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Exploring the Potentials of Wearable Devices in Research on Wellbeing and Stress in Workplaces

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ABSTRACT

Work-related wellbeing and stress are major research issues nowadays. Stress at work affects employee's mental and physical health and reduces productivity. Since the definitions of stress and wellbeing are various, different strategies to investigate the problem and promote solutions have been taken. This study was developed within the innovation ecosystem MUSA (Multilayered Urban Sustainability Action) in the challenge of Spoke 2, Big Data-Open Data in Life Sciences, which aims to create solutions for the collection, conservation, and process of big data to improve lifestyle, prevention, and treatment. The study is grounded on the requirement to meet the complexity of stress and wellbeing conditions, therefore integrating qualitative (EMA questionnaire diary) with quantitative (wearable device Fitbit) data. This article presents the preliminary studies with the principles and recommendations leading to the final design of the experiments included in the research.

Keywords: Work-related stress, Wellbeing, Monitoring system, Wearable devices, Interaction design, Design principles

INTRODUCTION

Work-related stress has emerged as a significant concern in contemporary society, affecting nearly one in three workers across Europe (Leka, 2010).

Stress at work impacts the mental and physical well-being of employees and leads to diminished productivity within companies. Work-related mental and physical wellbeing is important for individuals and organizations, impacting life quality, long and short-term health conditions, performances, commitment, availability, and creativity (WHO, 2022).

Research from different disciplines aims at identifying strategies to reduce strain and stressors, improve work organization and conditions, and favour wellbeing. The literature indicates a variety of situations and definitions associated with health, wellbeing, and stress, distinguishing hedonic from eudaimonic wellbeing, eustress from distress, i.e. positive and negative work engagement (Sonnentag, 2022). Several factors can potentially act as stressors and negatively affect health (Michie, 2002; Davis, 1989). After the COVID pandemic (EUA, 2024), the importance of researching for work wellbeing became even more cogent. The changes of the working processes and the pervasive use of digital tools also impact wellbeing (Juchnowicz, 2021; Tams, 2020).

The investigation of the work-related effects on wellbeing is an important research focus, asking for new approaches for collecting objective data to allow a deeper understanding of the correlation between stressors and stress. According to The Lancet, "work and employment are an underutilised lever to influence population health" (The Lancet, ed., 2023). A specific goal for Italy, is "*adapt monitoring of working conditions to the changing world of work, focusing on psychosocial risk factors. ii)Harmonise data on working conditions from records and registers for use in the national Information System for Prevention in the Workplace and expand the system's capture of psychosocial risk factors*" (Pega, 2023). Research for happiness at work is needed (Misra, 2023) for individual and common advantage.

This study was developed within the innovation ecosystem MUSA – Multilayered Urban Sustainability Action – project, funded by the European Union – NextGenerationEU, under the National Recovery and Resilience Plan (NRRP) Mission 4 Component 2 Investment Line 1.5: Strenghtening of research structures and creation of R&D "innovation ecosystems", set up of "territorial leaders in R&D". The Spoke 2 of the project, Big Data-Open Data in Life Sciences, aims at developing solutions to enable the collection, conservation, and processing of big data to improve lifestyle, prevention, and treatment. This document reports the preliminary study producing the strategies for conducting experimental investigations on the acceptability and efficacy of wearable devices in real office work environments. The experiments aim to collect and correlate objective physiological data with subjective experience during working hours. In doing so, it becomes crucial to find the right balance between gathering a sufficiently extensive dataset and avoiding imposing excessive burdens on the participants (Weale, 2023). The document includes a chapter dedicated to the complexity of defining and measuring wellbeing and stress; a part dedicated to the potential role of wearable devices in the experiments; design principles and strategic drivers for the research.

