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Sebastiano Bagnara
Riccardo Tartaglia · Sara Albolino
Thomas Alexander · Yushi Fujita
Editors

Proceedings of the 20th Congress of the International Ergonomics Association (IEA 2018)

Volume VII: Ergonomics in Design, Design for All, Activity Theories for Work Analysis and Design, Affective Design

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Preface

The Triennial Congress of the International Ergonomics Association is where and when a large community of scientists and practitioners interested in the fields of ergonomics/human factors meet to exchange research results and good practices, discuss them, raise questions about the state and the future of the community, and about the context where the community lives: the planet. The ergonomics/human factors community is concerned not only about its own conditions and perspectives, but also with those of people at large and the place we all live, as Neville Moray (Tatcher et al. 2018) taught us in a memorable address at the IEA Congress in Toronto more than twenty years, in 1994.

The Proceedings of an IEA Congress describes, then, the actual state of the art of the field of ergonomics/human factors and its context every three years.

In Florence, where the XX IEA Congress is taking place, there have been more than sixteen hundred (1643) abstract proposals from eighty countries from all the five continents. The accepted proposal has been about one thousand (1010), roughly, half from Europe and half from the other continents, being Asia the most numerous, followed by South America, North America, Oceania, and Africa. This Proceedings is indeed a very detailed and complete state of the art of human factors/ergonomics research and practice in about every place in the world.

All the accepted contributions are collected in the Congress Proceedings, distributed in ten volumes along with the themes in which ergonomics/human factors field is traditionally articulated and IEA Technical Committees are named:

I. Healthcare Ergonomics (ISBN 978-3-319-96097-5).
II. Safety and Health and Slips, Trips and Falls (ISBN 978-3-319-96088-3).
III. Musculoskeletal Disorders (ISBN 978-3-319-96082-1).
IV. Organizational Design and Management (ODAM), Professional Affairs, Forensic (ISBN 978-3-319-96079-1).
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VI. Transport Ergonomics and Human Factors (TEHF), Aerospace Human Factors and Ergonomics (ISBN 978-3-319-96073-9).
VII. Ergonomics in Design, Design for All, Activity Theories for Work Analysis and Design, Affective Design (ISBN 978-3-319-96070-8).
VIII. Ergonomics and Human Factors in Manufacturing, Agriculture, Building and Construction, Sustainable Development and Mining (ISBN 978-3-319-96067-8).
IX. Aging, Gender and Work, Anthropometry, Ergonomics for Children and Educational Environments (ISBN 978-3-319-96064-7).
X. Auditory and Vocal Ergonomics, Visual Ergonomics, Psychophysiology in Ergonomics, Ergonomics in Advanced Imaging (ISBN 978-3-319-96058-6).

Altogether, the contributions make apparent the diversities in culture and in the socioeconomic conditions the authors belong to. The notion of well-being, which the reference value for ergonomics/human factors is not monolithic, instead varies along with the cultural and societal differences each contributor share. Diversity is a necessary condition for a fruitful discussion and exchange of experiences, not to say for creativity, which is the "theme" of the congress.

In an era of profound transformation, called either digital (Zisman & Kenney, 2018) or the second machine age (Bnynjolfsson & McAfee, 2014), when the very notions of work, fatigue, and well-being are changing in depth, ergonomics/human factors need to be creative in order to meet the new, ever-encountered challenges. Not every contribution in the ten volumes of the Proceedings explicitly faces the problem: the need for creativity to be able to confront the new challenges. However, even the more traditional, classical papers are influenced by the new conditions.

The reader of whichever volume enters an atmosphere where there are not many well-established certainties, but instead an abundance of doubts and open questions: again, the conditions for creativity and innovative solutions.

We hope that, notwithstanding the titles of the volumes that mimic the IEA Technical Committees, some of them created about half a century ago, the XX Triennial IEA Congress Proceedings may bring readers into an atmosphere where doubts are more common than certainties, challenge to answer ever-heard questions is continuously present, and creative solutions can be often encountered.

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Contents

Ergonomics in Design

Wearable Devices and Smart Garments for Stress Management

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Abstract. Wearables are the cutting edge of electronic devices; as they are miniaturized, people can directly wear them, generating a continuous interaction with computers. The implementation of wearables in everyday life is going to change completely human behaviours. These devices create human-computer interaction potentialities that can be addressed to several directions: taking care of people, leading people to a different behaviour model for changing social dynamics, turning these ubiquitous computers into a "collective wearable".

