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Electronic Textiles and Product Lifetimes: Teardowns

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Abstract: Electronic textiles (E-textiles), the combination of electronics with textiles, pose significant challenges for the extension of product lifetimes, reuse, recycling and end-of-life disposal. E-textiles products can be divided into two categories: the first is the 'vision' of ubiquitous computing, achieved using computation seamlessly integrated into garments, home furnishings and other textiles; the second is the often-overlooked commercial reality of E-textiles that covers a variety of hybrid electronic-textile products such as electric blankets and novelty items such as light-up musical Christmas jumpers. The products in both categories contain a combination of hazardous and valuable substances dispersed throughout low value, difficult to recycle, heterogeneous material. The market for E-textiles is predicted to expand rapidly, but little has been done to ensure environmental factors are considered during product design and development. This paper reports on a series of E-textile product teardowns conducted to identify the strengths and weakness of commercially available E-textile products, using eco-design and clothing longevity guidelines (Cooper et al., 2016; Köhler, 2013b) as a framework for analysis.

Context

The electronic or E-textiles market is predicted to see considerable commercial growth (Hughes-Riley, Dias, & Cork, 2018). The inclusion of information and communication technology (ICT) in new product categories, such as textiles, could accelerate the rate at which these products are replaced. In the UK a jacket is expected on average to be actively used for over 5 years (Langley, Durkacz, & Tanase, 2013) whereas the lifecycle of a smartphone is usually less than 2 years (Baldé et al., 2017, p. 21). E-textiles need to be designed to avoid lowering the lifespan of otherwise longer lasting products, or strategies that reduce the impact of shorter lifespans should be adopted. This is especially important in the case of E-textile products, due to the difficulty in separating mixed textile-electronic materials for recycling (Köhler, Hilty, & Bakker, 2011). With current infrastructure, E-textile products are incompatible for processing either as textiles or electronics and are likely be sorted out by recyclers for disposal in landfill or through incineration, increasing the importance of longevity as a sustainability strategy.

Longevity as a sustainability strategy for E-textiles

The lifespan of both consumer electronics and clothing can be notoriously short. It is estimated that increasing the active lifetime of 50% of UK clothing by extending the period of active use by 9 months would reduce total carbon, water and waste footprint of UK clothing by around 4-10% (WRAP, 2017b, p. 2). Extending product lifetimes has also been identified as crucial to reducing the burden of Electrical and Electronic Equipment (EEE) on the environment (WRAP, 2017a), making it a fundamental strategy for more sustainable E-textiles.

Designers and brands can positively influence product lifetime by considering the physical durability of the materials used or the reparability of the products (Cooper et al., 2014). For garment design, reparability might mean providing a spare button or darning thread to fix a hole. For an electronic device, including an E-textile, it could mean using a standard battery type and making the battery easy to locate and replace (Köhler, 2013b).

A product's active life is also determined by emotional and experiential connection between person and object (Chapman, 2009; Fletcher, 2012), a concept known as emotional durability.

Product failure is frequently not the reason that clothing and textiles are discarded. More often it is due to being considered poorly fitting, out of fashion or looking worn (Langley et al., 2013, p. 9). Similarly, an exploratory study found that only 31% of smartphones were replaced because they were considered to be broken (Martinho, Magalhães, & Pires, 2017). Electronics, like textiles, are likely to be discarded for reasons other than physical product failure.

The Clothing Durability Dozen (Cooper et al., 2016) offers a range of strategies to increase clothing longevity, including physical and emotional durability, but also alternative business models, methods of communication and promotion, product labelling and longer life guarantees. These strategies can be equally useful when considering the longevity of E-textile products.

E-textile product teardowns

A teardown is a workshop in which items are deconstructed and analysed. Greenpeace uses repairability scores generated by carrying out teardowns as part of their 'Guide to Greener Electronics' (Cook & Jardim, 2017) and the RSA (Royal Society for the encouragement of Arts, Manufactures and Commerce) Great Recovery project (2015) used them to examine waste and circular economy design opportunities. Teardowns carried out for the project described in this paper were conducted by an interdisciplinary team as an opportunity to discuss the knowledge required to minimise the potential impact of E-textile production in a rapidly growing global industry. The findings from the teardowns were evaluated against eco design and longevity guidelines (Cooper et al., 2016; ECMA, 2010; Köhler, 2013) and are discussed in the latter section of this paper.

