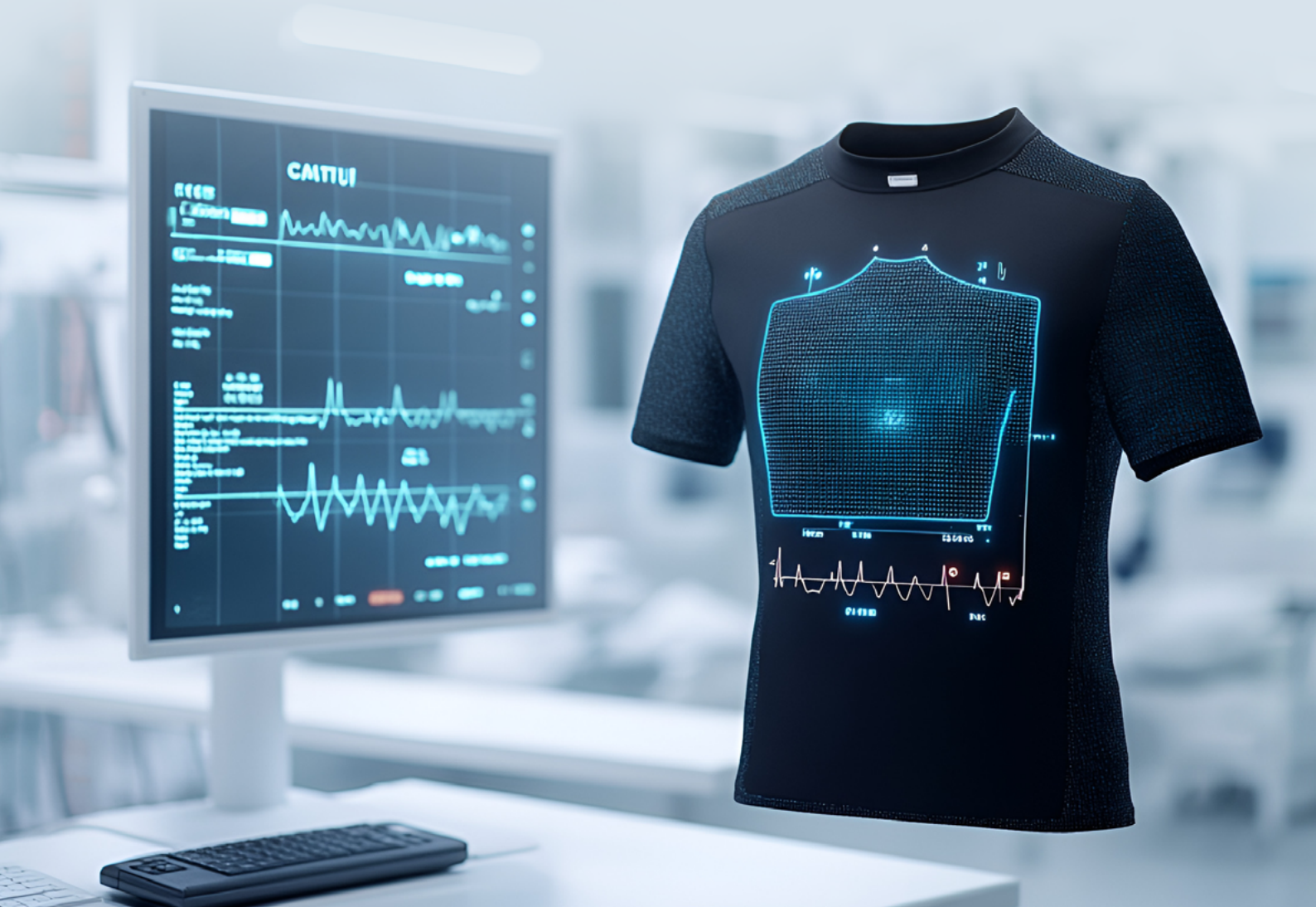
University of Southampton

E-Textiles Network

The role of e-textile wearables in healthcare



Electronic textiles (e-textiles)

The increasing capability of wearable technology presents opportunities for monitoring physiological parameters and providing real-time data for patients and healthcare providers.

