P/REFERENCES OF DESIGN

# E-TEXTILES IN THE FUTURE OF WELL-BEING AND CARE OF ELDERLY.

**Paula Veske-Lepp*[a], Kristi Kuusk[b], Helen Kool[c], Merje Beilmann[a], Ada Traumann[a]**

a Institute of Engineering and Circular Economy, TTK University of Applied Sciences, Estonia
b Sensorial Design Group, Estonian Academy of Arts, Estonia
c Institute of Service Economy, TTK University of Applied Sciences, Estonia
* paula.veske-lepp@tktk.ee

**DOI: 10.63442/UVSZ3856**

**KEYWORDS | HUMAN-COMPUTER INTERACTION (HCI), SMART TEXTILES, ELDERLY CARE, SOCIAL CARE CHALLENGES**

**ABSTRACT |** In Europe, the ageing population demands innovative solutions to enhance elderly well-being. In the European Union, long-term care services are most often needed by elderly people with health problems. Smart textiles, including electronic textiles (e-textiles), offer holistic care solutions, monitoring vital signs, providing real-time feedback, and supporting cognitive abilities. This paper explores e-textiles' role in addressing elderly care challenges, including physical health, and cognitive performance. The aim is to map the available technology, research, and products already on the market. The challenges, such as privacy concerns, costs, and end-user acceptance, are also discussed. The paper outlines the potential of e-textiles to create innovative solutions for elderly care, and the potential impact of these solutions on society.

# 1. Introduction

Innovative solutions are increasingly needed to enhance the well-being of elderly populations as communities in Europe age. Elderly people with health problems make up the largest part of those in need of long-term care services (Eurostat, 2020). For example, by 2050, it is predicted that almost 30% of the population in the European Union (EU) will be older than 65 (Eurostat, 2020). In 2020 around 75% of people aged 85 years or more had a long-standing illness or health problem that needed constant monitoring (Eurostat, 2020). More specifically, approximately a quarter of people aged 65 and older in Estonia will be aged 65 by 2030 and 30% by 2060, a significant leap from the 19% recorded in 2016 (Republic of Estonia - Ministry of Social Affairs, 2020). Estonia is a small country with several strong e-services and systems, demonstrating that technology can be seamlessly integrated into daily life. Despite its technology-driven environment, continuous care options supported by technology remain conspicuously absent, yet Estonia's small size can make it an ideal testbed. European care strategy states how the provision of long-term care services (home care, community-based care, and care in residential facilities) should be increased together with adopting quality criteria and standards for long-term care services and supervising their implementation (European Commission, 2022, 2023). In care institutions, elderly care presents a complex landscape of challenges that requires tailored and responsive solutions. Addressing the diverse needs of seniors, electronic textiles (e-textiles) can provide a holistic solution by combining sensory feedback with physical and mental care without losing bodily comfort.

E-textiles are made interactive by incorporating electronics, such as sensors, actuators and soft conductive materials in the textile structure (Hertenberger et al., 2014). Items with e-textiles can provide personalized real-time feedback, for example, support in monitoring vital signs, such as the respiration rate (Guay et al., 2017). Changes in physiological parameters can also be correlated with emotional states. Smart textiles embedded with biometric sensors can measure physiological signals associated with emotions, such as appeasement blanket (SENIORACTU, 2019; STUDIO TWINS PARIS, 2024), heart rate variability (HRV) (Amitrano et al., 2020), skin conductance (Healey, 2011), and temperature (Komolafe et al., 2019) similarly to a smart-watch or a smart ring (Ōura Health Oy, 2024). By detecting changes in residents' emotional states, smart textiles act as empathetic companions. They can improve the mental and emotional well-being of seniors who are isolated or are experiencing cognitive decline. For example, Jiang et al. (2021) developed a smart shawl to visualize physiological data and help regulate emotions. E-textiles can also be highly supportive of communication through tactile and haptic feedback (Schelle et al., 2015). Those solutions can improve the quality of elderly care services, as the care institutions are often short-staffed.

Many e-textile products are available on the market (Levi's et al., 2017; Sensoria, 2022; WearableX, 2022), however, several challenges need addressing to integrate e-textiles into elderly care, particularly in care institutions. To this day, it is customary for innovation and new technologies to reach social care with considerable delay. Many technological solutions that are completely commonplace in the private sector are still little known in the social sector (Republic of Estonia - Ministry of Social Affairs, 2020). The awareness and ability of social workers of different generations to use technical solutions varies greatly, and results in difficulties in introducing innovative solutions in the social sector.

E-textiles offer significant advantages over traditional wearables in healthcare settings, including improved comfort, continuous monitoring, customization, and integration with clothing without limiting movement or adding rigidness, ultimately leading to better patient outcomes and experiences. Thus, this paper explores how e-textiles might be shaping the future of well-being in elderly care, focusing on solutions designed for individual use, and nursing care in hospitals and care institutions. The paper examines the possible role of e-textiles in the well-being and comfort of elderly care in addressing: (1) challenges in physical health together with rehabilitation possibilities; and (2) support of mental and emotional health. The main goal of the work is to analyze current technologies and solutions together with the under-investigated aspects, such as producibility, privacy concerns, high cost, maintenance complexity, and market acceptance. The authors will discuss each of these aspects in the article and demonstrate their importance.

Literature was sourced through Google Scholar (including IEEE Xplore; PubMed; ScienceDirect; ACM Digital Library), Web of Science, and general Google searches (including the European Commission website), encompassing global products. Inclusion criteria emphasized English-language works focusing on technology-supported care, including prototypes, products, services, or studies targeting elderly or long-term care. Exclusions comprised studies not centred on elder well-being or continuous care.

## 2. Results

This section presents the results driven by the conducted analysis. The authors divided the projects into two umbrella topics: physical and cognitive health support for the elderly with e-textiles.
Figure 1 shows the overview of the division of the result. The physical health topics covered vital signs and movement monitoring, rehabilitation, and safety applications. Providing support for cognitive performance monitoring, assessment, and stimulus as well as emotional well-being was the focus of the cognitive health topics.

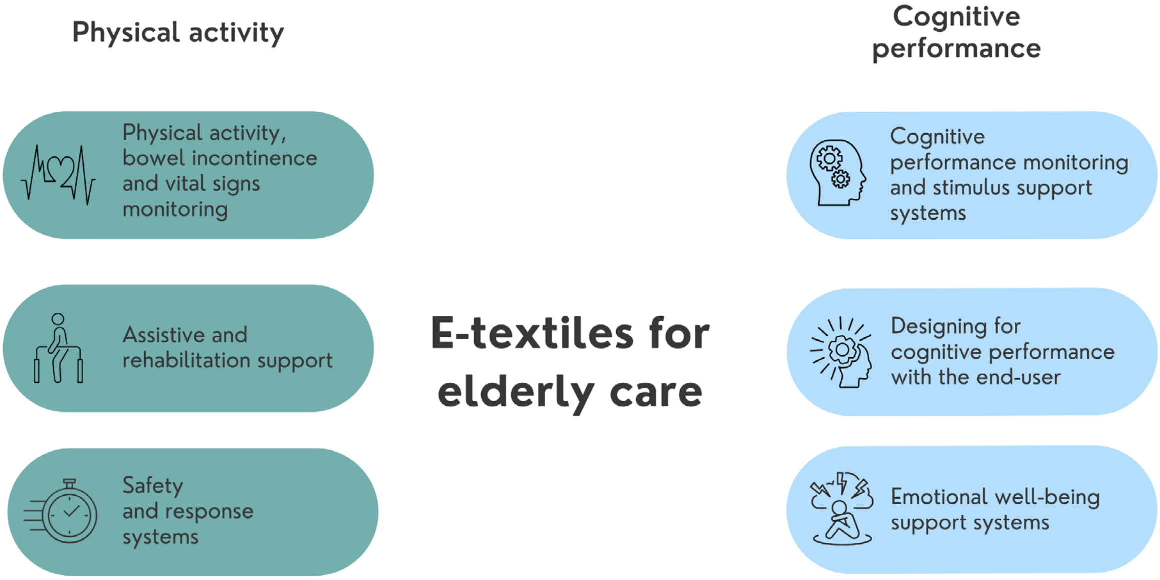


Figure 1. Overview of the results division which consists of two larger topics: Physical activity and Cognitive performance. Physical activity topics are divided into 3 areas: Physical activity, bowel incontinence and vital signs monitoring; Assistive and rehabilitation support; Safety and response systems. Cognitive performance topics are divided into 3 areas: Cognitive performance monitoring and stimulus support systems; Designing for cognitive performance with the end-user (subtopic of previous); Emotional well-being support systems.

