SmartWork: Designing a Smart Age-Friendly Living and Working Environment for Office Workers

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ABSTRACT

Europe is being severely challenged by the ageing of the population, and although for well over a decade now is looking for strategies to effectively increase the labour force participation of older workers and reduce the rates of early retirement and labour market exit, the unemployment amongst older people remains particularly high. The design and realization of age-friendly living and working environments is a huge challenge that we have just only started to address as the number of older citizens who are and want to continue being active members of society and live independently is constantly increasing. This paper introduces the SmartWork project, which aims at building a worker-centric Artificial Intelligence system for work ability sustainability, integrating unobtrusive sensing and modelling of the worker state with a suite of novel services for context and worker-aware adaptive work support.

CCS CONCEPTS

• **Information systems → Decision support systems**.

KEYWORDS

healthy ageing, office worker, unobtrusive and pervasive sensing, ubiquitous work environment, on-the-fly work flexibility management, training on-demand

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1 INTRODUCTION

Europe is being severely challenged by the ageing of the population, and although for well over a decade now is looking for strategies to effectively increase the labour force participation of older workers and reduce the rates of early retirement and labour market exit, the unemployment amongst older people remains particularly high, with the EU-28 employment rate of 55-64 year olds reaching only 55.3% by 2016 [6]. Ageing is a gradual process and there is no definition of when someone becomes an "older worker", but many physical changes associated with ageing including decline in vision, hearing and psychomotor coordination are estimated to start as early as the age of 50 [14]. Furthermore, health chronic conditions prevalence in case of people aged 50+ is very high, with every second person having hypertension and/or some other chronic disease (e.g. high cholesterol, heart disease, mental illness, diabetes, arthritis, back problems, asthma, COPD, etc.) [5], and multimorbidity being very common among people aged 65+ (prevalence rates estimated as high as 65%) [7].

In case of office workers, the prolonged sitting and overall sedentary life may significantly and independently of other factor increase the risk of cardiometabolic diseases and premature mortality [16], being recommended that people with occupations which are predominantly desk based should progress towards accumulating 2h/day of standing and light activity (light walking) during working hours (e.g. regularly broken up seated-based work with standing-based work, use sit-stand desks, take short active standing breaks) [11], [10]. Office work also affects functional abilities of the workers, with particular risk for the development of musculoskeletal pain [3] and computer-related visual symptoms [18]. Other contextual factors related to the office workspace, including illumination and ambient conditioning system, influence office worker's behaviour, comfort and productivity [1], [23]. Furthermore, there is evidence that high-intensity teleworkers are overall more satisfied than office-based employees and achieve significant benefits from their work arrangement, with work-life conflict most influential towards job satisfaction [9]. Although there is some evidence that job control decreases with age, other factors such as qualifications and job status may also have great impact on the feeling of job security.

The design and realization of age-friendly living, recreational and working environments is a huge challenge that we have just only started to address as the number of older citizens who are and want to continue being active members of society and live independently is constantly increasing. Maintaining an active professional life despite the ageing process and the functional limitations, health conditions or care needs that this process frequently entails is of paramount importance for active ageing and independent living. The continuation of the active involvement of older adults in the worklife can be beneficial for all related stakeholders: for the society, for themselves, for their families and friends, for employers, for their colleagues. However, a number of challenges may occur as workers grow older in their work environment:

- They face health conditions and experience increasing care needs that may impede or even conflict with current work practices and work environments. For example, an estimated 52 million EU citizens aged 55-74 (half of all people in this age group) report having a long-standing illness or health problem [8]. Health conditions may influence (usually increase) the number of hours that a person works from home or the amount of time that a person works while on the move. Health conditions may also create a feeling of insecurity at work (fear of a health crises while at work) which may influence the older worker's performance. In other cases, re-integration at the work environment is necessary after a long absence of a worker due to health problems.
- They face difficulties in adapting to the rapidly changing work conditions and the ever-evolving work requirements that necessitate the acquisition of new professional skills in very short periods of time. This includes but is not limited to the need to adapt to new technologies, new work processes, new forms of collaboration, while keeping up to date with massive amounts of information that may influence their work performance and decision-making.
- They face increasing accessibility needs due to degradation of physical and mental abilities caused by ageing: e.g. reduced vision, hearing, cognitive decline, and more. In these cases, there is a serious risk of experiencing social exclusion and difficulty in maintaining productivity in the work environment.