THE COMPLEXITY OF DEFINING STRESS AND WELLBEING

Wellbeing and stress have been studied for a long time, yet their relationship is still complex. A univocal definition of wellbeing is currently missing (Juchnowicz, 2021), and the same is true for wellbeing in the work context. Different approaches have been used for framing wellbeing: some define it by positive/negative outcomes (e.g. job satisfaction, work engagement, …) (Bordi, 2018); others distinguish from subject to objective dimensions (Bertoloni, 2016); and some consider its multidimensional structure composed by physical, psychological and social factors (Zani, 1999). Wellbeing and stress are two intertwined concepts, but the presence of one does not involve the absence of the other. According to the World Health Organization, "health is a state of complete physical, mental and social wellbeing and not merely the absence of disease or infirmity" (WHO, 1948). Shifting to the work context, one diffused conceptual model is the

J-DR by Demerouti et al. (Demerouti, 2001). According to the authors, work characteristics can be classified into two categories: demands (from the environment) and resources (owned by the individual). The equilibrium between demands and resources leads to *wellbeing*, while the disequilibrium is associated with *illbeing* (stress) (Bordi, 2018). Adding to this model a deepen interpretation, Lu et al. (Lu, 2021) distinguish between *sus-tress* (inadequate stress), *eustress* (good stress), and *distress* (bad stress). Eustress is marked by an increased pulse rate without any underlying feeling of threat or fear (Gedam, 2021). If one demand is perceived as a mild challenge, where resources are sufficient to deal with it, the body's response is positive, generating eustress. This means that stress is not always bad and strengthens the idea that wellbeing and stress are not two opposite concepts. Consistent with this approach, Abreu et al. (Abreu, 2002) consider stress as the "psychological and physical state that results when the resources of the individual are not enough to deal with the demands and pressures of the situation". This means that, since stress is a psychophysiological state, the integration of physical and psychological measures is crucial for the assessment of mental health. According to this idea, this article proposes an integrated approach based on EMA questionnaire and the use of the wearable device Fitbit. EMA, Environmental Momentary Assessment (Stone, 1994), is a research method for contextual measurement while reducing recall bias (Shiffman, 2008). Physiological data are collected through the Fitbit device to integrate the body's physical response into the framework.

WORK-RELATED STRESSORS

The identification of the job stressors is supported by theories and the scientific literature deploys a wide list of possible stressors in the work context. Here is a list of the three leading models to define stress:

- *J-DR model* by Demerouti et al. (Demerouti, 2001), mentioned above.
- *Effort-reward imbalance – ERI* model by Siegrist et al. (Siegrist, 1996). According to this theory, a job is a contract on what the worker gives (effort, time), and what he/she receives (money, esteem, career opportunities). When this relationship is imbalanced, distress might arise.
- *The transactional model* by Lazarus (1966) suggests that stress results from a dynamic interaction between the individual and the environment. The model starts from the same point as the J-DR model. Still, it adds, as an additional factor, the subjective perception of the worker about work demands and personal capabilities as well as the resources to deal with these demands. Since this perception can vary between individuals (Probst, 2010) and is influenced by personal traits, previous experience, and other factors, any aspect of the work environment can be perceived as a stressor.

Job stressors can be categorized from different perspectives. Thilagavathy and Geetha (Thilagavathy, 2021), distinguish individual, organisational, and social factors influencing wellbeing at work. The *Office Environment Model* (Bluyssen, 2011), identifies factors related to work context/physical environment; work context/social environment; worker health context.

Lukan et al. (Lukan, 2021) add a distinction between daily stressors and structural conditions. Lists of the main aspects influencing wellbeing at work have been reported by several authors (Misra, 2023; Susanto, 2022; Lilja, 2020; Tams, 2020; Bertoloni, 2016; Thilagavathy, 2021). The lists include job characteristics; Job satisfaction/content; job performance; meaningfulness of work; work variety; work role (e.g. role ambiguity, role conflict); effort-reward imbalance; work-life balance; engagement in work; relationship with others (colleague and supervisor) (e.g. social support); career opportunities/development; job control and autonomy/decision; physical environment; work-load. Finally, a relatively new factor generated has to be considered: the digitalisation of work. Digital tools make work more flexible while increasing autonomy (e.g., smart working). On the other hand, some relevant issues emerge, related to the possibility of being always connected and available, which blurs the line between work and private life (Bordi, 2018). The digitalisation of work is associated with a new term, technostress, a specific type of work stress that can cause anxiety, fatigue, skepticism, and inefficacy associated with the use of technology (Salanova, 2014).