### 1.1 Physical Health with E-Textiles

E-textiles can support comfortable continuous or short-term monitoring of elderly populations with minimal bulkiness and interference with the user's everyday life (Boehm et al., 2016). People's lives can be minimally impacted while supporting healthy ageing and healthcare.

**Physical Activity, Bowel Incontinence and Vital Signs Monitoring**

Health professionals and caregivers can use movement and vital sign monitoring to assess and manage the health and well-being of their patients. Chronic conditions can be managed more effectively and with lower loss of independence by using continuous vital sign monitoring. Regular monitoring helps healthcare professionals assess the effectiveness of medications and interventions. As a result, individual care plans can be developed more reliably and with fewer resources involved, such as staff involvement, patients' time, etc.

In care institutions, incontinence monitoring is often essential but time-consuming. There are several smart bed systems to monitor incontinence and movement from the bed (Health Quality Ontario, 2018). Fischer et al. (2019) described the development of a sensor mat for detecting urinary incontinence and bed occupancy that can be placed under the bed sheet. Martínez-Estrada et al. (2020), developed a wearable textile system to detect urine leakage. However, these studies were lacking end-user studies, thus, constructive feedback about the comfort and usability of the textile materials.

Electrodermal Activity (EDA) and Galvanic Skin Response (GSR) have emerged as valuable indicators of emotional stress and arousal levels (Healey, 2011; Poh et al., 2010). Electrodermal Activity (EDA) and Galvanic Skin Response (GSR) serve as vital indicators of emotional stress and autonomic nervous system activity, offering insights into overall health and physiological responses. Fluctuations in EDA and GSR patterns may signal changes in sympathetic nervous system activity, potentially indicating pain, discomfort, or medical conditions like urinary incontinence. By integrating these sensors into wearable devices, remote patient monitoring and proactive healthcare management become feasible. Healthcare providers can access collected data remotely, enabling trend tracking, pattern identification, and personalized interventions.

The use of textile electrodes for acquiring biomedical signals to monitor personal and vital functions long-term is one of the most researched e-textile applications (Kubicek et al., 2022). There are several methods of applying, processing and making applications to utilize them. Nigusse et al. (2021) reviewed textile electrodes for the monitoring of ECGs from fundamentals to advancements. In this work, we have emphasized the ones that have been researched for long-term use, more specifically for healthcare and the elderly.

For example, a textronics shirt can show the health status of the monitored person on a mobile device, together with the current date and time of their movements indoors (IPS - Indoor Positioning Systems) and outdoors (GPS - Global Positioning System) (Frydrysiak et al., 2016; Rambausek, 2014). This type of system can support monitoring physical activity and movement in general. However, no end-user tests were described in the reviewed papers. Moreover, using e-textiles with a multi-channel mechanocardiogram (MCG), a wearable system was developed to predict the left ventricular ejection fraction (LVEF) function and provide early warnings about cardiac risk (Lin et al., 2018). Lin et al. (2018) showed an e-textile-based health monitoring system consisting of sensing components, a control platform for the care institution, and a mobile device. The prototype collects electrocardiography signals and monitors heart rates. A fast empirical mode decomposition algorithm was integrated with a hidden Markov model-based algorithm for fall detection for electrocardiography denoising. Wang et al. (2017) and Esfahani (2021) give a comprehensive overview of similar developments and technologies, including body temperature measurements, blood pressure and pulse.

Hexoskin has several products on the market for precise and continuous cardiac, respiratory, and activity monitoring (Hexoskin, 2024). Emglare and Sensoria offer several similar products but only for sports applications (Emglare Inc, 2024; Sensoria, 2022). Sensoria also has Sensoria® Mat to support wheelchair-related in-seat movement and pressure (Sensoria Health, 2024).  In general, while the technology seems readily available, it has not reached the elderly care community (Jordan et al., 2023). This lack of access can be attributed to several factors, such as limited financial resources, lack of digital literacy, and lack of government support.

### Assistive and Rehabilitation Support

Clothing with embedded electronics can motivate movement and offer location-based real-time simulation feedback for rehabilitation. For example, Vigour "a knitted cardigan with integrated stretch sensors monitors the movements of the upper body to give tailored feedback to the patient's movement exercises in real-time utilizing sound" (Ten Bhömer et al., 2013a; Ten Bhömer et al., 2014). Ten Bhömer et al. (2013a) introduced Vibe-ing - a vibration therapy garment that invites the body to feel, move, and heal using electronic circuits in knitted pockets. The prototype with embedded electronics motivated movement and offered location-based stimulation for rehabilitation. However, no end-user study was introduced. Raad et al. (2019) presented a smart glove for rheumatoid arthritis rehabilitation support. Remotely analyzing a patient's finger flexions while performing various home activities can make an otherwise labour-intensive process more efficient. Yves Béhar's studio, in collaboration with robotics company Superflex, took a step further with The Aura Powered Clothing collection (Morby, 2017). They designed clothes for the ageing population to hold a higher level of physical strength through a series of motors embedded in hexagonal pods. Sensors were placed on the torso, hips, legs, and back. In each "pod," artificial intelligence reacts to the body's natural movements and adds muscle power to help the wearer get up, sit down, or remain upright. The robotics partner Superflex is now a company Seismic which produces similar products but is branded as workwear (Seismic ©, 2022).

Vibroacoustic therapy in e-textiles (blankets, vests etc) can improve well-being and support physical and mental health. In rehabilitation and physical health aspects, vibroacoustic therapy with low-frequency pure sound is found beneficial for muscle tension, chronic pain, insomnia, anxiety and many other mental and physical disorders (Ernst, 2022). However, it is also important to be careful with the vibroacoustic hazards and keep in mind the intensity and frequencies used (Koradecka, 2010).

Phototherapy uses light to treat certain medical conditions. It is most commonly used to treat skin abnormalities, but it can also help with pain management, depression, and anxiety (Seidel et al., 2021). Low-Level Laser Therapy (LLLT) and Ultraviolet light therapy (UV) are commonly used examples of light therapy. Biological response in tissue can be induced by UV therapy by using the electromagnetic wavelength between X-rays and visible light, as opposed to LLLT, which uses a low-powered laser light (Seidel et al., 2021). For example, a conformable blue light therapy device was demonstrated by Jablonski et al. (2014). Shen (2013) and Quandt et al. (2017) demonstrated how luminous polymer optical fibre (POF) fabrics can be used for phototherapy.

Physiotherapy requires a lot of one-on-one time from the therapists. K. Yang et al. (2018) developed a sleeve with electrodes to do seamless muscle stimulation on the upper limb for stroke patients to achieve functional tasks, like hand opening. Liu et al. (2023) described an e-textile-based functional electrical stimulation system for post-stroke upper limb rehabilitation with a small end/user test group. The authors concluded that the fabric electrode offered similar stimulation compared to commercial hydrogel electrodes' performance with the advantage of being suitable for wearable applications and having a long service life.

Moreover, Grimm et al. (2016) described how wearable sensors can benefit the elderly as clinometric tools by counting specific events, such as stairs, or analyzing qualitative parameters, such as step frequency. The article also highlighted that popular consumer activity monitors, such as Fitbit, did not provide the accuracy needed, especially for elderly or disabled patients. Error rates for hip and wrist sensors were more than 60% for both.