Although in each particular field efforts have been made to answer some of these challenges, there is no unified framework integrating them with focus on maintaining the working ability of the older person and increasing their capacity and desire for a prolonged professional life. A wide range of ambient assistive technologies are emerging, supporting home health monitoring of elderly people (over 65 years old) for their independent living, but in most cases such solutions are either too focused (e.g. disease specific) or not available/transferable at the workplace or on the move (e.g. home embedded sensing technologies). Human functional abilities, musculoskeletal system and physiology have been modelled at various levels of details to provide support for personalization of eHealth and mHealth applications and services [19], [15], [12]. Models have been also proposed to model the broad-spectrum cognitive mechanisms mediating the impact of age on stress for older workers in ICT-related jobs [20], and to predict behavioural intention with respect to technology acceptance and actual use (e.g. technology acceptance model – TAM) [22] based on technology experience, personality dimensions of agreeableness and openness to experience and attitudes. However, the links between such models along with standardized qualitative and quantitative metrics to assess overall work ability sustainability are yet to be established. Furthermore, ICT accessibility technologies have been mostly developed with disability in mind in the past and are currently re-designed to accommodate for interoperability and transferability of "one-fits-one" solutions for any particular user needs and abilities. In all cases, employers are reluctant to adopt (or even find out about) good solutions enabling independent living (including workability) of older adults.

2 THE PROPOSED SMARTWORK SOLUTION

The SmartWork project builds a Worker-Centric AI System for work ability sustainability, which integrates unobtrusive sensing and modelling of the worker state with a suite of novel services for

context and worker-aware adaptive work support. The unobtrusive and pervasive monitoring of health, behaviour, cognitive and emotional status of the worker enables the functional and cognitive decline risk assessment. The holistic approach for work ability modelling captures the attitudes and abilities of the ageing worker and enables decision support for personalized interventions for maintenance/improvement of the work ability. The evolving work requirements are translated into required abilities and capabilities (i.e. work ability model), and the adaptive work environment supports the older office worker with optimized services for on-the-fly work flexibility coordination, seamless transfer of the work environment between different devices and different environments (e.g. at home, at the office, or on the move), and on-demand personalized training. The SmartWork services and modules for on-the-fly work flexibility also empower the employer (manager) with AI decision support tools for efficient task completion and work team optimization through flexible work practices. Formal/informal carers are enabled to continuously monitor the overall health status, behavioural attitudes and risks for the people they care for, and adapt health and lifestyle interventions to the evolving workers status, thus providing full support to the older office workers for sustainable, active and healthy ageing.

3 USER GROUPS AND WORK FUNCTIONS

The main user groups of SmartWork are identified as follows:

- Older office workers, who will benefit from the User-Centric AI system for multi-dimension work ability sustainability, continuous unobtrusive and pervasive monitoring and risk assessment for their health status and overall functional and cognitive capacity, and provision of context- and worker-aware flexible and adaptive work support
- Employers, including managers and supervisors, who will be able to improve efficiency and productivity of office workers teams through a novel approach, by shifting focus on increased job satisfaction through work flexibility and optimal contextual knowledge management
- Carers, formal and informal, who will be able to continuously monitor the health status of the workers they care for, through automatically extracted higher level of health status and potential short- and long-term risks assessment, and adapt health and behavioural interventions to the evolving worker state.

When examining the future of ICT and ageing at work, the main Work Functions [17] describing the requirements to be analysed for any new ICT solution, in order to make it appealing also from the employers' point of view, are:

