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E-Textiles: A Soft Touch Barometer for Female Students to Self-Manage Their Stress

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ABSTRACT The surge in student anxiety and stress in universities continues to escalate, and with over 50% of young people now going to university, and finite university support resources available, finding complementary ways to support student wellbeing is essential. Enabling students to recognise, understand and manage their in-the moment stress can empower them to take some control over their own mental health. This paper focuses on female students. It adopts a mixed methodology approach of experiential learning informed by themes of social and technology acceptance. Overlapping methodologies including *"what if… ?"* scenarios around wellbeing are posed to inspire textile-based concepts as an intervention. The research presents novel approaches and proposes five early design concepts to consider the monitoring, management and prevention of female student stress through the design of crafted, wearer-centred e-textiles. The research is underpinned by both quantitative and qualitative data generated at

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two female student focus groups. The interactive textile outcomes and playful narratives encouraged student discussion and illuminated wider debate around female student mental health issues. The findings revealed that students are receptive to taking greater responsibility for their own mental wellbeing and open to exploring new paradigms of self-management of stress. The research outcomes built new interdisciplinary knowledge in design practice by exploring the intersections between fashion and textiles, science, technology and wellbeing.

Keywords: E-textiles, design for wellbeing, playful-narratives, self-managed wellness, social acceptance, female student stress

Introduction

This paper outlines the growing epidemic of student stress, its causes, coping mechanisms and barriers to seeking university or professional support. It contends that enabling students to recognise, understand and manage their in-the moment stress can empower them to take some control over their own mental health. The rationale for this research was to explore how the interface between skin and textile can act as a barometer of emotional and physical health. It sought to ascertain if electronic textile (e-textile) garments or accessories could bring a greater awareness to wearers' stress and enable them to monitor, manage or limit their stress. A mixed methodology framework was adopted for this research (Figure 1). A review of relevant literature highlighted the contrasting ways that females and males respond to, and are impacted by stress. This research drew upon the literature and data around female student wellbeing from a previous survey conducted by the author. The research was underpinned by a methodology of experiential design (Hanington 2006; Kolb et al. 2014); informed by themes of social and technology acceptance (Venkatesh et al. 2012). This approach enabled a series of *"what if."* scenarios around wellbeing to be posed. These shaped the design and development of five crafted, wearer-centred e-textile concepts which explored how students might self-monitor and manage their well-being. The interactive textile outcomes and playful narratives were evaluated through two focus groups. The findings revealed that female students were receptive to exploring new paradigms of self-management and taking greater responsibility for their own mental wellbeing. The research outcomes built new interdisciplinary knowledge in design practice at the intersections of fashion, textiles, science, technology and wellbeing.

Target Demographic

Mental health issues in the UK account for 28% of the burden of disease (McManus et al. 2016). Females are more susceptible to mental