### Safety and Response Systems

Safety and response systems are essential components of elderly care. However, these systems often lack context-based sensors. Thus, they need activation to work, or have not been developed with user comfort in mind, e.g. materials are not breathable (Medi.ee, 2024; RehabMart.com LLC, 2023, 2024a, 2024b). Movement monitoring technology is evolving rapidly. For example, different IoT (Internet of Things) technologies are available to help monitor remotely and support caregivers - either monitoring the movement with set-up sensors in the room or wearable technology (Ianzito, 2020; Stack Labs, 2023). However, it is still often rejected by the end user due to not trusting the technology or uncomfortable wear (Sung et al., 2022; Tan et al., 2022).

Movement monitoring for safety reasons can have many aspects, like monitoring for wandering or fall (risk) detection. For example, the BalanceBelt is an assistive device that uses haptic feedback to help patients with severe balance disorders overcome their problems and regain their independence (Elitac Wearables, 2024). Using vibrational feedback, the belt detects the direction the wearer is leaning in and alerts them. Moreover, there are several use cases for movement monitoring with e-textiles (Edmison et al., 2004; Elo et al., 2022; Li et al., 2020; Veske et al., 2022). Yu et al. (2020) presented an integrated carpet for self-powered fall detection, using textile-triboelectric nanogenerators (t-TENGs). While the prototype showed excellent first results, there were no end-user tests mentioned.

Furthermore, fall detection is an essential component of elderly care. Similarly to BalanceBelt, (Rahemtulla et al., 2023) investigated near-fall with e-textile socks. The work focused on identifying near-falls, such as tumbles, and more specifically, distinguishing them from falls. USA-based company Palarum offers socks “developed by nurses for nurses to prevent patient falls” (PUP® socks) (Palarum, 2024). Ning et al. (2021) showcased technology for wearable hip-protection airbags to protect the elderly during the fall. One example from the market is TangoBelt (Tango Technologies®, 2022; Tarbert et al., 2021). The belt is equipped with an IMU (inertial measurement unit) that detects falls through an algorithm and deploys an airbag before the user touches the ground. With several examples, Buffagni (2019) gives an extensive overview of this type of research.

Movement monitoring for wandering can be essential in private and care institutions for the elderly due to dementia. While the market offers many remote tracking devices for homes, it can be difficult in care institutions (Just Checking, 2024). Constant supervision requires high staffing numbers. To have quality care with minimal invasion of independence, e-textiles can provide alternative support systems. Fong et al. (2018) proposed how smart clothing can be used in nursing care. The work showed how an emergency can be managed with location tracking by computing the relative position of residents from wireless access points. Sung et al. (2022) made a study with a smart vest that was worn by dementia patients in nursing care. The vest had sensors integrated into them and communicated with movement detectors in the room. However, the authors highlighted that patients were reluctant to wear the vest which is an important note for the product developers.

## 1.2 Cognitive Performance with E-Textiles

Cognitive assistance technologies, including both textile and non-textile solutions, are being studied alongside passive materials like regular textiles. These innovations aim to offer reminders for medication, appointments, and daily tasks, providing support for seniors facing memory-related challenges (Jiang et al., 2021; Oatley et al., 2021). It is possible to send these reminders through voice, text, or even haptic feedback. As a result, seniors can stay organized and on track with their daily activities, improving their overall quality of life (Motti, 2019).

### Cognitive Performance Monitoring and Stimulus Support Systems

Cognitive performance can be assessed and improved through gamification or playful methods. One concept study aimed to both entertain and monitor together with an assessment of the behaviour of people with dementia or its precursor of Mild Cognitive Impairment (MCI) (Oatley et al., 2021). The study used light-emitting diodes (LEDs) and capacitive touch sensors woven into a fabric to augment the traditional activity apron by incorporating light and sound effects as feedback when people interact with different regions of the textile.

Communication can be or feel inhibited by the elderly due to different diseases, loneliness, staying in long-term care institutions or other factors (Comiotto et al., 2016). Vihriälä et al. (2023) highlight the term “complex communication needs”. It refers to natural communication methods, such as speech, writing, and gestures, being inadequate to fulfil the person's functional communication needs. Tactile Dialogues are designed to stimulate movement and communication for patients in the late stages of dementia, their family members, and their caregivers (Schelle et al., 2015; Ten Bhömer, 2016, 2022). Through using vibrotactile stimulus patterns and haptic sensations, the developed pillow encourages patients to move and develop conversations in a more alternative yet bodily manner. The project was evaluated in different sessions together with the end-users. Family members were given space and inspiration to encourage their loved ones with dementia to talk and move more through the prototype. The activity also served as a conversation starter.

A smart shawl developed by Jiang et al. (2021) visualized physiological data and regulates emotions. Based on the wearer's emotional arousal, the prototype captured emotion data using the EDA (electrodermal activity) sensor. Then the emotional state was visualized through light and vibration. Morrison et al. (2018) presented vibrotactile vests that interacted with a vibroacoustic wall in an urban space. This wall was designed to exchange vibrational and physiological information with the wearable vest. In pairs, people interacted with a friend, family member, social friend, romantic partner, or colleague. In two areas of the wall, participants heard and felt their heartbeat and breath rate while performing actions on the wall (such as knocking and swiping). The work reported that in response to the patterns, the participants reported feeling peaceful, therapeutic, and good.

The “Joy, Peace, Grace and Life” project developed a sensory wall (Tan et al., 2022). The polymeric optical fibre fabric was woven with different motifs, and touch-sensitive e-textile embellishments were created using conductive yarn through knitting, embroidery, and other textile constructions. To provide different textures, conductive yarn was combined with textural yarns, feathers, and sequins. Different stakeholders evaluated the prototype: 13 people with early-stage dementia, 9 caregivers, 4 family members, 6 social workers, 1 occupational therapist and the care institution director. Overall, the reception was good, but the authors highlighted that better customization would benefit the prototype.

### Designing for Cognitive Performance with the End-User

Literature for elderly care with e-textiles showcased studies that focused on co-designing with caregivers and the elderly. Loss of communication skills can be one of the most significant and detrimental psycho-social characteristics and can have a dehumanizing effect thus creating psychological and emotional distress (Gowans et al., 2007).

Nevay et al. (2015) describe workshops in which older adults living in care institutions designed their own wearables. Design activities focused on craft enabled residents and designers to have new conversations and gain a deeper understanding of residents' real-life experiences, ideas, and skills. Furthermore, Elo et al. (2022) highlighted how diverse studies are focusing on individual applications of assistive e-textiles, few involve a diverse range of stakeholders in the design process. Therefore, the authors organized five multidisciplinary ideation workshops with 50 participants from different backgrounds and roles to gain stakeholder-oriented knowledge on the development of assistive e-textiles. Yang et al. (2022) conducted qualitative research and co-creation workshops to bring together older adults and a multidisciplinary team to develop smart assistive technology solutions. For example, they aimed to identify the critical factors affecting technology acceptability among older adults and how the products should look and feel to be accepted.

Mann et al. (2017) showcased a positive design method involving caregivers in the process of producing customized solutions that are meaningful and helpful. Authors came up with several prototypes, such as a Memory Game to tackle cognitive decline where LEDs were used to interact. Another example is from Jakob et al. (2017), where interdisciplinary research on “Multi-Sensory Environments” for elderly care started by identifying the challenges in the healthcare system and then using a user-centred design approach. The authors also highlighted how textiles have several benefits, such as “creating a warm, comfortable and calm atmosphere reducing negative sensory stimuli such as glares and noise”. Also, members of the general public were invited to participate in Hand i Pocket “funshops” to create sensory textile pockets for those with late-stage dementia (Cardiff Metropolitan University - CARIAD - LAUGH, 2017). The workshops created awareness around dementia and allowed the caregivers and family members to share knowledge and experiences and lose stigma around the topic.