There is a global adoption of the preventive approach to health: it consists of measures taken for disease prevention, as opposed to disease treatment. There is also an increasing attention to security and to risk management in the sanitary field in terms of products, ergonomic communication and innovation of processes. Moreover, users demand to know their real wellness status, independently of the individual perception. It's necessary to inform users about the biofeedback recorded by wearable devices, but it is essential to effectively communicating them to caregivers or patients.

This paper, presenting some results of interaction design research for human wellbeing and healthcare, explores tangible interfaces focused on biomedical fields: it concerns security, stress management, collection of biofeedback for preventive healthcare and also emotional issues connected with the human-computer interaction.

Keywords: Interaction design · Smart garments · Wearable computers

1 Introduction

The demographic change and the progressively ageing population are generating new challenges for designing adaptive working and living environments for elders, impaired people or with chronical diseases. Because of this trend it is necessary to change the design perspective and to improve preventive interventions.

Medical Sciences had a *healing* approach to diseases. Nowadays there is a tendency to apply a different approach defined as *preventive*. The *preventive* approach is aimed to actuating strategies to reduce disease risks or to invert its degenerative process.

Likewise, at European and extra-European level, there is a growing attention to security and risk management issues in working and living environments, in terms of

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intrinsic quality of products, of ergonomics in design, communication and technology area and of process-system innovation.

In this context, the contribute of the research becomes essential to improve persons' awareness about their health status and their stress levels, by sensing and collecting their physiological parameter, beyond an unconscious or individual perception.

"The appreciation of being over-stressed often comes too late, when health problems already manifest themselves: people's ability to recall, recognize and understand their stress may be hampered by their life style, with multiple tasks and responsibilities encountered every-day" [1].

The Research contribution represents the basis to identify stress management solutions and to adopt best practices to reduce stress levels.

In addition to information about collected biofeedback, it is important to have an effective communication of measured data not only to the monitored person but also to all those which are involved, such as colleagues or relatives. The health and stress level self-awareness, both physical and mental, and the knowledge of strategies aimed at preventing any potential bad consequence in working contexts, are a primary need to enhance workers' security and a method to improve the working quality and to reduce any kind of risk in these contexts. Security and psycho-physical well-being in workplaces, both in terms of stress management and of effective immediate communication, are fundamental factors to disease prevention and risk or error reduction in working environments. This is a cross-cutting sector study, in which the risk evaluation and the definition of intervention strategies request a high interrelation between medical, managerial, sociological, psychological and design expertise.

The following research project is aimed to give contributions in this direction.

2 Methodological Approach

The research is based on the design and innovation methodologies of Human-Centred Design and Ergonomics in Design. These methodologies have been used to survey users' needs and expectations, within the design process and development of two different product-service systems for the stress management.

The first system is aimed to the achievement of realistic and verifiable benefits to identify longevity measures in workplaces, with a flexible and sustainable approach. The identified user group includes experts over 50, for whom are necessary strategies aimed to define a workplace which allows users to complete autonomously and safely the required tasks.

The second system is aimed to stress management through digital wearable solutions, in working and recreational environments, in which the devices can allow to keep a wellness condition for experts in healthcare and clinical risk area, autonomously and independently from external devices such as computers, tablets or docking stations.

In this context of use, which is the healthcare area, the product usability and security, the quality of the provided information and the satisfaction of users' needs are essential factors to prevent errors and reduce risks, both for doctors and for healthcare professionals and patients.

For both projects, the biofeedback acquisition through electrode and textile sensors has been tested. The usability and safety testing methods were based on collecting data about how the human-product interaction is performed within the investigated context of use: they allowed to identify and analyse users' behaviour, needs, the error incidence and the different kinds of error that users' can make during execution of required tasks. The collected data have been used both to define the products brief and to evaluate the prototypes. The user trials methods are:

- *direct observation* of users' activities;
- *interviews* aimed to understanding decisional process;
- *task analysis* based on the breakdown and analysis of required tasks;
- *time line analysis* aimed to analyse the task sequences and the methods with which the tasks are executed;
- *layout analysis* used for evaluating the graphic interfaces; it was based on four criteria: functional classification, contents relevance, sequence of use, frequency of use.