(1) WF1: Learning and Exercising. Learning is a central aspect of work, and the ICT skills for office workers are a good example of the importance of learning when knowledge and skills evolve rapidly. The only way to counteract the outdating of knowledge and skills is to integrate education and training in working life. For ageing office workers, the following dimensions are of major importance: transfer of explicit knowledge for up-to-date valuable knowledge; transfer of tacit knowledge for up-to-date valuable skills; physical exercise to maintain physical abilities; mental exercise to maintain mental abilities.
(2) WF2: Communication. ICT has high capacity to improve this work function for the older office workers. Communication is fundamental to the other work functions: learning possibilities increase with communication alternatives, collaboration among team members depend on how well they can communicate with each other, worker's productivity depends on having the right information at the right time in the work place, etc.
(3) WF3: Coordination. Depending on the type of organization, the coordination challenges are different: large organizations may need to use ICT tools to coordinate availability of part-time employees who need flexibility at short notice; SMEs may benefit from better coordination technologies for external coordination with partners and customers; mature entrepreneurs may benefit from better external coordination with potential partners and resource suppliers.
(4) WF4: Collaboration and Teamwork. Collaboration and teamwork takes advantage of communication, coordination and control to facilitate combining the knowledge to create new value propositions or deliver products and services to customers.
(5) WF5: Knowledge Management. When it comes to management of knowledge within an organization, multiple aspects of ICT-based knowledge management must be considered: (i) improved access to ICT-based knowledge repositories facilitates access to expertise that otherwise would be hard to identify; (ii) leveraging knowledge base by well targeted training actions at organization level; (iii) exploiting human resources for informal knowledge transfer.
(6) WF6: Psycho-physical capacity. Psycho-physical capacity (productivity) ICT tools support people to create more in less time, by simplifying access to data, assisting with decision making, simplifying communication or simplifying complex tasks. It depends on the quality of software to automate, simplify and reduce human intervention in organisational processes. Process automation software (Enterprise Resource Planning - ERP, Customer Relationship Managment - CRM, Material Requirements Planning - MRP) are important, technologically advanced, sources of productivity for the office worker, and better and friendlier human-technology interface positively impact on health at the work place by reducing the level of stress and job satisfaction. Stress management at work and in the private life has a strong impact on the overall psycho-physical capacity of the worker, especially for job with an increased mental work-load, as the case of office workers.

4 GENERIC ARCHITECTURE

The SmartWork project goal is to develop and validate a Worker-Centric AI System which enables work ability sustainability for office workers. In this scope it integrates a series of unobtrusive and ubiquitous ICT tools to support the implementation of a Suite of Novel Services for context (work tasks, location) and worker-aware adaptive work support, with focus on the enhanced health