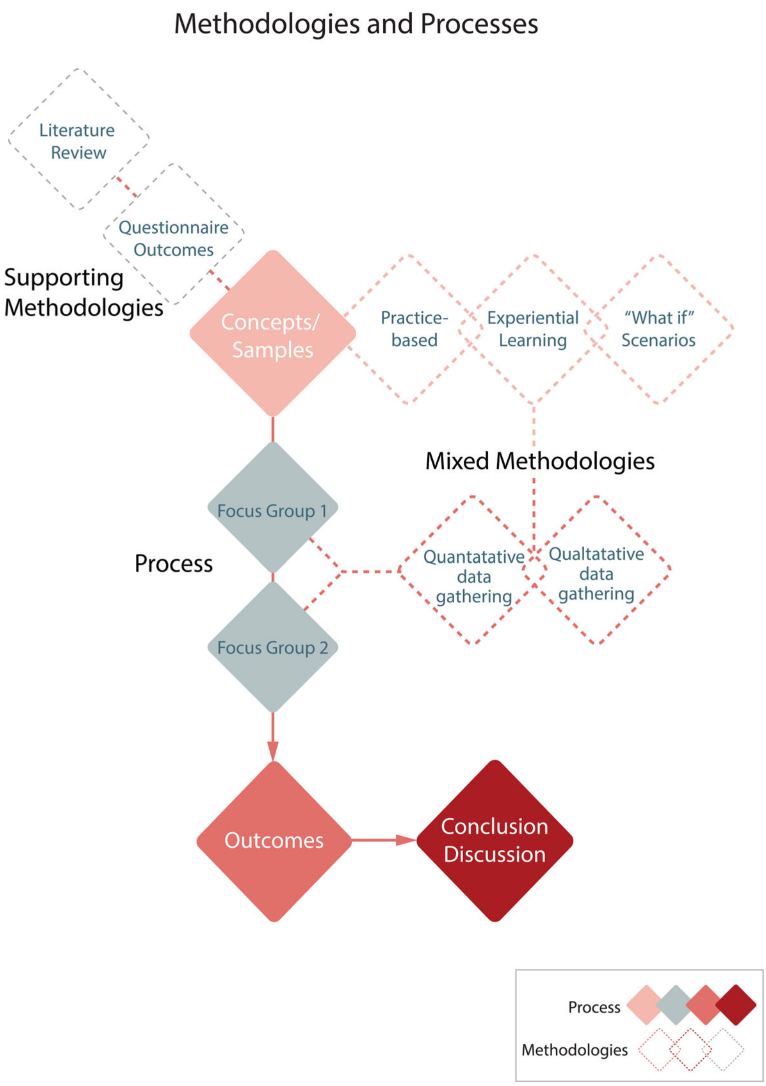

Figure 1
Flow chart showing the methodology framework.

health issues such as anxiety and depression than males (McManus et al. 2009; YouGov 2016; NHS 2020). This trend is consistent across England, Scotland, Wales and Northern Ireland (NHS Digital 2021). Females also react differently to stressors than males (Jose and Ratcliffe 2004). A YouGov survey (2016) found that 77% of students reported depression, and 74% reported anxiety as key effects of their stress. Whiteford et al. (2013) highlight that depression and anxiety are more prevalent in a 19-to-34-year-old demographic than in other age groups. Collectively the data gathered formed the basis for the inclusion criteria for this research which was female students aged between 19 and 34. There is a body of practice that informs the indicators of mental health (Suchert et al. 2015; Faelens et al. 2021), for example a sense of control (Kurtović et al. 2018), self-esteem (Bracke et al. 2008) and optimism (Kleiman et al. 2017). However, there is no definitive set of indicators. Within this research study, participating students were not required to meet a given set of mental health indicators to be included. The term "mental health" was not defined for them at the outset as individuals' perceptions and definitions are unique to them. This approach gave students freedom to express their personal perspectives and individual viewpoints of mental health which brought rich insights to the study.

Stress is a major contributing factor to mental health issues. It damages the body physiologically, leading to increased blood pressure, increased insulin resistance, carbohydrate intolerance; immune dysfunction; hypertension, osteoporosis and cardiovascular disease (Dhabhar 2014). There is evidence to suggest that stress can occur at a sub-conscious level (Freud 1966). Individuals are not always aware of this and are therefore not in a position to activate their attention towards their physical and mental health. The physiological damage caused by stress occurs regardless of an individual's awareness. Actively being present in-the-moment, which is sometimes referred to as mindfulness can enhance self-knowledge and positively impact on physical and mental health (Lambie 2009; Navarro-Haro et al. 2017; Abbasi et al. 2021).

Causes and Effects of Stress in University Students

The long-lasting effects of stress impact young people more than any other health condition (NSPCC 2017), with 1 in 4 students in the UK declaring themselves as having mental health issues, and almost 50% reporting that they struggle with completing simple daily tasks (YouGov 2016). Universities point to numerous examples of good practice with interventions and platforms to support student mental health issues. However, their resources are outstripped by demand and for a myriad of reasons many students do not engage with the available resources. Stress amongst the student population in the UK is increasing (Denovan and Macaskill 2017). Widening Access strategies have resulted in reduced funding (Robotham and Julian 2006) and the introduction of student fees has exacerbated student stress (Richardson et al. 2015; McCloud and Bann 2019). Mental health charity Mind reports that the 28% increase in university students seeking counselling correlates with the cost of tuition fees trebling (The Guardian 2016). Research shows that students perceive stress at university as normal. They often fail to recognise the seriousness of the effects of stress on their health and some lack the time to pursue appropriate treatment (Downs and Eisenberg 2012). Many students do not disclose their mental health issues for fear of being stigmatised (National Union of Students, (NUS) 2011). Long waiting lists to access support services within universities (Office for Students 2019) and finite resources further compound the issue. Thresholds for accessing support have increased to prioritise those considered "most severe" (Edbrooke-Childs and Deighton 2020), leaving a majority demographic who are subjectively considered "less severe" with less opportunity to access support at an early intervention stage. Complementary approaches to managing mental health can treat emotional and physical distress (Biggs 2017; Lazarus 2020) and enable individuals to actively take responsibility for their own wellbeing.