Three commercially available E-textile products from different market segments were selected for analysis: the Levi's® Commuter™ Trucker jacket with Jacquard™ by Google, a premium fashion product and the first commercially available outcome of the Google Jacquard™ project; a heart rate (HR) monitoring sports bra, an example of a functional E-textile; and a light-up musical Christmas jumper, representing the novelty end of the E-textile market. In tearing-down the products they were unavoidably destroyed, except for the Levi's® jacket which was required for future research.

The Premium

A Levi's® Commuter™ Trucker jacket with Jacquard™ by Google, launched in 2017, was purchased for this project in August 2018 for $350 US.

Figure 1. Levi's® Commuter™ Trucker jacket.

The jacket (Figure 1) came in a cardboard box containing the garment, the electronic tag required for the jacket to function and an information leaflet. The jacket was labelled with a standard garment label stating country of manufacture (China), composition (outer 100% cotton, lining 86% polyester and 14% elastane, trim 93% polyamide and 7% elastane) and laundry care instructions (Figure 2). No reference was made to the metal and plastic of the Jacquard™ threads or connector in the left sleeve, but details of their composition have been published by the research team that developed the technology (Poupyrev et al., 2016).

The laundry care instructions on the jacket's label indicated that it should be washed at 30°C. It cannot be dry cleaned and the left cuff of the jacket containing the Jacquard™ threads, seen magnified in Figure 3, cannot be ironed. The electronic snap tag (Figure 4) must be removed before washing. Information stating that the jacket has been tested by the developers to last 'at least 10 washes' was in the pamphlet that accompanied the jacket and on the product website (Google, 2019), not on the laundry care label.

Figure 2. Jacket label.

Unlike traditional textile products, the Levi's® jacket was labelled with the Waste Electrical and Electronic Equipment (WEEE) symbol (see Figure 2) that indicated the product was considered to be EEE and should not be disposed of in household waste. Products are classed as EEE when their primary function is considered to be electrical or electronic, so not all E-textiles fall under this classification. The CE mark has also been used, indicating that the product conforms to the health, safety and environmental protection standards of the European Economic Area (EEA).

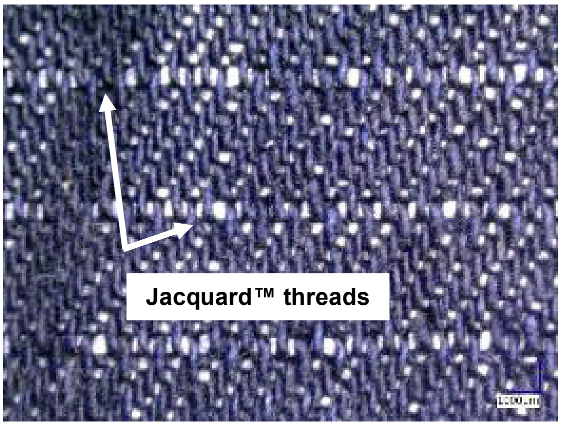

Figure 3. Jacquard™ cuff close-up.

Some of the jacket's electronic components are integrated into the textile, whereas other components are removable. The Jacquard™ threads that make up the sensor are woven into the fabric of the cuff and as such are completely inseparable from the other textile fibres. However, the electronic tag can be removed and must be for washing. The tag has a USB rechargeable battery, but should it fail it cannot be replaced.

Google offers a support service for battery issues, though it is unclear if this applies after the one-year warranty expires. This information could be found in the pamphlet that accompanied the jacket and on the product's website, but not on the product label. A quark code label on the inside of the jacket also led to the online information.

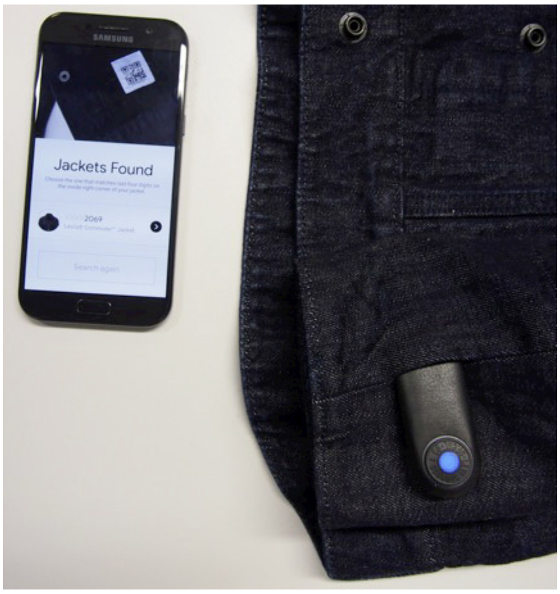

Figure 4. Jacket tag and app.