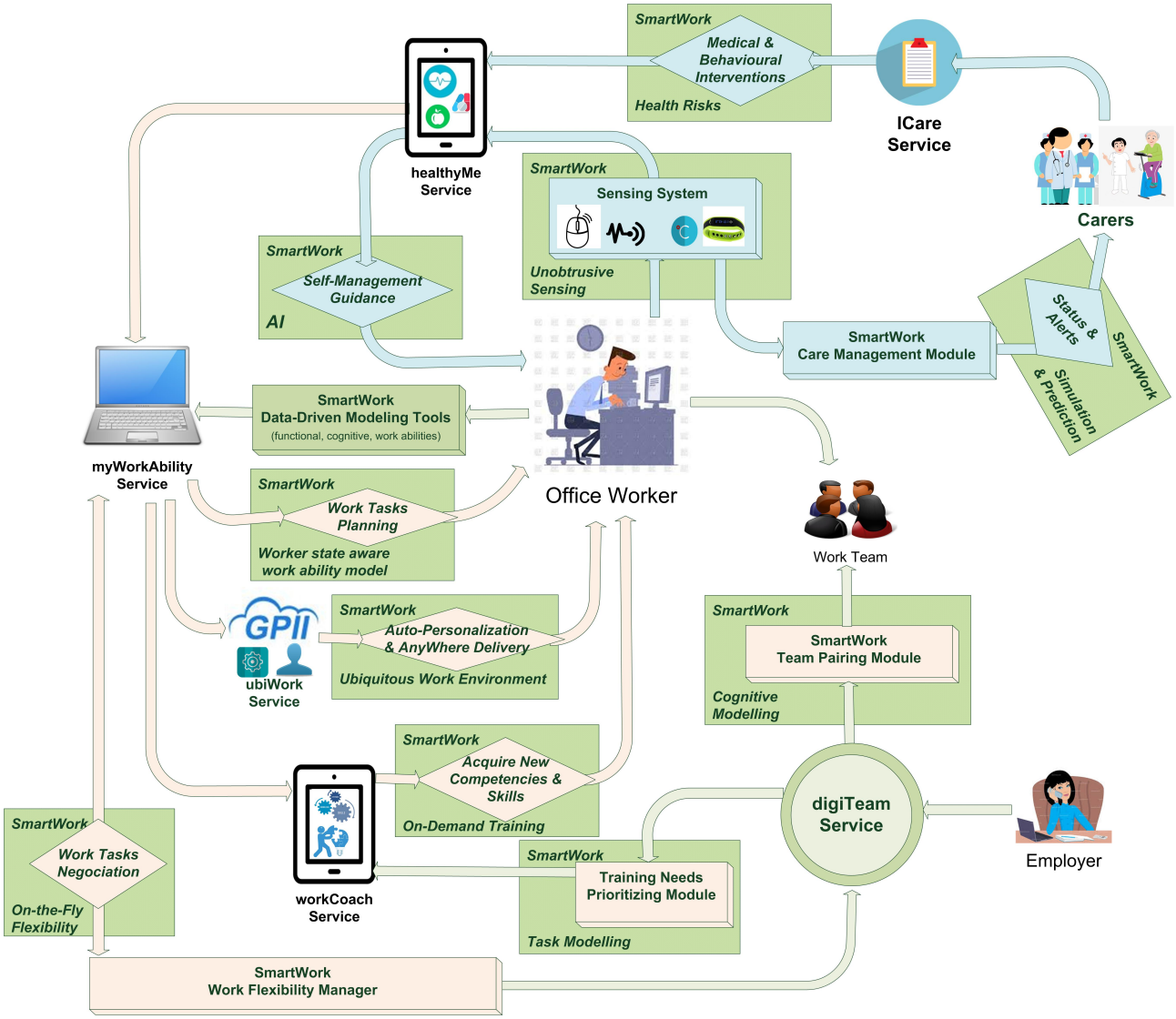

Figure 1: Generic Architecture of the SmartWork Suite of Novel Services.

and working conditions, and improved overall quality of life (QoL) of the older office workers. At the same time, being productive is critical work ability for a lifelong employability of ageing workers, allowing them to have the possibility to maintain a high level of activity and a longer period of working time. Thus, the developed SmartWork system and suite of services, aim at addressing also the requirements of the employers, helping them to maintain/increase work efficiency and productivity of the employees through better management of the available resources in relation to the work tasks. Optimization of team formation, driven by the semantic modelling of the work tasks, along with training needs prioritization at team level to identify unmet needs, allow employers to optimize tasks (e.g. resources needed to complete them), shifting focus on increased job satisfaction for increased productivity.

SmartWork will support active and healthy ageing at work through a suite of smart services, integrating transdisciplinary Artificial Intelligence (AI) methods and technologies as shown in Figure 1 and further detailed in Section 5, and addressing the needs of three main user groups: the employee (the office worker), the employer (managing and supervision personnel) and care givers (formal and informal).

5 SMART SERVICES SUITE

The implementation of the Smart Services Suite integrates and shares on the various dimensions of the Worker State aware Work Ability modelling, a series of transdisciplinary methods and technologies (e.g. functional modelling, cognitive modelling, accessible-born interaction interfaces), to address the needs and requirements

of the main user groups. By implementing a suite of smart services instead of a compact system, SmartWork aims at achieving a realistic target through the lightweight, on demand, personalized tractable and usable services. The main technologies and infrastructure used for the implementation of the services (further detailed in sections 5.1-6) include:

(1) Unobtrusive Sensing at the workplace and on-the-move, using: (i) an intelligent mouse for monitoring of physiological parameters of the office worker during work time [4]; (ii) an innovative wearable ECG prototype for cardiac diseases monitoring on the move [2]; (iii) an interconnected data storage platform; and (iv) low-level heterogeneous data processing algorithms for efficient data transmission.
(2) The implementation of the Ubiquitous Workplace, allowing for instant adaptation/personalization and seamless transfer of the computer work environment to the office worker state, represented by evolving needs and contextual factors (e.g. location, temporary health issue), and building on the Global Public Inclusive Infrastructure (GPII) auto-personalisation architecture [21].
(3) Modelling and Artificial Intelligence for risk assessment on multiple dimensions related to the work ability of the employee, which will exploit existing and implement new tools for simulation, prediction and decision support.
(4) On-the-fly Flexibility and on-Demand Training which will be implemented by instantiating the open source Assistance-on-Demand platform [13].
(5) Care Management and Interventions to deliver health and lifestyle self-management services to people with chronic conditions, through remotely controlled data collection and efficient smart coaching.