The *User trials* conducted throughout the whole design process, allowed us to define users' needs and expectations, in terms of efficacy, efficiency and satisfaction related to the usability of the devices.

The emotional aspects of User Experience during the interaction with the product, such as the *pleasure in use*, that is the measurement of the sensorial quality satisfaction, were also considered.

With a users' sample of different gender and age, were conducted trials on the signal validation of the acquired biofeedback and the correct correspondence between inputs and feedbacks transmitted by devices to users.

The aim was to validate the correspondence between the signals collected by textile sensors and those collected by standard devices, such as Biopac.

Among scientific literature, there are no standard guidelines concerning the procedure for measuring the skin conductance. So, the trials were improved and adjusted, during their own development: the procedure was changed according to the different microcontrollers and electronics used; it also required variations concerning the breathing-stimulus lasting and the relaxing period.

During the prototyping phase, the 'stimulation by picture' method was; it showed that signals were correctly acquired, both by standard electrodes and by textile electrodes. The pictures used (pictures of people, animals, objects, nature, events and so on), were chosen among those recommended by the International Affective Picture System (IAPS) [2].

The IAPS was developed by University of Florida to provide a sequence of emotional stimuli which can be used in emotion and attention experimentations; the system aims to develop a wide range of standard pictures to evoke emotions and that are universally accessible, which includes coloured photographs concerning several semantic fields.

Emotional state changes were produced by viewing standard images from the IAPS [3]. Each picture used in the system has been extensively tested and rated for valence (its subjective impact ranging from extremely negative to extremely positive) and arousal [4].

The IAPS setting-up assumes that emotions can be defined by a coincidence of values on a number of different strategic dimensions. Factor analyses indicated that the variance in emotional assessments are accounted for by three major dimensions:

- affective valence (ranging from pleasant to unpleasant);
- arousal (ranging from calm to excited);
- dominance or control [4].

2.1 Wearable Devices for Healthy Ageing in Working Place

Digital solutions can support people to stay healthy and active, both in their professional and in their private live, as long as possible.

The strategies for a preventive approach could be: (i) adopting ICT into working and living environments, to make the contexts more fitting to user' needs and more adaptive to the elderly; (ii) designing devices for monitoring and improving the life quality and the health status.

Wearable computers and smart garments actually represent the new age of electronic devices; they are compact, miniaturized and they produce a constant user-computer interaction. The adoption of wearable technologies in everyday life is changing people's behaviour.

The possibility to make users able to interact with living contexts and other people at any time and everywhere, lead to new opportunities which catalyse a new research field: the persuasive technology. Persuasive technology focuses on the formalization of project and is aimed to design digital products able to change attitudes or behaviours of the users.

The possibilities of the interaction between people and ubiquitous and pervasive computing systems, that the wearable devices offer, can be addressed forward several directions: helping and assisting people, nudging users to adopt new behaviours, changing social dynamics, until the possibility to turn wearable systems into a "collective wearable", a globally extended super-system of interactive digital assistants [7].

In the coming years, our everyday life will be appreciably influenced by smart products and many of them will be wearable devices, including e-textiles and smart garments. The current trend of wearable computing consists in directly integrating technology into garments without adding further components in close contact with the body: computing systems are embedded into garments or accessories, such as clothes, shirts, eyeglasses, wristbands and watches.

Clothing, shoes, eyeglasses, wristbands and watches are becoming smarter, embedding seamlessly computing resources and increasingly powerful communication technologies, and our interaction with these devices is becoming more intuitive [5, 6, 8].

Wearable technologies have huge potentialities to increase human skills and the production of smart garments and textiles is going to open new opportunities for the design. Designers' vision can highly push forward new technological progresses and turn them into several categories of emerging products, giving singular points of view both in problem solving and in problem setting. It has been evaluated that the growth of wearables, in terms of market value, is increasing. It will be essential to focus attention on aesthetics, functionalities and, most of all, on the 'good looking technology' linked to the 'context awareness' [5, 6].

3 Results

The research conducted by the team of University of Florence consist on the design of two different digital product-service systems. The products aim to point out and forecast working stress conditions, in relation to the tasks to carry out and the context in which they are achieved. Those allow an easy stress measurement and improve the awareness of users themselves, and of the workers and companies with whom they interact.