### Emotional Well-Being Support Systems

Emotional well-being is essential for any age. However, elderly people can feel loneliness more due to moving to care institutions, lack of everyday contact with loved ones, and other factors. This can cause feelings of isolation and depression, leading to a decrease in quality of life. Different e-textile solutions can support well-being providing comfort, warmth, and a sense of security due to their nice tactile feel.

Treadaway et al. (2015) showcased with several small prototypes that interactive textiles have assisted patients with late-stage dementia in communication and connection with others. Moreover, the results showed they have provided a means of relaxation and distraction and stimulated interest in general (Treadaway & Kenning, 2015). Moreover, Kristin Neidlinger from the Sensoree designed several wearables prototypes to monitor physiological states and translate feelings into auditory, visual, and or tactile displays. Ger Mood Sweater, for example, uses an illuminated collar to read emotion and show excitement levels instantly (Sensoree, 2013). Furthermore, the FleXo prototype acts as a remote physiotherapist by detecting mood and adjusting inflatable acupressure points based on biosensors (Sensoree, 2018).

Multisensory blanket from Maase utilizes non-heat generating LED lights and plush materials to induce a calming effect to aid those dealing with anxiety, autism and sensory processing disorders (SENIORACTU, 2019; STUDIO TWINS PARIS, 2024). The soft glow from the LED lights promotes relaxation, and the plush texture of the blanket provides a soothing tactile experience. Multisensory blankets have the flexibility to integrate various textures and colours, engaging different senses such as touch and sight. This active stimulation can help revive forgotten memories from earlier years by triggering sensory associations and connections. Beyond memory enhancement, these blankets contribute to the overall well-being and safety of elderly individuals. Another study presented a reactive undershirt with embedded textile-based pneumatic actuators that deliver tactile stimulation in response to a change in emotional state to calm anxiety (Goncu-Berk et al., 2020). The prototype has not been validated by end-users yet but such testing is planned (Goncu-Berk et al., 2020; Goncu-Berk et al., 2021).

## 1.3 Overview

Table 1 shows an overview of tested prototypes and products highlighted in the text. The table overview excluded pure research and proofs-of-concept because they were too far away from the user.

Table 1. Overview of tested prototypes and products highlighted in text.

| Category | Sub-category | Solution | Materials | Author | Goal |
|---|---|---|---|---|---|
| Physical | Assistive/ Rehabilitation | Vigour | Stretch sensors are made of conductive yarn, electronics, and wool. | (Ten Bhömer et al., 2013b; Ten Bhömer & Van Dongen, 2014) | Measure movement of the arms and lower back, thus, improving the rehabilitation service by keeping the exercises challenging |
| Physical | Assistive/ Rehabilitation | Smart glove for rheumatoid arthritis | Flex sensor and BLE Nano. | (Raad et al., 2019) | Assist physiotherapists in remotely analysing patients' finger flexions when performing diverse activities at home |

| Category | Sub-category | Solution | Materials | Author | Goal |
|---|---|---|---|---|---|
| Physical | Assistive/ Rehabilitation | Seismic suits | IMUs, sensors, CPU (central processing unit). Materials described: lightweight, breathable | (Seismic ©, 2022) | Reduce muscle strain and fatigue by providing your core with extra power and stability. |
| Physical | Assistive/ Rehabilitation | Electrode sleeve | IMUs, conductive wires, non/woven fabric with carbon material layers. | (K. Yang et al., 2018) | Training system for stroke rehabilitation |
| Physical | Physical activity | Balance-Belt | Vibration motors, accelerometer. | (Elitac Wearables, 2024; Kingma et al., 2019) | Correction of body position and improving balance based on haptic feedback. |
| Physical | Physical activity | MCG shirt | Accelerometers. | (Lin et al., 2018) | Predict the left ventricular ejection fraction (LVEF) function and provide early warnings about cardiac risk |
| Physical | Physical activity | Hexoskin | ECG & Respiratory sensors and a precise Activity sensor. Textile: 73% Polyamide Micro/27% Elastane. | (Hexoskin, 2024) | Monitoring continuous cardiac, respiratory, and activity |
| Physical | Physical activity | Sensoria® Mat | Four pressure sensors, Bluetooth-enabled box with electronics. | (Sensoria Health, 2024) | Wheelchair cushion to remind to do pressure relief activities; tracks and monitors the quality of each repetition. |
| Physical | Safety | Near-fall socks | Microcontroller, IMU, "e-yarns" braided with polyester yarns, knitted sock using Stretchline and Nylon yarns | (Rahemtulla, 2023) | Senses near-fall situations and sends alerts. |

| Category | Sub-category | Solution | Materials | Author | Goal |
|---|---|---|---|---|---|
| Physical | Safety | Palarum - fall prevention socks | Electroconductive fibre with pressure sensors on the bottom | (Palarum, 2024) | Senses fall and send alerts. |
| Physical | Safety | TangoBelt | IMU, airbags. | (Tango Technologies®, 2022) | Protects the users during a fall by using airbags on hips. |
| Physical | Safety | Smart vest for dementia patients | Movement sensors. | (Sung et al., 2022) | Tracks movements and sends alerts when needed. |
| Cognitive | Emotional well-being | Smart sock | Fabric electrodes, electronics. | (Healey, 2011) | Psycho-physiological monitoring system and a wearable sensing unit for emotional reactions |
| Cognitive | Emotional well-being | Maase | LEDs, speakers. | (STUDIO TWINS PARIS, 2024) | Create a calming effect through music and sound. |
| Cognitive | Emotional well-being | Different textile artefacts | Electronics, sensors, LEDs. | (Treadaway et al., 2016) | Assisting patients with late-stage dementia in communication and connection with others. |
| Cognitive | Performance and/or assistance | E-motion-Wear prototype | LEDs, vibration motors, conductive wires, electronics jersey fabric | (Jiang et al., 2021) | Emotional data sensing and visualization through light and vibration. |
| Cognitive | Performance and/or assistance | Smart textile apron prototype | Electronics, sensors, LEDs. | (Oatley et al., 2021) | Gamification of cognitive tests. |
| Cognitive | Performance and/or assistance | Tactile Dialogues | Vibration motors, conductive yarn, electronics, cotton. | (Schelle et al., 2015; Ten Bhömer, 2022) | Stimulate movement and communication for patients in the late stages of dementia, their family members, and their caregivers. |
| Cognitive | Performance and/or assistance | Vibrotactile Wearable Vest and Wall | Vest: 32 vibration actuators, The Zephyr BioHarness 3. | (Morrison et al., 2018) | Wall and vest were to exchange vibrational and physiological information together with people using them. |

| Category | Sub-category | Solution | Materials | Author | Goal |
|---|---|---|---|---|---|
| Cognitive | Performance and/or assistance | Sensory wall | Polymeric optical fibre, conductive yarn. | (Tan et al., 2022) | Support sensory activities to increase social engagement for people with dementia. |

## 3. Discussion

Wearable devices like smartwatches and rings have gained widespread popularity, especially among people keen on monitoring and enhancing their health, sleep, and overall well-being. However, criticisms have been raised regarding their suitability for elderly care, citing issues such as forgetfulness to wear them, discomfort with prolonged use, and difficulty in wearing them (Sung et al., 2022). Despite these drawbacks, they offer durability, reliability, and easy maintenance. On the other hand, e-textile-based clothing shows promise for addressing these concerns, offering comfortable materials and seamless integration of technology. It allows for the collection of movement and other relevant data for personalized care, blending seamlessly into everyday clothing and providing a comfortable touch to the body. However, challenges remain in terms of cleaning and longevity.

This work examined available or researched solutions designed for elderly care for individual use, and nursing care in hospitals and care institutions. The focus was the challenges in physical health together with rehabilitation possibilities and the support of mental and emotional health. The found works are now analyzed based on different aspects, such as end-users (elderly and caregivers) validation, producibility and cost, privacy concerns, materials information, sustainability, and standardization.