CAN LOW-COST WEARABLE DEVICES BE EFFECTIVE IN RESEARCH ABOUT STRESS AND WELLBEING AT WORK?

Due to size/cost reduction and improved ease of use (Di Flumeri, 2019), the use of wearable devices to monitor and assess physiological and mental activity has recently spread (Haghi, 2017). Investigations on stress response often take place in laboratory settings where participants are exposed to standardized stressors. Conducting such experiments is costly and demanding for participants, limiting the feasibility of large-scale assessments (Pakhomov, 2020). On the other side, wearable devices can be easily used to record bio signals without interfering with participant activities (Giorgi, 2021), making it possible to operate long-term and real-life stress monitoring (Stojchevska, 2022). Compared to gold-standard equipment, consumer wearable devices showed similar accuracy in measuring different biomarkers in different conditions (Menghini, 2019). Studies that aim to identify stress commonly depend on physiological reactions of the sympathetic nervous system triggered by stress, such as alterations in Hearth Rate (HR), Hearth Rate Variability (HRV), Skin Temperature (SK), and Electrodermal Activity (EDA) (van Kraaij, 2020; Hickey, 2021). Integrating more of these parameters is preferable to obtaining valid results (Gedam, 2021). Among all the physiological parameters, HRV is the most studied one (Peake, 2018), as it is the most useful physiological metric for stress detection (Hernando, 2018; Hong, 2010; Rodrigues, 2018). Unfortunately, some devices on the market use average HR to monitor stress conditions, albeit this parameter is not as accurate as HRV. This is the case of Fitbit, an accessible fitness tracker used in different research to assess stress (Pakhomov, 2020; Chalmers, 2022). Although the authors of such studies proved that HR measurements obtained with Fitbit increase as expected in response to stressors, they were not able to determine the accuracy of the measure (Pakhomov, 2020) and failed to identify consistent HR patterns changes during stress (Chalmers, 2022). Giorgi and colleagues (2021) aimed to assess the reliability of two other wearable devices (i.e., Empatica E4) in detecting different mental states. Even if the result was positive, some consideration had to be given. The Empatica E4 is a high-level wearable device, and it is sold at a high price. This condition may represent a constraint, limiting its adoption to large-scale scientific research.

Two important factors have to be considered when designing a protocol to investigate mental health conditions using the wearable device: (1) to obtain a valid result, the physiological parameters must be measured for a long real-time period; (2) the signal recorded can be altered by contextual factors, such as posture, temperature, and physical activity (Wijsman, 2011). For example, physical exercise can increase HR and change ST, even if it is not correlated with stress triggers (Nelson, 2014). This is the case of Fitbit, when the participant remained stationary and could not differentiate between stress caused by physical activity or mental burden (Pakhomov, 2020). The use of wearable devices to detect stress conditions represents a major opportunity due to their low impact and accuracy compared to gold-standard equipment (Menghini, 2019). Some limitations still emerge when choosing which type of device, and the selection of the suitable device should accord with the following requirements:

- The acceptability of the technology, directly connected with the perceived usefulness and the perceived ease of use, as described in the Technology Acceptance Model (TAM) (Davis, 1989).
- The cost of the device, which can limit the scalability of the experiment to an extended cohort.
- The reliability of the device: different wearables monitor different parameters to assess stress; HRV vs HR are physiological measures with different effectiveness as indicator of stress.

Based on the literature analysis summarized in this document, the possibility of obtaining accurate stress measurement through low-cost wearable devices seems limited. Despite that, experiments to assess stress conditions employing low-cost devices are interesting because they support the assessment of methodologies that can be adopted in large cohort future experiments with more expensive devices (e.g. Fitbit for wristband-type devices). As technology advances, the costs are expected to decrease while keeping the quality of the data collected (Haleem, 2023), eliminating the trade-off between the reliability of the measures and the scalability of experiments.