Data collection allows to immediately activate security measures, aimed to solve detected problems which, if ignored, could have heavy consequences for workers themselves or lead to human error with bad impacts on third persons.

Design proposal are based on a transdisciplinary research, which involves sociological, psychological, medical and design disciplines.

3.1 S.A.M. (Scan – Alter Ego – Monitoring)

S.A.M. (Scan – Alter Ego – Monitoring) is a wearable device for improving stress management. It is placed in the wellness achievement and health preservation context, according to the WHO definition of "wellness": "Wellness is the optimal state of health of individuals and groups. It is a state of complete physical, mental, and social well-being, and not merely the absence of disease or infirmity. Wellness is a conscious, self-directed and evolving process of achieving full potential" [9].

S.A.M. represents a combination between medical devices, smart bands and wearable technologies. It was developed starting from the GSR (Galvanic Skin Response) biofeedback collection – also defined as Electrodermal Activity (EDA) [10], which has many areas of applicability. The acquiring of GSR signals allows to verify a physiological reaction of the body to stressful events or external inputs [11]. S.A.M. provides light and sensorial feedbacks in real time. Light signals (LED based) and tactile signals (buzz-motor based) enable users to know how high it is their body stress level.

Moreover, the device help relaxing with the body natural response to rhythm: according to autogenic training theories, the device can support people to prevent heavy consequences of stress, improving people's health status and supporting an active aging in working and living environments.

Due the possibility to acquire the GSR signal only by specific areas of the non-dominant hand and wrist, the design solution fell on a modular system of product.

S.A.M. was designed as a system of interchangeable products: a smart band, a double ring and a smart necklace. Users can choose three different positions according to the function they want to use: the necklace detects specific physical parameters; but by rotating and wearing S.A.M. as a smart band, other biofeedback can be acquired; the device can also be worn as a double ring, which has magnetic conductors and additional functions (Fig. 1).

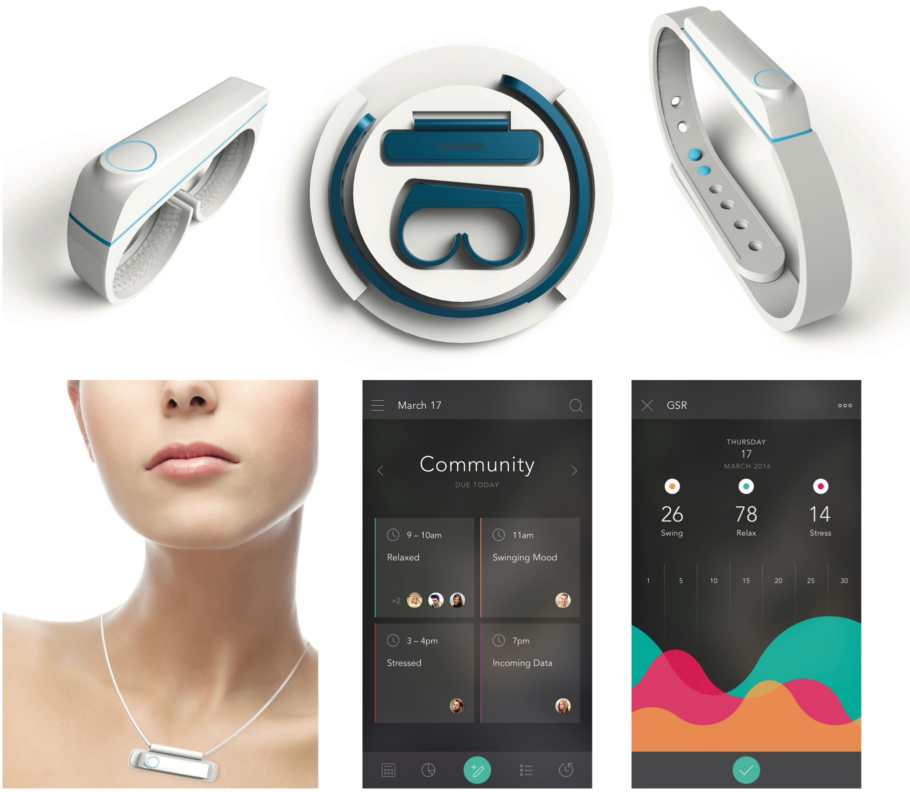

Fig. 1. S.A.M. (Scan – Alter Ego – Monitoring): wearable device for improving stress management. Design by Claudia Becchimanzi, and Mattia Paoli. The system includes a mobile application to register and share GSR data with users' network.