However, despite the potential benefits of e-textile-based items, the end-user validations appeared to be lacking. Thus, to make use of the potential benefits of e-textile-based care, there is a critical need for end-user validation and further research and development (Bryson, 2015; Yang et al., 2019). Moreover, research shows that fear of innovation can be a significant barrier to change in social care (Bryson, 2015; Nevay & Lim, 2015; Nevay et al., 2017). Social scientists are essential to such studies and should be part of the future development of e-textile applications for care and their evaluation. Incorporating e-textile technology into care institutions may present integration challenges. Innovative technologies might not always be welcomed, and optimizing the benefits of these tools requires ongoing education. In addition to being comfortable, easy-to-use, and aesthetically pleasing, e-textiles should also support people with varied vision, hearing, physical, and cognitive abilities. Authors believe that as the younger generation enters the field, it may alleviate barriers to integrating new technologies and drive innovation in elderly care. This also prompts reflection on the attractiveness of the caregiving profession, necessitating upgrades to compensation packages and fostering a culture of learning.

Launching new digital solutions can be a significant source of stress for caregivers and other employees, leading to burnout or resistance to work if there is insufficient leadership and support. Thus, caring for caregivers is essential, as evidenced by initiatives like MVO Caring workwear (by-wire.net, 2014), which addresses issues such as posture and air quality to support nurses in their demanding roles. Research by Han et al. (2022) highlights the significant impact of assistive smart textiles in reducing caregiver anxiety, further emphasizing the potential of e-textiles in enhancing the overall well-being of both seniors and those who care for them. To reduce stress during the transition period to technology, the authors emphasize that caregivers must be fully informed of these changes.

The absence of standardized regulations poses challenges in ensuring the quality and safety of e-textiles in elderly care. Social workers, dedicated to the well-being of their clients and communities, may fear unintended consequences or ethical dilemmas that could arise from implementing innovative technologies. Furthermore, gathering sensitive health data through wearable technology raises privacy and ethical concerns (European Union, 2016a). Authors highlight that striking a balance between safety monitoring and respecting residents' privacy and personal autonomy is essential (European Union, 2016b). Monitoring a vulnerable person requires special attention - if the person can understand their situation, intervention is always based on personal informed consent. Ethical rules are essential and may vary based on the culture, country, and end-user. Furthermore, any type of data collection, analysis and exchange between products is considered confidential data. This can include product sizes, medical data, frequency of use, etc. Additionally, e-textiles require regular maintenance and software upgrades. Ensuring a sustainable, long-term strategy for maintenance and keeping the technology up to date is essential for continued success. They might work better in a service system rather than standalone products. All these aspects were not addressed in the reviewed work and need very strong future developments.

As a result of the regulations and the need for medical documentation, the subject of cost needs to be discussed. E-textile solutions are expensive to implement. Ensuring accessibility for all residents, regardless of financial means, is a challenge that needs to be addressed for widespread adoption. Thus, different smart solutions are often late in the social field and that is caused by several factors (Yang et al., 2019). Social work and related fields are often very distant and unfamiliar to technology developers. Research finds that the market does not seem appealing, because there are often few financial resources and there is no formulated client - often the user and the owner are different (respectively, for example, elderly service user and local municipality). For instance, currently, the social sector and technology-based entrepreneurship in Estonia are still practically separate. Universal terminology, compatible systems, and consensus on data protection and ethical issues are seriously lacking. Any inaccuracies or malfunctions could lead to incorrect health assessments compromise the safety of residents and hinder future technological support system integrations. Materials used must prioritize durability, antibacterial properties, and comfort, including tactile feel and breathability, to maximize user acceptance and adherence. Interestingly, acceptance of such solutions may be higher among individuals accustomed to wearing technology, suggesting the importance of designing for future elderly populations who grew up with digital advancements. Most studies and products in this work did not expand on the textile materials. However, this might be one of the main arguments in user acceptance and, thus, would need to be a part of future developments.

Moreover, our contributions to the world today must meet sustainability regulations and consider beyond human needs to have a positive effect. From the screened literature, only a few highlighted the topic. As an example, Elo et al. (2022) found that sustainability was not a topic raised by different stakeholders in elderly and healthcare workshops. However, Van der Velden et al. (2015) discuss the importance of material selection in developing e-textiles.

## 4. Conclusions

As the elderly population in Europe is ageing, innovating solutions for care is essential to their well-being, especially for those with long-term health issues. This article provided an overview of how personalized real-time feedback can be provided by e-textiles to address both physical (activity, incontinence, and vital signs monitoring) and mental (cognitive performance and emotional well-being) care needs. This interdisciplinary approach not only benefits the elderly but also shares similarities with designing for individuals with various cognitive abilities (Kuusk et al., 2019) and children (Kubinyi et al., 2021), as demonstrated in educational initiatives. E-textiles promote independence and health in the elderly by utilizing close-to-body technology. Overall, e-textiles can provide feedback to healthcare professionals, allowing them to give continuous support and tailor different rehabilitation programs to each patient's individual needs. This can help to reduce healthcare costs, and accessibility and improve patient outcomes together with early intervention or even prevention.

There are still challenges in using e-textiles in elderly care settings. External factors play a key role – such as the priorities in the society related to a particular problem and the political, economic, and cultural context. Overcoming these challenges requires addressing issues, such as awareness amongst social workers, producibility, privacy concerns, cost, complexity of maintenance, and end-user acceptance. Despite this, the potential of e-textiles to improve elderly care, particularly when it comes to addressing physical and emotional challenges, demonstrates the need for continued research and development. To have a system that is supported by the social system, these products and practices must be developed closely with the end-users (caregivers and the elderly) to be fully implemented later. Estonia, as a small, technology-driven country can serve as a testbed where e-textiles as part of the care system could be implemented via its lively start-up scene.

## References

Amitrano, F., Coccia, A., Ricciardi, C., Donisi, L., Cesarelli, G., Capodaglio, E. M., & D'Addio, G. (2020). Design and validation of an e-textile-based wearable sock for remote gait and postural assessment. *Sensors*, *20*(22). https://doi.org/10.3390/s20226691

Boehm, A., Yu, X., Neu, W., Leonhardt, S., & Teichmann, D. (2016). A novel 12-lead ECG T-shirt with active electrodes. *Electronics, 5(*4), 75. https://doi.org/10.3390/electronics5040075

Bryson, D. (2015). 5 - The adoption and non-adoption of new technologies by the active ageing. In J. McCann & D. Bryson (Eds.), T*extile-led design for the active ageing population* (pp. 47–58). Sawston: Woodhead Publishing. https://doi.org/10.1016/B978-0-85709-538-1.00005-5

Buffagni, A. (2019). Designing smart clothing for fall prevention in older adults. A brief overview on the current status. Paper presented at the *Design Tech 2019: International Conference on Design and Technology: Conference Proceedings*.

by-wire.net. (2014). MVO sustainable and supportive garments for nurses. Retrieved July 22, 2024, from https://www.by-wire.net/sustainable-and-supportive-garments-for-nurses/

Cardiff Metropolitan University - CARIAD - LAUGH. (2017). Hand i Pockets. Retrieved July 22, 2024, from https://www.laughproject.info/home-2/sensory-textiles/hand-i-pockets/

Comiotto, G. S., Kappaun, S., & Cesa, C. C. (2016). The knowledge of healthcare professionals about augmentative and alternative communication in the long term care institutions for the elderly. *Revista CEFAC, 18*, 1161-1168. https://doi.org/10.1590/1982-0216201618522215

Edmison, J., Jones, M., Lockhart, T., & Martin, T. (2004). An e-textile system for motion analysis. *Stud Health Technol Inform, 108*, 292-301.