The jacket was tested with the app that controls the use of the jacket's electronics. Limited testing found installation and use of the Jacquard™ cuff, which recognises four user gestures (up-swipe, down-swipe, double tap and hold), to be relatively simple.

The Functional

A Heart Rate (HR) monitoring sports bra branded 'Berlei' was purchased in August 2017 from Amazon for £23.14. An electronic module to pick up the readings from the sensor, and a sports watch to display the readings, were not included, so functionality of the garment could not be tested. The modules and watches are made by a number of brands, including Garmin and Géonaute.

The garment came in a clear plastic bag with no information indicating the compatibility of the product with different modules or display devices. The bra had two metal snap fasteners at the front to attach the electronic module (Figure 5). The product was labelled as 'Made in China' and consisted of 47% polyamide, 37% polyester and 16% elastane (exclusive of trims). The garment was hand wash only and could not be ironed or tumble dried. The WEEE symbol was not present and the garment did not have a warranty.

Figure 5. Front HR monitoring sports bra.

An electrode was on the inside of the bra to pick up HR signals (Figure 6). The conductivity of the electrode was tested, but without the electronic module it was unclear if the electrode was sufficiently conductive to produce a reliable HR signal. To understand the composition of the electrode, a small section was heated so the polymer layers could be separated. The electrode was made up of several layers of polymer-based film adhered to the fabric. Some of the film contained carbon particles and was conductive, with other non-conductive film areas acting as an insulator (Figure 7).

Figure 6. Inside HR monitoring sports bra.

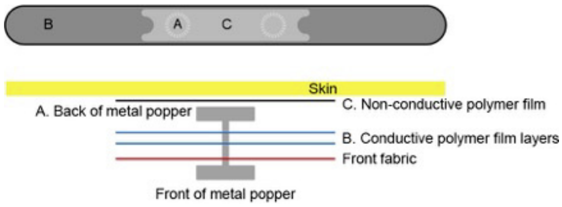

Figure 7. Electrode construction.

The Novelty

A Next women’s Christmas jumper was purchased from Ebay second-hand for £6.00 in July 2018 (Figure 8). The date or price of its first purchase are unknown but prices for this type of product in December 2018 were around £30. Prior to the teardown the electronics in the jumper were still functional. The reindeer’s nose would light up and play a Christmas jingle when pressed.

Figure 8. Christmas jumper.

The label indicated that the jumper was 100% acrylic and washable but made no reference to the electronic pod held in a textile pocket on the back of the jumper (Figure 9), either in terms of materials or any instruction indicating whether the pod should be removed for washing. Unsurprisingly for a relatively low-cost novelty item, the jumper did not come with a warranty.

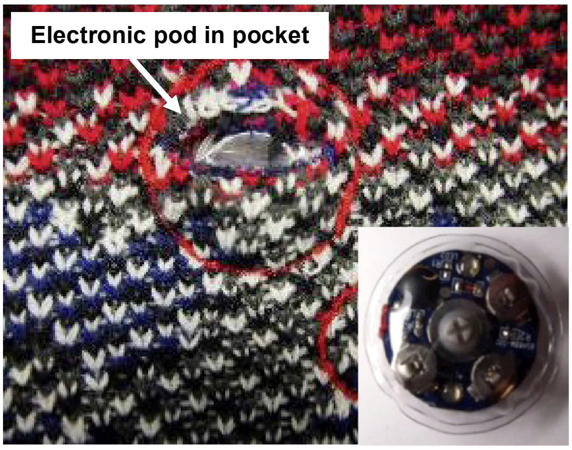

Figure 9. Electronic pod.

The electronics were encapsulated in a sealed plastic capsule 4cm in diameter and held tightly inside the pocket on the reverse of the garment. The label did not carry the WEEE symbol despite the Bliss Electronic (2019) pod containing many electronic components, as shown in Figure 10. To access the components the pod had to be cut open.

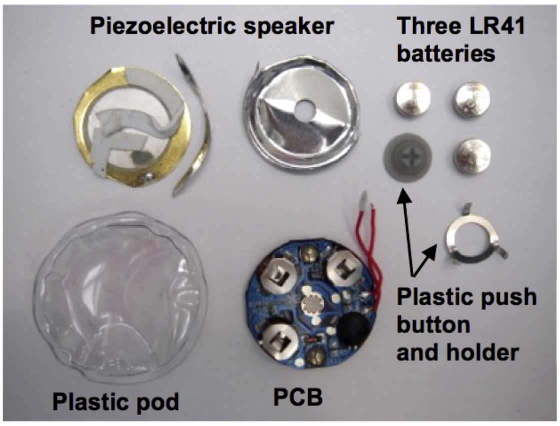

Figure 10. Pod components.