AWARENESS AND BEHAVIOURAL CHANGE INDUCED BY SELF-MONITORING SYSTEMS

Experiments based on wearable devices collecting personal data can affect participants' behaviour and mental health self-awareness due to the self-monitoring effects. The potential of self-monitoring lies in the possibility of mirroring themselves (Varisco, 2019), making people more aware of personal habits. Using a device to monitor personal health conditions can help people to correlate physiological measures with subjective experience, thus promoting self-awareness and stimulating reflection (Chianella, 2021). Moreover, thanks to the collection of data framing past and current personal health states, individuals can identify and modify potentially unhealthy behaviours (Mercer, 2016). Indeed, in line with Oinas-Kukkonen, definition (Oinas, 2013), wearables can be described as "*socio-technical information systems with psychological and behavioral outcomes designed to form, alter or reinforce attitudes, behaviors or an act of complying without using coercion or deception*".

When considering behaviour change, both positive and negative outcomes should be considered. On the one hand, the possibility of setting goals, receiving motivational reminders, tracking progress, and obtaining contextualized user data can lead to positive behaviour change (Kang, 2022). Conversely, the constant surveillance imposed by the wearable can also bring negative outcomes, such as feelings of disempowerment.

The collection, processing, conservation, and sharing of personal data can impact individual and collective levels. Sharing personal data can change the image of people in the community where they live or work and it can, therefore, impact personal relationships and opportunities (Varisco, Pillan, 2019; Pillan, 2017) and the exercise of privacy rights. The acceptability of smartwatches for medical purposes has also been investigated. Al-Maroof et al. (Al-Maroof, 2021) point out the importance of the perceived usefulness and ease of use for the acceptability of these devices. Shandi et al. (Shandi, 2024) reported data on the dependability of the acceptance and adoption of these solutions on factors such as age, education, occupation, economic status, fitness levels, and health conditions.

PARTICIPATORY DESIGN FOR RESEARCH

Research on stress and wellbeing involving personal data in working environments is a complex task, calling for the accurate design of experiments with a focus on the fair involvement of people. The development of new approaches for research on health and wellbeing, allowing the collection of functional data on bio-parameters correlated to contextual events, requires suitable strategies addressed to the acceptability of the final users. In this scenario, the adoption of participated design methodologies and codesign are promising to cope with the delicacy of collecting and using personal data through wearable devices, as reported by some authors (Perego, 2022; Bajaj, 2023). Participatory design for health research can involve therapists, technicians, and final users of the solutions adopted in the investigations. It can concern factors such as the contents and goals of the experiments, the design of devices and applications, and the requirements for accessibility, usability, and security (Jones, 2020). This approach can be successfully adopted in the design of programs for eHealth and well-being (van Hierden, 2021) and in the reflection of the ethical principles in research involving different actors (Sleigh, 2022). The long tradition of user studies and participatory design in the Interaction Design discipline provides the theoretical background and expertise on prototyping and tests to create optimal participated design processes.

CONCLUSION

Wearable devices have great potential in research about stress and in collecting physiological measurements that may indicate unhealthy conditions. To effectively investigate wellbeing at work, the physiological data should be associated with the qualitative data on users' experiences. Wearable devices alone, in fact, could be ineffective in catching mental stress, that can instead be better investigated through the correlation of qualitative with quantitative data.

When selecting the type of device, the important factors to be considered are their acceptability and cost, and the type of data collected. These factors can influence the participation to the experiments, the scalability of the measurement, and the reliability of the data collected. Considering acceptability by the users, some elements may act as barriers to the adoption and prolonged use of the device: the motivational profile (degree of autonomy and motivation) (Friel, 2020), design aspects (Auerswald, 2020), technical issues (Coughlin, 2020) and privacy concerns. Regarding the latter, collecting and processing personal data may impact individuals' sense of self, the perception of personal status, perceptions of contexts, and behaviours. Envisioning a successful experiment, the solutions and the processes for the collection of quantitative and qualitative data should be designed according to ethical guidelines and principles. To this purpose, participated design methodologies and codesign strategies can represent an effective way to increase the acceptability and effectiveness of the whole process.

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