklopädie der Psychologie, 100*, 799–864.

Martinez, B., Valstar, F., Michel, Jiang, B., & Pantic, M. (2017). Automatic Analysis of Facial Actions: A Survey. *IEEE Transactions on Affective Computing*.

Mattila M, Karwowski W, Vilkki M. Analysis of working postures in hammering tasks on building construction sites using the computerized OWAS method. *Applied Ergonomics* 1993;24(6):405–12

May, J. G., Kennedy, R. S., Williams, M. C., Dunlap, W. P., & Brannan, J. R. (1990). Eye movement indices of mental workload. *Acta Psychologica, 75*(1), 75–89.

McAtamney, L., & Nigel Corlett, E. (1993). RULA: a survey method for the investigation of work-related upper limb disorders. *Applied Ergonomics, 24*(2), 91–99.

Mertens, A. (2014). *Altersgerechte Gestaltung von Mensch-Maschine-Schnittstelle zur ergonomischen Interaktion mit telemedizinischen Systemen und Dienstleistungen*. Dissertation, RWTH Aachen, Aachen.

Meyer-Delius, J., Kriesel, W., & Johnson, D. (1981). Training und Ermüdung der visuellen Wahrnehmungsleistung im Bilde eines Elektrookulogramms. *Zeitschrift für arbeitswissenschaft, 35*, 168–173.

Meyer-Delius, J., & Lackner, K. (1983). Augenbewegungen beim Lesen von Ziffernreihen auf dem Bildschirm. *Zeitschrift für arbeitswissenschaft, 37*, 110–112.

Moridis, C. N., & Economides, A. A. (2012). Affective Learning: Empathetic Agents with Emotional Facial and Tone of Voice Expressions. *IEEE Transactions on Affective Computing, 3*(3), 260–272.

Mulder, L. J. M. (1992). Measurement and analysis methods of heart rate and respiration for use in applied environments. *Biological Psychology, 34*(2-3), 205–236.

Munnichsm, J. M. (1989). *Evaluation and intervention: research on aging: Proceedings of symposium on European Behavioural and Social Science Research Section*. Nijmegen: Department of Social Gerontology, University of Nijmegen.

Ng, R. W. M., Leung, C.-C., Lee, T., Ma, B., & Li, H. (2010). Prosodic attribute model for spoken language identification. In S. C. Douglas (Ed.), *IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP), 2010. 14-19 March 2010, Sheraton Dallas Hotel, Dallas, Texas, USA ; proceedings* (pp. 5022–5025). Piscataway, NJ: IEEE.

Origgi, J.-M. (2018). *PATHOSnet: Parallel, audio-textual, hybrid organization for sentiment network*. Master´s thesis, Politecnico di Milano, Milan.

Pinker, S., & Prince, A. (1994). Regular and Irregular Morphology and the Psychological Status of Rules of Grammar. In S. d. Lima, R. Corrigan, & G. Iverson (Eds.), *[Studies in language / Companion series] Studies in language Companion series: Vol. 26. The Reality of Linguistic Rules*. Amsterdam: Benjamins.

Plantard, P., Shum, H. P. H., Le Pierres, A.-S., & Multon, F. (2017). Validation of an ergonomic assessment method using Kinect data in real workplace conditions. *Applied Ergonomics, 65*, 562–569.

Pleva, M., Ondas, S., Juhar, J., Cizmar, A., Papaj, J., & Dobos, L. (2011). Speech and mobile technologies for cognitive communication and information systems. In *2nd International Conference on Cognitive Infocommunications (CogInfoCom), 2011. 7 - 9 July 2011, Budapest, Hungary*. Piscataway, NJ: IEEE.

Pu, Q., Gupta, S., Gollakota, S., & Patel, S. (2013). Whole-home gesture recognition using wireless signals. In S. Helal (Ed.): *ACM Digital Library, Proceedings of the 19th annual international conference on Mobile computing & networking* (pp. 27–38). New York, NY: ACM.

Ramshur, J. T. (2010). *Design, Evaluation, and Application of Heart Rate Variability Analysis Software (HRVAS)*. Master Thesis, University of Memphis, Menphis.

Rogez, G., Weinzaepfel, P., & Schmid, C. (2019). LCR-Net++: Multi-person 2D and 3D Pose Detection in Natural Images. *IEEE transactions on pattern analysis and machine intelligence*.

Rohmert, W. (1983). Formen menschlicher Arbeit. In W. Rohmert & J. Rutenfranz (Eds.), *Praktische Arbeitsphysiologie*. Stuttgart, New York: Georg Thieme Verlang.

Rohmert, W. (1984). Das Belastungs-Beanspruchungs-Konzept. *Zeitschrift für arbeitswissenschaft, 38*(4), 193–200.

Rohmert, W., & Landau, K. (1979). *Das arbeitswissenschaftliche Erhebungsverfahren zur Tätigkeitsanalyse (AET): Handbuch*. Bern: Huber.

Rohmert, W., & Rutenfranz, J. (Eds.) (1983). *Praktische Arbeitsphysiologie*. Stuttgart, New York: Georg Thieme Verlang.

Rohmert, W. (1962). *Untersuchungen über Muskelermüdung und Arbeitsgestaltung*. Habilitationsschrift, Aachen, RWTH Aachen.