Wearable devices like fitness trackers and smartwatches can support physical exercise and monitor vital signs, sleep, physical activity and novel stress markers to help detect health issues early and inform clinical decision-making. The global market for medical wearables is valued at $45 billion in 2024 and is expected to grow to $151.8 billion by the end of 2029 [1]. However, existing wearables are rigid devices suitable for limited body locations (e.g. wrist) and require frequent recharging. Some users find the devices uncomfortable and have concerns about aesthetics so patient adherence remains a primary challenge.

Electronic textiles (e-textiles) integrate smart functionalities, such as sensing and therapeutic applications, seamlessly into everyday clothing, allowing patients to benefit from these technologies simply by getting dressed. Sensors and other electronics can be placed at any position in the garment and can be integrated invisibly within the fabric making them virtually imperceptible to the wearer. This provides a comfortable, familiar, convenient and invisible wearable technology platform that improves patient adherence and sensor data quality and enables therapeutic functions not currently available through traditional wearables. Smart functionality can also be added to clothing (scrubs) and Personal Protective Equipment (PPE) worn by healthcare professionals. Textiles transcend clothing and are widely used in healthcare settings, for example, in wound dressings, sutures, bedding and towels.

Highlights

- E-Textiles are a new platform for wearables that provides a comfortable and familiar form for the technology. Patients can engage with their wearable technology by getting dressed reducing digital exclusion and health inequalities and improving patient adherence to wearables.
- E-textiles enable sensors to be placed at optimum locations around the body and increase the range of physiological parameters that can be monitored and the quality of the data captured.
- E-textile devices include garments that provide multi-lead electrocardiogram (ECG) readings, respiratory monitoring and monitoring skin conditions.
- E-textiles enable comfortable and familiar wearable solutions suitable for long-term monitoring and supporting the ‘hospital at home’. They can also benefit PPE and improve the protection provided.
- E-textiles can apply therapies such as smart bandages that treat wounds using ultraviolet light and textile electrodes that apply electrical stimulation for rehabilitation and pain relief.

Findings

E-textiles outperform traditional wearables and present opportunities for improved patient care and reduced healthcare costs.

Wireless patient monitoring

Key patient vital signs (pulse rate, blood pressure, temperature and respiration rate (RR)) should be monitored at least once every 8 hours. E-textiles can continuously, simultaneously and accurately monitor multiple vital signs. For example, e-textiles can offer multimodal “whole chest” measurement of RR and simultaneously capture clinical-grade electrocardiogram (ECG) data. RR is the most difficult vital sign to measure and yet the most associated with patient deterioration [2]. Textiles also provide a natural platform for sweat sensors that can monitor biomarkers (e.g. glucose) and help avoid patient dehydration.

Treatment at home

The monitoring of patients outside of clinical settings reduces the need for hospital visits, supports the “hospital-at-home” and enables the early discharge of patients (potentially saving over £3,000 per patient [3]). In the event of a problem, continuous patient monitoring enables fast intervention, improving patient outcomes. E-textiles enhance ambient assisted living by promoting independence and improving the quality of life for older adults. E-textiles enable many more physiological parameters to be effectively measured at home.

Reducing health inequality

E-textiles enable the embedding of digital technology in everyday clothing and simplify user engagement. The technology is suitable for all ages, avoids stigma [4] and addresses low adherence often associated with traditional wearables [5].

Smart PPE

The importance of PPE was highlighted by the COVID-19 pandemic which also catalysed smart textiles development to benefit healthcare workers and patients. The ubiquitous textile facemask has been modified using e-textile technologies to include respiration sensors, antifouling mechanisms and sensors that improve the mask fit [6]. Future opportunities for facemasks include electronics that amplify sound to improve communication and early warning of mask movements that affect fit and increase inhalation risk.