Elitac Wearables. (2024). BalanceBelt. Retrieved July 22, 2024, from https://elitacwearables.com/projects/balancebelt/

Elo, C., Rauhala, E. L., Ihalainen, T., Buruk, O., Vihriälä, T., Sipilä, E., ... & Virkki, J. (2022). E-textiles assisting healthcare, rehabilitation, and well-being - To whom, for what, and how? Paper presented at the *2022 IEEE 10th International Conference on Serious Games and Applications for Health* (SeGAH). https://doi.org/10.1109/SEGAH54908.2022.9978598

Emglare Inc. (2024). EmGlare. Retrieved July 22, 2024, from https://emglare.com/

Ernst, E. (2022). Physical therapies alternative medicine: A critical assessment of 202 modalities. New York: Springer. https://doi.org/10.1007/978-3-031-10710-8

Esfahani, M. I. M. (2021). Chapter 6 - Smart textiles in healthcare: A summary of history, types, applications, challenges, and future trends. In A. Ehrmann, T. A. Nguyen, & P. Nguyen Tri (Eds.), *Nanosensors and nanodevices for smart multifunctional textiles* (pp. 93-107). Amsterdam: Elsevier. https://doi.org/10.1016/B978-0-12-820777-2.00006-6

European Commission. (2022). A European care strategy for caregivers and care receivers. Retrieved July 22, 2024, from https://ec.europa.eu/social/main.jsp?langId=en&catId=89&furtherNews=yes&newsId=10382#navItem-relatedDocuments

European Commission. (2023). Demographic change in Europe. Retrieved July 22, 2024, from https://ec.europa.eu/commission/presscorner/detail/en/ip_23_4807

Eurostat. (2020). *Ageing Europe — Looking at the lives of older people in the EU* (2020 Edition ed.). Luxembourg: Eurostat.

Fischer, M., Renzler, M., & Ussmueller, T. (2019). Development of a Smart Bed Insert for Detection of Incontinence and Occupation in Elder Care. *IEEE Access, 7*, 118498-118508. https://doi.org/10.1109/ACCESS.2019.2931041

Fong, A. C. M., Fong, B., & Hong, G. (2018). Short-Range Tracking Using Smart Clothing Sensors: A case study of using low power wireless sensors for patients tracking in a nursing home setting. Paper presented at the *2018 IEEE 3rd International Conference on Communication and Information Systems (ICCIS)*. https://doi.org/10.1109/ICOMIS.2018.8645003

Frydrysiak, M., & Tesiorowski, L. (2016). Health monitoring system for protecting elderly people. Paper presented at the *2016 International Multidisciplinary Conference on Computer and Energy Science (SpliTech)*. https://doi.org/10.1109/SpliTech.2016.7555935

General data protection regulation (GDPR), (2016a).

Goncu-Berk, G., Halsted, T., Zhang, R., & Pan, T. (2020). Therapeutic Touch: Reactive Clothing for Anxiety. Paper presented at the *Proceedings of the 14th EAI International Conference on Pervasive Computing Technologies for Healthcare*. https://doi.org/10.1145/3421937.3421962

Goncu-Berk, G., Zhang, R., & Yilmaz, C. (2021). CalmWear: A Smart Tactile Sensory Stimulation Clothing. Paper presented at the *Proceedings of the 2021 ACM International Symposium on Wearable Computers*. https://doi.org/10.1145/3460421.3478829

Gowans, G., Dye, R., Alm, N., Vaughan, P., Astell, A., & Ellis, M. (2007). Designing the Interface Between Dementia Patients, Caregivers And Computer-Based Intervention. *The Design Journal, 10*(1), 12-23. https://doi.org/10.2752/146069207789318018

Grimm, B., & Bolink, S. (2016). Evaluating physical function and activity in the elderly patient using wearable motion sensors. *EFORT Open Reviews, 1*(5), 112-120. https://doi.org/10.1302/2058-5241.1.160022

Guay, P., Gorgutsa, S., LaRochelle, S., & Messaddeq, Y. (2017). Wearable Contactless Respiration Sensor Based on Multi-Material Fibers Integrated into Textile. *Sensors, 17*(5), 1050. https://doi.org/10.3390/s17051050

Han, C., Lei, S., Ruoan, R., Han, X., & Yanbing, L. (2022). Research and Design of Smart Care-Giving Clothing for Disabled Elderly. *Fibres & Textiles in Eastern Europe, 30*(4), 21-31. https://doi.org/10.2478/ftee-2022-0034

Healey, J. (2011). GSR Sock: A New e-Textile Sensor Prototype. Paper presented at the *2011 15th Annual International Symposium on Wearable Computers*. https://doi.org/10.1109/ISWC.2011.36

Health Quality Ontario. (2018). *Electronic monitoring systems to assess urinary incontinence: A health technology assessment*. *Ontario Health Technology Assessment Series*, *18*(3), 1-60.

Hertenberger, A., Scholz, B., Contrechoc, B., Stewart, B., Kurbak, E., Perner-Wilson, H., … Nachtigall, T. R. (2014). 2013 e-textile swatchbook exchange: The importance of sharing physical work. In *Proceedings of the 2014 ACM International Symposium on Wearable Computers: Adjunct Program* (pp. 1-4). Seattle, Washington. https://doi.org/10.1145/2641248.2641276

Hexoskin. (2024). *Hexoskin - Health sensors & AI*. Retrieved July 22, 2024, from https://hexoskin.com/

Ianzito, C. (2020). *Remote monitoring systems can give caregivers peace of mind*. Retrieved July 22, 2024, from https://www.aarp.org/caregiving/home-care/info-2020/ces-caregiving-products.html

Jablonski, M., Bossuyt, F., Vanfleteren, J., Vervust, T., & De Smet, H. (2014). Conformable, low level light therapy platform. In *Biophotonics: Photonic Solutions for Better Health Care IV*. https://doi.org/10.1117/12.2054390

Jakob, A., & Collier, L. (2017). Sensory design for dementia care–the benefits of textiles. *Journal of Textile Design Research and Practice*, *5*(2), 232-250. https://doi.org/10.1080/20511787.2018.1449078

Jiang, M., Nanjappan, V., ten Bhömer, M., & Liang, H.-N. (2021). On the use of movement-based interaction with smart textiles for emotion regulation. *Sensors*, *21*(3). https://doi.org/10.3390/s21030990

Jordan, K., Vos-Draper, T., Morrow, M., & Sonenblum, S. (2023). The usability of two mobile health assistive technologies for wheelchair-related in-seat movement and pressure. *Journal of Rehabilitation and Assistive Technologies Engineering*, *10*. https://doi.org/10.1177/20556683231211808

Just Checking. (2024). *Just Checking*. Retrieved July 22, 2024, from https://justchecking.co.uk/family/dementia/

Kingma, H., Felipe, L., Gerards, M.-C., Gerits, P., Guinand, N., Perez-Fornos, A., … van de Berg, R. (2019). Vibrotactile feedback improves balance and mobility in patients with severe bilateral vestibular loss. *Journal of Neurology*, *266*(1), 19-26. https://doi.org/10.1007/s00415-018-9133-z

Komolafe, A., Torah, R., Nunes-Matos, H., Tudor, M., & Beeby, S. (2019). Integration of temperature sensors in fabrics. In *2019 IEEE International Conference on Flexible and Printable Sensors and Systems (FLEPS)*. https://doi.org/10.1109/FLEPS.2019.8792294

Koradecka, D. (2010). *Handbook of occupational safety and health*. CRC Press. https://doi.org/10.1201/EBK1439806845

Kubicek, J., Fiedorova, K., Vilimek, D., Cerny, M., Penhaker, M., Janura, M., & Rosicky, J. (2022). Recent trends, construction, and applications of smart textiles and clothing for monitoring of health activity: A comprehensive multidisciplinary review. *IEEE Reviews in Biomedical Engineering*, *15*, 36-60. https://doi.org/10.1109/RBME.2020.3043623

Kubinyi, E. L., Naydenova, V., & Kuusk, K. (2021). Children and design students practicing playful co-creation in a youth creativity lab. *Research in Arts and Education*, *2021*(1), 102-131. https://doi.org/10.54916/rae.119320

Kuusk, K., & Nimkulrat, N. (2019). Mediating (nonverbal) communication between persons with different cognitive abilities using interactive artifacts. In *Cumulus conference proceedings Rovaniemi*.