Rouast, P. v., Adam, M., & Chiong, R. (2019). Deep Learning for Human Affect Recognition: Insights and New Developments. *IEEE Transactions on Affective Computing*.

Sariyanidi, E., Gunes, H., & Cavallaro, A. (2015). Automatic Analysis of Facial Affect: A Survey of Registration, Representation, and Recognition. *IEEE transactions on pattern analysis and machine intelligence, 37*(6), 1113–1133.

Schlick, C. M., Winkelholz, C., Motz, F., & Luczak, H. (2006). Self-generated complexity and human-machine interaction. *IEEE Transactions on Systems, Man, and Cybernetics - Part A: Systems and Humans, 36*(1), 220–232.

Schlick, C., Bruder, R., & Luczak, H. (2018). *Arbeitswissenschaft* (4. Auflage). Berlin: Springer Vieweg.

Sequeira, H., Hot, P., Silvert, L., & Delplanque, S. (2009). Electrical autonomic correlates of emotion. *International journal of psychophysiology : official journal of the International Organization of Psychophysiology, 71*(1), 50–56.

Setz, C., Arnrich, B., Schumm, J., La Marca, R., Tröster, G., & Ehlert, U. (2010). Discriminating stress from cognitive load using a wearable EDA device. *IEEE transactions on information technology in biomedicine : a publication of the IEEE Engineering in Medicine and Biology Society, 14*(2), 410–417.

Shotton, J., Sharp, T., Kipman, A., Fitzgibbon, A., Finocchio, M., Blake, A., et al. (2013). Real-time human pose recognition in parts from single depth images. *Communications of the ACM, 56*(1), 116–124.

Sloan, R. P., Shapiro, P. A., Bagiella, E., Boni, S. M., Paik, M., Bigger, J. T., et al. (1994). Effect of mental stress throughout the day on cardiac autonomic control. *Biological Psychology, 37*(2), 89–99.

Stein, J. F. (1992). The representation of egocentric space in the posterior parietal cortex. *The Behavioral and brain sciences, 15 Spec No 4*, 691–700.

Stern, J. A., Boyer, D., & Schroeder, D. (1994). Blink rate: a possible measure of fatigue. *Human factors, 36*(2), 285–297.

Sun, F.-T., Kuo, C., Cheng, H.-T., Buthpitiya, S., Collins, P., & Griss, M. (2012). Activity-Aware Mental Stress Detection Using Physiological Sensors. In M. Gris & G. Yang (Eds.), *Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering: Vol. 76. Mobile Computing, Applications, and Services. Second International ICST Conference, MobiCASE 2010, Santa Clara, CA, USA, October 25-28, 2010, Revised Selected Papers* (pp. 282–301). Berlin, Heidelberg: Springer Berlin Heidelberg.

van Kempen, E., & Babisch, W. (2012). The quantitative relationship between road traffic noise and hypertension: a meta-analysis. *Journal of hypertension, 30*(6), 1075–1086.

Virmani, A., & Shahzad, M. (2017). Position and orientation agnostic gesture recognition using wifi. In E. Cuervo (Ed.), *MobiSys'17. Proceedings of the 15th Annual International Conference on Mobile Systems, Applications, and Services* (pp. 252–264).

Weekly, K., Jin, M., Zou, H., Hsu, C., Bayen, A., & Spanos, C. (2014). *Building-in-Briefcase (BiB),* from http://arxiv.org/pdf/1409.1660v1.

Westman, J. C., & Walters, J. R. (1981). Noise and stress: a comprehensive approach. *Environmental health perspectives, 41*, 291–309.

Williams, L. J. (1982). Cognitive load and the functional field of view. *Human factors, 24*(6), 683–692.

Wilson, G. F. (1993). Air-to-ground training missions: a psychophysiological workload analysis. *Ergonomics, 36*(9), 1071–1087.

Wilson, G. F., & Fisher, F. (1991). The use of cardiac and eye blink measures to determine flight segment in F4 crews. *Aviation, Space, and Enviromental Medicine, 62*(10), 959–962.

Wilson, T. d., Laser, P. S., & Stone, J. I. (1982). Judging the predictors of one's own mood: Accuracy and the use of shared theories. *Journal of Experimental Social Psychology, 18*(6), 537–556.

Wright, K. P., McHill, A. W., Birks, B. R., Griffin, B. R., Rusterholz, T., & Chinoy, E. D. (2013). Entrainment of the human circadian clock to the natural light-dark cycle. *Current biology : CB, 23*(16), 1554–1558.

Wurtman, R. J. (1975). The effects of light on the human body. *Scientific American, 233*(1), 69–77.

Zijlstra, F. R. H., & van Doorn, L. (1985). The construction of a scale to measure subjective effort. *Delft, Netherlands, 43*.

Zou, H., Zhou, Y., Yang, J., Gu, W., Xie, L., & Spanos, C. (2018). Wifi-based human identification via convex tensor shapelet learning. In AAAI (Ed.), *Thirty-Second AAAI Conference on Artificial Intelligence* .

Zou, H., Chen, Z., Jiang, H., Xie, L., & Spanos, C. (2017). Accurate indoor localization and tracking using mobile phone inertial sensors, WiFi and iBeacon. In *IEEE Inertial Sensors 2017. The 4th IEEE International Symposium on Inertial Sensors & Systems* (pp. 1–4). Piscataway, NJ: IEEE.