The device includes microelectronics, textile electrodes and sensors produced, by Smartex[1]. Thanks to textile sensors, S.A.M. can be flexible and adaptable for a wide range of users: its use is easy and intuitive for people of every age, social and cultural background. Its development has scientific relevance in the field of design, specifically in the area of design for health, of medical and clinical risk prevention in working environments.

Electronics. At the first stage of data collection they've been used custom-built board and non-textile sensors. At the second stage of data collection, aimed to a rapid prototyping of the device, they've been used textile sensors and Arduino compatible boards.

[1] Smartex is a SME and its core business is the research and development in the field of wearable solution for comfortable monitoring, integration of electronics solution and devices with textile, used both as support and sensor.

Acquired data post-production has been made by Matlab software environment for computing and graphics, which allows to manipulate matrixes, visualize data functions and implement algorithms. During the experimentations for the device development they've been used two different electronic configurations. At a first step, electronics have been custom-built by Adatec[2], which developed the Physio system, specifically designed to collect physiological data. Physio is made up of four modules: ECG (interbeat interval, motor activity level), BRE (breathing rate, motor activity level), EDR (electrodermal activity, motor activity level), HUB USB (battery recharge, download of acquired data).

For S.A.M. tests they've only been used EDR module and its related software for signal visualization.

Design requirements have been defined by these tests: (i) to have a custom-built miniaturized board, dedicated to computing the GSR signal; (ii) the possibility to have a flexible microcontroller; (iii) to see in real time the acquired data; (iv) to validate the acquired signal by textile sensors; (v) to allow the microcontroller to communicate with light actuators; (vi) to customize the data management and system feedbacks.

The protocol at the first stage consisted in short-term tests, aimed to define guidelines for signal behaviour. During the prototyping phase they've been used textile sensors and Arduino compatible boards to satisfy the above mentioned six requirements.

The GSR acquisition was actuated by the development of a circuit, including textile sensors, to collect data by distal phalanges of index and middle finger of the non-dominant hand.

Small sizes of the GSR module and microcontroller make them suitable for a wearable device prototyping. The light feedback is generated by a Led: it lights up red in stressful status, green in average-stress status, blue in relax status. The rhythm feedback is generated by the Grove module – Vibrator Motor. It senses the stress and supports the achievement of relaxation levels through relaxing rhythm.

The device functioning was tested by several experimental trials. Every test session was represented by graphics which allowed to view the EDR signal tendency. Moreover, Processing software allowed to see in real time the signal tendency, during the testing sessions. Before testing the acquisition of the GSR signal, it has been necessary to set a specific protocol, based on different stimuli experimentations and on different kinds of electrodes (RedDot and textiles) and electronics.

Tests and experimentations were conducted at Smartex, on a wide range of individuals from both genders and without diseases. Tests have shown a direct relation between individuals' breath and the GSR growth. The protocol consisted of deep inspirations at regular intervals as stimuli. The GSR signal had the same behaviour in every test: during the inspiration it rapidly reaches the peak (phasic component) and transmits high values. During the absence of stimuli, GSR values takes twice the time to stabilise and return to the initial balance (tonic level).

[2] Adatec is a spin-off the University of Pisa, which does research and development on the field of electronic engineering, informatics and biomedical devices.

GSR signal has been acquired by distal phalanges of index and middle finger of the non-dominant hand. Additional tests consisted in acquiring the GSR signal both by the wrist and by the single distal phalange of the index finger and the two outer points of the palm of non-dominant hand. Tests have shown that GSR signal is optimally acquired by distal phalanges of index and middle finger of the non-dominant hand.

During the last test, it has been used the following electronics: Grove module-GSR Sensor, Pro Trinket 3V, Smartex textile electrodes.

3.2 Smart Garments for Aged People at Work

The main aim of this research concerns design and development of a system of smart uniform for healthcare professionals, independent from external devices, non-invasive and able to provide adaptive feedback for the individual response, in relation to users' needs and to the tasks they have to accomplish.