5.1 healthyMe Service

This is a service for continuous, unobtrusive and ubiquitous monitoring of physiological and behavioural parameters, for efficient self-management of chronic health conditions, positive change of behavioural attitudes and improved quality of life of the older office worker. Managing chronic conditions and long-standing illness can require a great deal of time and effort on the part of both, patients and families. People must often take many different medications, each with their own special instructions, and must keep track of numerous medical appointments with various providers. The may have some type of activity limitation and can necessitate care assistance from family, friends or paid attendants. The more chronic conditions a person has, the greater their out-of-pocket medical expenditures, adding additional burden to patients and families. Continuous monitoring of clinical and lifestyle parameters related to the major risk factors of the specific health condition of the older worker, guidance and engagement, and early prediction of potential risk of health status deterioration allow for improved self-management of health and positively impact on the Healthy Life Years (HLY) of older workers in SmartWork.

5.2 myWorkAbility Service

This is a service for continuous assessment of the psycho-physical capacity of the office worker, provision of flexible working practices, and provision of AI decision support to enhance their psycho-physical capacity by predicting short- and long-term changes in capabilities and abilities of the office worker and translating such changes into evolving work requirements. Fluctuating demands on flexibility and changing job requirements requires the employee to have a sustainable Work Ability, which can be defined as their capability to participate in present and future jobs while preserving good health and well-being as well as the necessary conditions for this to occur. This is not a personal characteristic, but rather the results of an interaction between the individual and their work. A good balance between the strain (physical and mental) caused in the job and the employee's working capacity is crucial to keep employees healthy and vital at work, thus it is important to detect signs of stagnation in functioning as early as possible. A match between person and work is the results of a wide range of interdependent factors. The employee brings in personality as well as emotions and motivations, where the job is a combination of specific tasks along with cultural aspects and development possibilities. Thus a good fit between an employee and his/her job is determined by the work context (work and task demands) as well as personal characteristics . The construction of the Work Ability model, the driving force behind the decision support offered to the office worker in SmartWork, must account for: (i) health, both physical and mental; (ii) competence, including knowledge and skills to perform the work tasks; (iii) motivation, involvement and values, taking into account the aspects of enjoying work, the willingness to perform, work satisfaction, job control, the sense of togetherness with the organization and colleagues, social support. Furthermore, contextual changes that are not always related to the work itself (e.g. family issues) will impact on the Work Ability and can be captured through emotional and stress factors. Monitoring the worker state and predicting potential changes in the Work Abilities, both on the short- and long-term, along with decision support tools and intervention procedures (e.g. cognitive training) provide the means to ensure sustainability of the Work Ability.

5.3 ubiWork Service

This is a service to support on-the-fly work flexibility through an ubiquitous computer work environment. Teleworking, as a form of flexible work provision, has demonstrated advantages in improved productivity and increased job satisfaction for the worker. Thus, its adoption rate is fast increasing worldwide, especially jobs that are computer-based. Cloud-based services are emerging to support collaborative work from remote locations (out of the office space), but do not consider potential accessibility needs of older workers (inclusion) and additional knowledge and skills are required from the users to use and setup the work environments. SmartWork exploits the GPII auto-personalization infrastructure to build inclusive, accessible-born interfaces for the office workers, which adapt to their current needs and preferences and are pervasive between devices, operating systems and technologies. Furthermore, the Install on Demand (IoD) infrastructure will be used to build the AnyWhere Delivery system for seamless transfer of work materials

and computer working environment setting (including on-need software install/uninstall) without any effort from the side of the office worker.