Therapeutic applications

The application of electrical signals to stimulate muscles (functional electrical stimulation, FES) has been demonstrated. E-textiles enable multiple electrodes to be positioned across the body enabling FES to address a much wider range of conditions such as stroke rehabilitation [7]. E-textiles that provide electrical stimulation [8] or emit UV light for wound treatment have also been demonstrated in smart therapeutic bandages [9].

Barriers to Adoption

User experience

E-textiles currently rely on bulky conventional rigid batteries that are incompatible with fabrics and require frequent recharging. Developing alternatives (e.g. wireless power supplies and flexible textile batteries) is highly desirable [10]. Wearable e-textiles must be developed with input from end users and other stakeholders, including garment designers to ensure patient acceptance and use.

Certification

New medical devices require the appropriate approvals for clinical investigation (e.g. Medicines and Healthcare products Regulatory Agency (MHRA) in the UK) and bringing products to market (e.g. UKCA in the UK). Similarly, PPE is regulated by the Health & Safety Executive (HSE), where little to no standards exist specifically for use in health and care settings. This should be factored into the development at an early stage and the relevant requirements identified and addressed.

Manufacturing and cost

Translating research into mass-producible products requires input from across the supply chain. Innovations should be suitable for automated manufacturing to reduce labour costs and realise cost-effective solutions.

Reliability/Aftercare

E-textiles employed within clinical settings must be suitably durable and withstand appropriate laundry processes. This typically involves wash temperatures of 70–98°C.

Sustainability

Product circularity and end-of-life processing must be considered during development to minimise environmental impact.

Proposed recommendations

- **Include e-textiles as part of a strategy for implementing wearables in healthcare.** The ability of e-textiles to embed wearables within standard garments will improve patient adherence, enable the application of therapies and increase the range of physiological parameters that can be monitored. E-textiles are an essential platform for future wearables development. E-textiles democratise wearable technology and support the objectives of the Build Back Better: Our Plan for Health and Social Care Policy.
- **E-textile technologies that target respiration rate (RR) will have the most immediate impact.** The specific development of e-textiles towards this application will provide high-accuracy multimodal measurement and address current technical limitations [11]. It will provide early warning of patient deterioration.
- **E-textile developments must be sustainable.** The textiles and electronics industries are highly polluting and the combination will complicate end-of-life processes (e.g. recycling) unless addressed during development. Legislation for the disposal of electronic textiles should be adopted.
- **Translate technologies to applications beyond healthcare.** E-textile wearables can benefit other applications, including first responders, the construction industry, and creative industries. Not just wearables: e-textiles can be used wherever fabrics are found, from bedding to car interiors. Secondary markets for related e-textile products include well-being, fitness and technical textiles across industrial sectors. E-Textile technology should be represented through Innovate UK's Business Connect programme to support organisations developing technology and through MHRA processes.
- **Support the development of e-textile technology and the transfer of innovations from universities to product development.** This technology will support the UK textile garment and textile manufacturing industry which comprises over 10,000 enterprises with over 90,000 employees and an annual turnover of £9.4B[12]. E-textile technologies provide product differentiation and added value and support regional economic growth, reducing inequalities in line with the Invest 2035 UK Industrial Strategy. Collaborative funding in wireless power and communication [13] and automated manufacturing processes will drive UK leadership in e-textiles through technical innovations and reduced labour costs. E-textiles should also leverage developments in AI and adopt edge computing (on-device processing) to minimise GDPR issues around personal data.

About the research

The findings originate from workshops hosted by the E-Textiles Network on e-textiles for healthy ageing (February 2019) [14, 15], healthcare (January 2024) [16] and personal protective equipment and workwear (September 2024) [17] attended by over 180 professionals from academia, industry and healthcare. Interviews have been conducted with over 40 industry professionals experienced in wearables and e-textile production.

Scan to find out more
https://e-textiles-network.com

E-textile network and authors

The E-Textiles Network brings together researchers and developers from academia and industry with end users from organisations such as the NHS, who are interested in adding electronic functionality to textiles, developing related products and exploiting their benefits. Originally funded by the EPSRC (2018-2022) and now self-sustaining, the Network is managed on behalf of the community by the University of Southampton.

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