Discussion

All three E-textile products were labelled with standard textile product labels informing consumers of where they were manufactured, their textile composition and laundry care requirements. Only the Levi's® jacket, representing the premium end of the market, made any reference to the electronic components on the label in the laundry care instructions. Textile manufacturers are not required to include the material composition of trimmings and non-textile parts on their labels and hence the electronics can be excluded (BIS, 2016). The Levi's® jacket was also the only product that gave disposal instructions through the use of the WEEE symbol and a product warranty.

The Levi's® jacket and HR monitoring sports bra both required separate electronic modules and display devices, but they also both had electrical components that were inseparable from the fabric. This heterogeneous material is nearly impossible to repair, recycle or separate and reuse (Köhler, 2013a). The Christmas jumper has the advantage that the electronics were contained in a removeable pod which allows the electronics and textile to be separated and processed through their designated waste streams. However, for this to happen the WEEE symbol and ideally a written explanation would be needed to inform the consumer.

When electronic modules are not attached to the jacket or bra there is a visible missing piece. Despite them still functioning as garments, users may not want to wear these items should the electronics fail or become obsolete, due to them appearing incomplete or unattractive. A standard denim jacket can be considered a design classic and remain in active use for decades, a lifespan few electronic products can claim. The electronics can be removed from the Christmas jumper without anything perceivably missing, in contrast to the other products reviewed, perhaps making the garment more likely to be used after the electronic components have failed.

Making E-textiles washable is a considerable technical challenge. The Levi's® jacket is engineered to last only 10 washes, which is a problem as the jacket was designed with commuters in mind. A cycling jacket could easily need frequent washing to remain in acceptable condition for its user. The bra was not tested to see whether washing affected the performance of the electrode, but it is a garment that would be likely to require washing each time it was used. The information regarding the limited number of washes the Levi's® jacket was engineered to withstand was not found on the jacket label alongside other laundry care information, but in the pamphlet that accompanied the jacket and on the website (Google, 2019), placing the onus on the consumer to find the necessary information.
Research has shown that care labels are rarely followed after the first wash and often poorly understood, ignored or removed (Mclaren, Goworek, Cooper, Oxborrow, & Hill,

2016). Not following care instructions can reduce product longevity and, in the case of E-textiles, may irreversibly damage the electronic components and invalidate the warranty. The jacket's care instructions highlight the greater demands placed on consumers to correctly care for E-textile products. The premium nature of this product may mean owners are more likely to take necessary caution, but may not be with cheaper products, which are more likely to be viewed as disposable.

Compatibility achieved through the standardisation of components is a recommended eco-design principal to ward against obsolescence (Köhler, 2013b). The Levi's® jacket uses a standard USB connection to recharge the tag making it widely compatible. The bra is compatible with a range of electronic modules which can be seen as positive, but the fact the manufacturer takes no responsibility for product compatibility creates a risk that the product will not function. Any lack or loss of functionality could lead to the product being quickly discarded as it has a relatively low price and no warranty.

Traceable supply chains are a longevity strategy that involves better connection between consumers, brands and manufacturers (Cooper et al., 2016). The bra was purchased through Amazon, not directly from Berlei. Contact with the Berlei customer service team confirmed that the product was genuine but discontinued several years ago. As the bra was bought through a third party, the consumer potentially has no support in the case of product failure. In contrast, the consumer of the Levi's® jacket is provided with a point of contact to resolve any problems.

Conclusion

Only the premium product analysed during this project was labelled with the WEEE symbol. While its use is a small improvement, it is made somewhat redundant when the electronics cannot be separated from the textile. Integration is seen as key to the development of E-textiles (Cherenack & Van Pieterson, 2012) but limits opportunities for repair, re-use or recycling, and likely reduces the longevity of products and components. All the products analysed potentially have a shorter lifespan than a classic textile equivalent due to the possible failure of the electronics.

In the case of novel smart materials such as E-textiles, it can appear that any transformation that uses their functional capability can be seen as a success independent of whether it creates value to society (Karana, Barati, Rognoli, & Van Der Laan, 2015). However, arguably the utility of E-textile products should be assessed in the context of their environmental impact, and the societal need for E-textile products is an issue deserving of further research (Berglin, 2008, p. 98).

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