5.4 workCoach Service

A service for on-Demand training support and new skills acquisition to support the older worker prolong his/her functional work ability and increase technology acceptance. Individual differences in qualifications are highly important for professional employability and flexibility, and these differences increase with age. Older workers (compared to younger employees) are generally not up to date with, and rarely participate in or are excluded from, training. Yet, the difference within this cohort are extreme, even more so than among youngsters. This leads to ageing being connected with reduced professional flexibility without actually causing it. Especially in the case of office workers, the exclusion from training when combined with the avalanche of new technologies being used (e.g. communication tools, cloud data storage, IoT, collaboration tools, knowledge management systems, etc.) further increases the gap between the young and older generations. Ageing workers also face various limitations when it comes to training. First, there is the cultural belief that training pays off with younger people because the returns to learning accrue over a longer work life, which is no longer the case especially for any worker that uses a computer on a daily basis. Years ago, a college degree virtually guaranteed the holder a good job and a good income, but time have changed. As the velocity of business and technology change continues to accelerate, the value of a college degree has shifted: it only help new graduates enter the workforce, but it is no longer sufficient for long-term career success. Both, organizations and individuals need to embrace lifelong learning to remain relevant in virtually every field. Second, ageing people also face decreasing physical and mental abilities. The speed at which these abilities depreciate depends partly on constantly training them. Therefore, learning has various dimensions relevant to aged workers: (1) Transfer of explicit knowledge for up-to-date valuable knowledge; (2) Transfer of tacit knowledge for up-to-date valuable skills; (3) Physical exercise to maintain physical abilities; and (4) Mental exercise to maintain mental abilities. In the case of older workers, the latter two actually are matched to health and lifestyle interventions, to maintain overall functional and cognitive capacity of the older adult. Explicit and tacit knowledge have different transfer costs. Explicit knowledge is transferable through time and effort. Tacit knowledge has a much higher cost of transfer because it happens through experience, observation and apprenticeship. Explicit knowledge is often associated with knowledge transfer, while tacit knowledge has a large component of skills and practice.

5.5 digiTeam Service

The digiTeam Service allows for smart and flexible management of the workforce from the side of the employers (e.g. manager, supervisor) to increase efficiency and productivity of teams working on specific tasks, and to optimize training and knowledge management activities. In order to make it through the highly competitive and constantly shifting markets in all domains, businesses must also exploit novel ICT technologies to improve psycho-physical capacity of their teams, improve knowledge management, and collaboration and team work. Recognizing the importance of personal growth of the workers, along with correct identification of interdisciplinary skill requirements and training needs and sources for a team is not always straightforward. Managers and team supervisors need innovative tools to support their decision making based on an interdisciplinary perspective building on the personal abilities and capabilities of each individual in a team. For example, it is becoming more important for employees to increase their emotional intelligence (EQ) in order to be able to build rapport and solve problems as part of a team. Most mechanical engineers now need programming skills. Data scientists have extensive knowledge of mathematics but need good business analysis skills necessary to understand how to apply the insights gleaned from the math. Including ongoing learning in annual performance plans, expecting everyone to upgrade some skills periodically, and offering staff with new skills opportunities to utilize those skills, requires decision support tools to prioritize training based on constantly evolving work tasks needs.

5.6 iCare Service

This is a service for efficient continuous care management and health risk assessment of the people they care for. Active and healthy ageing of older office workers implies the continuous support for daily health care management from a team of formal/informal carers, especially when chronic diseases or other health issues are on-going. Although a very large number of services and applications have been implemented to allow carers monitor patient status and provide support (e.g. intervention plan) for the self-management of health conditions, they have been developed with focus on a specific disease, providing low-level information on very specific physiological and/or behavioural parameters. The iCare Service focuses on providing carers with a higher-level monitoring and information service, with high degree of flexibility in the selection of parameters to be visualized per patient. Structured higher-level information will be extracted by the AI decision support tools (status, alerts), and their visualization will be adaptable to the accessibility needs of each carer. Carers will also be able to modify/adapt the interventions to the current worker state, based on the AI predicted short- and long-term risks.

6 CONCLUSION

The worker-centric AI system being developed in the SmartWork project integrates a series of unobtrusive and ubiquitous ICT tools to build a suite of Novel Services to provide the means for work ability sustainability of the older office worker. Each service answer requirements imposed by one or more of the Work Functions that must be sustained or even enhanced for ageing at work. The proposed services also address the requirements of the employers, helping them to maintain/increase work efficiency and productivity of the employees through better management of the available resources in relation to the work tasks (e.g.optimized team formation, task optimization with respect to needed resources, prioritizing training needs, etc.).

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