Levi's, & Google. (2017). *Levi's Commuter Jacket with Jacquard by Google*. Retrieved July 22, 2024, from https://atap.google.com/jacquard/about/

Li, M., Torah, R., Nunes-Matos, H., Wei, Y., Beeby, S., Tudor, J., & Yang, K. (2020). Integration and testing of a three-axis accelerometer in a woven e-textile sleeve for wearable movement monitoring. *Sensors*, *20*(18), 5033. https://doi.org/10.3390/s20185033

Lin, W.-Y., Ke, H.-L., Chou, W.-C., Chang, P.-C., Tsai, T.-H., & Lee, M.-Y. (2018). Realization and technology acceptance test of a wearable cardiac health monitoring and early warning system with multi-channel MCGs and ECG. *Sensors, 18*(10), Article 3538. https://doi.org/10.3390/s18103538

Liu, M., Ward, T., Keim, O., Yin, Y., Taylor, P., Tudor, J., & Yang, K. (2023). Design and test of e-textiles for stroke rehabilitation. *Engineering Proceedings, 30*(1), Article 16. https://doi.org/10.3390/engproc2023030016

Mann, G., & Oatley, G. (2017). Positive design of smart interactive fabric artifacts for people with dementia. In *2017 IEEE 5th International Conference on Serious Games and Applications for Health (SeGAH)*. https://doi.org/10.1109/SeGAH.2017.7939257

Martínez-Estrada, M., Fernández-García, R., & Gil, I. (2020). A wearable system to detect urine leakage based on a textile sensor. In *2020 IEEE International Conference on Flexible and Printable Sensors and Systems (FLEPS)*. https://doi.org/10.1109/FLEPS49123.2020.9239554

Medi.ee. (2024). *Medi.ee*. Retrieved July 22, 2024, from https://medi.ee/

Morby, A. (2017). Yves Béhar's Aura Power Clothing helps the elderly with mobility. *Dezeen*. Retrieved July 22, 2024, from https://www.dezeen.com/2017/01/12/yves-behar-aura-power-clothing-helps-elderly-mobility-design-museum-london/

Morrison, A., Manresa-Yee, C., Knoche, H., & Jensen, W. (2018). Vibrotactile and vibroacoustic communications: Pairs in interaction and play—An interactive structure and bodies in an urban environment. *Universal Access in the Information Society, 17*(3), 585–605. https://doi.org/10.1007/s10209-017-0576-9

Motti, V. G. (2019). Assistive wearables: Opportunities and challenges. In *Adjunct Proceedings of the 2019 ACM International Joint Conference on Pervasive and Ubiquitous Computing and Proceedings of the 2019 ACM International Symposium on Wearable Computers* (pp. 957-962). https://doi.org/10.1145/3341162.3349573

Nevay, S., & Lim, C. (2015). Co-designing appealing wearables with care home residents. In *11th International Conference of the European Academy of Design: The Value of Design Research* (pp. 1–14). https://doi.org/10.7190/ead/2015/23

Nevay, S., Lim, C. S. C., & Gowans, G. (2017). Textile connections: E-textiles to enhance connectedness for older adults experiencing loneliness. *The Design Journal, 20*(sup1), S4065–S4075. https://doi.org/10.1080/14606925.2017.1352908

Nigusse, A. B., Mengistie, D. A., Malengier, B., Tseghai, G. B., & Van Langenhove, L. (2021). Wearable smart textiles for long-term electrocardiography monitoring—A review. *Sensors, 21*(12), Article 4174. https://doi.org/10.3390/s21124174

Ning, Y., Diao, Y., Wang, G., Lou, N., Li, G., & Zhao, G. (2021). Automatic fall protection for hips based on micromechanical double gas cylinder rapid puncture and bionic capsule inflation. In *2021 43rd Annual International Conference of the IEEE Engineering in Medicine & Biology Society (EMBC)*. https://doi.org/10.1109/EMBC46164.2021.9630780

Oatley, G., Choudhury, T., & Buckman, P. (2021). Smart textiles for improved quality of life and cognitive assessment. *Sensors, 21*(23), Article 8008. https://doi.org/10.3390/s21238008

Ōura Health Oy. (2024). *Õuraring*. Retrieved July 22, 2024, from https://ouraring.com/

Palarum. (2024). *Palarum - The leading solution for fall prevention*. Retrieved July 22, 2024, from https://palarum.com/

Poh, M. Z., Swenson, N. C., & Picard, R. W. (2010). A wearable sensor for unobtrusive, long-term assessment of electrodermal activity. *IEEE Transactions on Biomedical Engineering, 57*(5), 1243–1252. https://doi.org/10.1109/TBME.2009.2038487

Quandt, B. M., Pfister, M. S., Lübben, J. F., Spano, F., Rossi, R. M., Bona, G.-L., & Boesel, L. F. (2017). POF-yarn weaves: Controlling the light out-coupling of wearable phototherapy devices. *Biomedical Optics Express, 8*(10), 4316–4330. https://doi.org/10.1364/BOE.8.004316

Raad, M. W., Deriche, M. A., Hafeedh, A. B., Almasawa, H., Jofan, K. B., Alsakkaf, H., ... Salem, M. (2019). An IoT-based wearable smart glove for remote monitoring of rheumatoid arthritis patients. In *Biosignals 2019* (pp. 224–228). https://doi.org/10.5220/0007573302240228

Rahemtulla, Z. (2023). *Electronic textile garments for fall and near-fall detection* (PhD thesis). Nottingham Trent University, Nottingham, UK.

Rambausek, L. (2014). *Textronics: Definition, development and characterization of fibrous organic field-effect transistors* (PhD thesis). Ghent University, Faculty of Engineering and Architecture.

Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC (General Data Protection Regulation). (2016). *Official Journal of the European Union*.

RehabMart.com LLC. (2023). *RehabMart - Tools for the job of living*. Retrieved July 22, 2024, from https://www.rehabmart.com/

RehabMart.com LLC. (2024a). *DFree wearable incontinence bladder sensor with Bluetooth connectivity*. Retrieved July 22, 2024, from https://www.rehabmart.com/product/dfree-wearable-incontinence-bladder-sensor-with-bluetooth-connectivity-48431.html

RehabMart.com LLC. (2024b). *Skil-Care UnderMattress sensor pads*. Retrieved July 22, 2024, from https://www.rehabmart.com/product/skilcare-undermattress-sensor-pads-39332.html

Republic of Estonia - Ministry of Social Affairs. (2020). *Roheline raamat "Tehnoloogiakasutuse suurendamine inimese igapäevase toimetuleku ja heaolu toetamiseks kodus" [The Green Book "Increasing the use of technology in a person's everyday life to support coping and well-being at home"]*. Retrieved July 22, 2024, from https://www.sm.ee/sites/default/files/documents/2022-05/roheline_raamat_tehnoloogiakasutuse_suurendamine_inimese_igapaevase_toimetuleku_ja_heaolu_toetamiseks_kodus.pdf

Schelle, K. J., Naranjo, C. G., Bhömer, M. t., Tomico, O., & Wensveen, S. (2015). Tactile dialogues: Personalization of vibrotactile behavior to trigger interpersonal communication. In *Proceedings of the Ninth International Conference on Tangible, Embedded, and Embodied Interaction* (pp. 789–798). https://doi.org/10.1145/2677199.2687894

Seidel, A., Chang, L., & Greenberg, A. (2021). Therapeutic modalities. *PM&R Knowledge NOW*. Retrieved July 22, 2024, from https://now.aapmr.org/

Seismic. (2022). *Seismic™ powered clothing - Intelligent wearable strength™*. Retrieved July 22, 2024, from https://www.myseismic.com/

SENIORACTU. (2019). Maase: Un plaid sensoriel pour l'accompagnement non médicamenteux des patients Alzheimer. Retrieved July 22, 2024, from https://www.senioractu.com/Maase-un-plaid-sensoriel-pour-l-accompagnement-non-medicamenteux-des-patients-Alzheimer_a21814.html

Sensoree. (2013). *The GER MOOD SWEATER*. Retrieved July 22, 2024, from https://www.sensoree.com/artifacts/ger-mood-sweater/

Sensoree. (2018). *FleXo*. Retrieved July 22, 2024, from https://www.sensoree.com/artifacts/flexo/

Sensoria. (2022). *Sensoria fitness*. Retrieved July 22, 2024, from https://www.sensoriafitness.com/

Sensoria Health. (2024). *Sensoria® mat*. Retrieved July 22, 2024, from https://www.sensoriahealth.com/sensoria-mat/

Shen, J. (2013). *Development and evaluation of phototherapy device made of luminous polymer optical fiber fabrics* (PhD thesis). Hong Kong Polytechnic University, Institute of Textiles and Clothing.