The research is grounded in the context of stress at work, which "has become a serious problem affecting many people of different professions, life situations, and age groups. The workplace has changed dramatically due to globalization of the economy, use of new information and communications technologies, growing diversity in the work- place, and increased mental workload. In the 2000 European Working Conditions Survey (EWCS) [12], work-related stress was found to be the second most common work-related health problem across the EU. 62% of Americans say work has a significant impact on stress levels. 54% of employees are concerned about health problems caused by stress. One in four employees has taken a mental health day off from work to cope with stress (APA Survey 2004)" [13].

Security and psycho-physical wellness of healthcare professionals and doctors, in terms of stress management and effective and efficiency communication of the detected health status, are essential factors for prevention and reduction of clinical risks and human error, which can have serious consequences both for workers and for patients.

This is a cross-cutting sector study, in which the risk evaluation and the definition of intervention strategies request a high interrelation between medical, managerial, sociological, psychological and design expertise.

In this context, the design of a system of smart uniform for healthcare professionals and doctors, in terms of smart garments and smart wearable devices, aimed to acquire several biofeedback, to manage stress level and to communicate the results in real time.

At the same time, it is planned a study concerning the design of a product-service system, which can support the interaction between uniforms, and between uniform, healthcare professionals and patients, according to Internet of Things parameters.

The uniforms aim to manage stress, to communicate individuals' health status, to have an active role in preventing user's stress-related disease. It is important their improvement in terms of technology, visual communication, materials and support for risk situations or high stressful workplaces. The system is able to give users feedback about their physiological needs and stress levels, but it also provides a clear communication when high risk situations occur, supporting an effective stress management and improving an appropriate concentration.

The technological background concerning the wearable system and data collection is constantly evolving and enhancing, providing several solutions for this research project. In particular, the biofeedback required for the stress recognition are the Galvanic Skin Response (GSR), the Heart Rate Frequency (HRF) and the Respiratory Rate.

The general aim of the research concerns the achievement and support of a higher quality of life and wellness for workers, more specifically for older workers, in comparison to their current status, so that they can stay active, independent and involved in working context as long as possible or they can come back to work, after diseases.

The descripted system will improve comfort, security, accessibility, functionality, safety and health on working and living environments for older persons or people with chronic diseases, to prevent other ageing and stress-related illness.

The wearable system will be appositely designed for sensing data about users and the context in which they operate. It aims to nudge persons towards a better quality of their work, also according with the best practices suggested by WHO [9], with general suggestions and individual feedbacks about safe working rhythms, physical activity, right posture and personalized tips that can improve their working life quality.

Research results will provide a scientific methodological and innovative analysis for the transdisciplinary approach concerning individuals' health status evaluation and an efficacy stress management in healthcare areas.

At this time, in our knowledge, there are no systems which allow to guarantee the highest autonomy of usage, security and the better adaption to the users' real needs.

The research impact concerns companies which main core is the production and distribution of high-technological innovative products, companies in the healthcare sector and law enforcement agencies in the security at workplaces area, such as the Department of Health and the European Union (EU). The general aim is to guarantee a support for stress management, also in terms of communication of the health status, in order to prevent any stress-related risks.

4 Discussion and Conclusion

The research results can have relevance in design area and in the healthcare sector, both for large and for small or medium enterprises. This research is specifically addressed to older workers (over 50), for which it is essential to improve the working conditions in order to prevent stress related diseases or security related risks. For companies the aim is to involve older people in the working places as long as possible. In fact, older workers represent an added value in terms of know-how and experience. Another fundamental point concerns the importance of active ageing in workplaces, to improve older workers' skills: mental growth, strategic thinking, judgment, perspicacity, rationalization, holistic perception and language skills are strengthened over the years.

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DICHIARANO

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Nonostante ciò, il paragrafo *1. Introduction* è da attribuirsi a Francesca Tosi; i paragrafi *2. Methodological Approach, 3.2 Smart Garments for Aged People at Work*, *4. Discussion and Conclusion* sono da attribuirsi ad Alessandra Rinaldi; il paragrafo *3.1 S.A.M. (Scan – Alter Ego – Monitoring)* è da attribuirsi a Claudia Becchimanzi.

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