Stack Labs, I. (2023). *Stack Care - Peace of mind*. Retrieved July 22, 2024, from https://stack.care/
STUDIO TWINS PARIS. (2024). *Maase*. Retrieved July 22, 2024, from https://maase.fr/

Sung, Y.-L., Huang, H.-L., Lin, C.-C., Kröger, T., Hsu, W.-C., Hsu, J.-L., & Shyu, Y.-I. L. (2022). Experiences of family caregivers of persons living with dementia with and without a smart-clothes assisted home nursing program during the heightened COVID-19 alert. *BMC Geriatrics, 22*(1), 697. https://doi.org/10.1186/s12877-022-03379-8

Tan, J., Chen, A., Shao, L., Kim, H., & Ge, L. (2022). Customization of e-textile sensory tools for people with dementia. *The Design Journal, 25*(1), 104-125. https://doi.org/10.1080/14606925.2021.1992943

Tango Technologies®. (2022). *The Tango Belt - Life in Motion - A wearable Smartbelt designed to enable safer mobility*. Retrieved July 22, 2024, from https://www.tangobelt.com/

Tarbert, R. J., & Singhatat, W. (2021). Skilled nursing resident adherence with wearable technology to offer safer mobility and decreased fall injuries. *Journal of Patient Safety and Risk Management, 26*(1), 41-45. https://doi.org/10.1177/2516043520979193

Ten Bhömer, M. (2016). *Designing embodied smart textile services: The role of prototypes for project, community and stakeholders* (Doctoral dissertation). Technische Universiteit Eindhoven. Industrial Design.

Ten Bhömer, M. (2022). *Tactile Dialogues*. Retrieved July 22, 2024, from https://www.mtbhomer.com/project/tactile-dialogues/

Ten Bhömer, M., Jeon, E., & Kuusk, K. (2013a). Vibe-ing: Designing a smart textile care tool for the treatment of osteoporosis. Paper presented at the Design and Semantics of Form and Movement (DeSForM 2013), Wuxi, China.

Ten Bhömer, M., Jeon, E., & Kuusk, K. (2013b). Vibe-ing: Designing a smart textile care tool for the treatment of osteoporosis. Paper presented at the 8th International Conference on Design and Semantics of Form and Movement (DeSForM 2013), Wuxi, China.

Ten Bhömer, M., & Van Dongen, P. (2014). Vigour. *Interactions, 21*(5), 12–13. https://doi.org/10.1145/2641396

Treadaway, C., & Kenning, G. (2015). Designing sensory e-textiles for dementia. Paper presented at the ICDC 2015-Proceedings of the 3rd International Conference on Design Creativity.

Treadaway, C., & Kenning, G. (2016). Sensor e-textiles: Person-centered co-design for people with late stage dementia. *Working with Older People, 20*(2), 76-85. https://doi.org/10.1108/WWOP-09-2015-0022

Van der Velden, N. M., Kuusk, K., & Köhler, A. (2015). Life cycle assessment and eco-design of smart textiles: The importance of material selection demonstrated through e-textile product redesign. *Materials & Design, 84*, 313-324. https://doi.org/10.1016/j.matdes.2015.06.129

Veske, P., Bauwens, P., Bossuyt, F., Sterken, T., Schuermans, J., & Vanfleteren, J. (2022). Development of a stretchable circuit and its integration method on knit fabrics for lower back injury prevention. *Journal of Biomimetics, Biomaterials and Biomedical Engineering, 57*, 17-26. https://doi.org/10.4028/p-681g46

Vihriälä, T. A., Raisamo, R., Ihalainen, T., & Virkki, J. (2023). Towards e-textiles in augmentative and alternative communication: User scenarios developed by speech and language therapists. *Disability and Rehabilitation: Assistive Technology*, 1-11. https://doi.org/10.1080/17483107.2023.2225556

Wang, Z., Yang, Z., & Dong, T. (2017). A review of wearable technologies for elderly care that can accurately track indoor position, recognize physical activities, and monitor vital signs in real time. *Sensors, 17*(2), 341. https://doi.org/10.3390/s17020341

WearableX. (2022). *WearableX Yoga Pants*. Retrieved July 22, 2024, from https://www.wearablex.com/
Yang, K., Isaia, B., Brown, L. J. E., & Beeby, S. (2019). E-textiles for healthy ageing. *Sensors, 19*(20), 4463. https://doi.org/10.3390/s19204463

Yang, K., & Moody, L. (2022). Challenges and opportunities for use of smart materials in designing assistive technology products with, and for older adults. *Fashion Practice, 14*(2), 242-265. https://doi.org/10.1080/17569370.2021.1938823

Yang, K., Meadmore, K., Freeman, C., Grabham, N., Hughes, A.-M., Wei, Y., & Tudor, O. (2018). Development of user-friendly wearable electronic textiles for healthcare applications. *Sensors, 18*(8), 2410. https://doi.org/10.3390/s18082410

Yu, A., Wang, W., Li, Z., Liu, X., Zhang, Y., & Zhai, J. (2020). Large-scale smart carpet for self-powered fall detection. *Advanced Materials Technologies, 5*(2), 1900978. https://doi.org/10.1002/admt.201900978

**About the Authors:**

**Paula Veske-Lepp** (PhD) is a guest professor at the Institute of Engineering and Circular Economy in the TTK University of Applied Sciences. As an engineer, she is interested in designing smart textiles that meet the needs of different end users.

**Kristi Kuusk** (PhD) is currently a Senior Researcher at the Sensorial Design Group in the Estonian Academy of Arts. She is interested in finding alternative futures for clothing and textile design via the implementation of technology. www.kristikuusk.com

**Helen Kool** is a leading lector of social work, with main research interests in elderly wellbeing, social services and technologies in social work and social care. Founder of a Wellbeing Technologies Lab. Has experience in several international projects.

**Merje Beilmann**'s research topics are related to the textile and clothing sector. Her main interest and focus are on the properties of textile materials and product development. She has co-authored several scientific articles.

**Ada Traumann**'s (PhD) main research is in the field of textile technology and the clothing sector. The topic of her doctoral studies was health and safety in the work environment. She has over 20 scientific publications and experience in several international projects.

# P/REFERENCES OF DESIGN

**This contribution was presented at Cumulus Budapest 2024: P/References of Design conference, hosted by the Moholy-Nagy University of Art and Design Budapest, Hungary between May 15-17, 2024.**

**Conference Website**
cumulusbudapest2024.mome.hu

**Conference Tracks**
Centres and Peripheries
Converging Bodies of Knowledge
Redefining Data Boundaries
Bridging Design and Economics
Speculative Perspectives
The Power of Immersion
The Future of Well-being
Taming Entropy: Systems Design for Climate and Change
Ways of Living Together
Cumulus PhD Network

**Full Conference Proceedings**
https://cumulusbudapest2024.mome.hu/proceedings

ISBN Volume 1: 978-952-7549-02-5 (PDF)
ISBN Volume 2: 978-952-7549-03-2 (PDF)

DOI Volume 1: https://doi.org/10.63442/IZUP8898
DOI Volume 2: https://doi.org/10.63442/TADX4016

**Conference Organisers**
Moholy-Nagy University of Art and Design Budapest (MOME)
mome.hu
Cumulus Association
cumulusassociation.org