Constructing or engaging with craft-based textiles are already recognised as an effective therapy to support individuals and have a positive effect on wellbeing and self-esteem (Kenning 2015), but to the best of the author's knowledge no work has been carried out on using embedded, craft-based textile sensors as a self-management strategy for student stress. Considering this context provides opportunities to investigate alternative approaches to enhancing self-awareness, self-monitoring and management of personal health, through the interface of e-textiles wearables. There is no definitive protocol for assessing stress. It is most commonly gauged using the Social Readjustment Rating Scale (Holmes and Rahe 1967) or more recently self-assessment tools such as a psychological tool called Perceived Stress Scale (PSS) (Cohen et al. 1983) which is retrospective and paper-based. The medical profession use laboratory-based tests such as the Trier Social Stress Test (TSST) which monitors changes in saliva as a stress response (Kirschbaum et al. 1993) or sensors in clinical settings to measure other physiological changes as indicators of stress (Akmandor and Jha 2017). These do not take into account feelings nor do they offer remedy. The research presented here is novel in how it assesses stress by measuring both physiological changes in the body and offers embodied experiences using affective touch and e-textiles as therapy. This elicits emotional in-the-moment experiences which are not retrospective and less sterile than paper-based evaluation tools used in clinical environments. Tactile sensations can positively affect cognitive responses (Singh et al. 2014), and the touch combined with the associated gestures in this research educed bodily perceptions which had the potential to signify or conceal the bodily and mental state of the wearer.

E-Textiles, Touch, and Wellbeing

The kinaesthetic phenomenon of touch is referred to as haptics (Marks 2002). This elicits feelings whereby the body instinctively knows how to act. French philosopher Maurice Merleau-Ponty (Merleau-Ponty 1962) describes this phenomenon as embodied knowledge, suggesting the "knowledge in the hands is known by the body." There is a body of literature exploring kinaesthetic qualities through textiles (Ripin and Lazarsfeld 1937; Kettley et al. 2011; Chung 2019). Kettley's work extends to include embodied textiles for wellbeing using human computer interaction (HCI) which provides a useful context for this research. However, the topic remains underexplored and is worthy of further study. Expressive touch is not only externally referenced on the surface of the body, but is also experienced within the body. This embodied perception (Proffitt 2006; Schnall 2017) explains how individuals feel and react to an environment or situation. In this research the expressive touch of the crafted e-textiles alongside their sensing properties brought an awareness to embodied perceptions and the resultant embodied emotions experienced. As individuals connected with the digitally crafted textiles their physiological data was elicited and interpreted both visually and through haptic sensation. The textiles played a pivotal role in acting as a catalyst to notice unnoticed stress, and as a gauge to reveal, monitor and manage individuals physical state and their embodied perceptions. In this sense the textiles became a unique wellbeing barometer, and the holistic experience enhanced wearers' sense of wellbeing.

Methodology

The learning process in art and design is experiential (Lachapelle 1997; Kolb 2014) and rooted in constructivist learning (Jonassen and Land 2012), which is the act of doing and reflecting upon the experience of doing. However, experiential, studio-based practice alone is not sufficient for learning in a research context (Barrett and Bolt 2014). It should co-exist with theoretical learning to create a valid research method in the field of art and design (Lachapelle 1997). To ensure rigour, a mixed methodology approach was taken for this research which involved 3 elements encompassing (i) theoretical learning, (ii) experiential learning drawing upon the theories of Dewey, and Polanyi, and (iii) an evaluation of quantitative and qualitative data gathered as a result of the experimental outcomes. The framework for the mixed methodology in Figure 1 shows where each methodology was utilised in the workflow.

Dewey (1934) argues that all knowledge by its definition is experiential and relies on both explicit and tacit knowledge. Tacit knowledge implies that individuals know more than they can articulate (Polanyi 1983), and this approach to research is appealing in the creative field of design. It is particularly interesting in fashion and textiles, and specifically relevant in the context of this research where the experiential process adopted was aesthetic, tactile, and driven by the instinctive act of thinking, feeling and making simultaneously. This approach was useful for exploring the hidden qualities that textiles can offer to support wellbeing. Social norms dictate that we are enveloped in textiles for most of our lives. This often intimate and immersive experience of engaging in human time (Philpott 2012) brings a sensuous awareness of how the body reacts to self, others and the environment. The unique characteristics of textiles contribute to wellbeing in a number of tacit ways. Their qualities and handle encourage direct engagement through rubbing or stroking to offer a self-soothing experience. Squeezing, pinching or wringing textiles often intuitively, can provide indications of a person's emotional state.

The theoretical and practice-led approaches were further underpinned by drawing upon the analysis of questionnaire data taken from the author's PhD study. Detailed outcomes of the survey are beyond the scope of this paper. However in brief, the analysis had identified the main causes and coping strategies of female university student stress. It revealed that often they were not aware of their stress; that they fidgeted with clothing as a coping mechanism to stress, and that they were receptive in principle to engaging with e-clothing as an early stand-alone or complementary intervention strategy to manage their stress. (Table 1 highlights how these outcomes informed the practical elements of the research). These findings alongside the author's tacit and experiential knowledge in textiles, informed personal, speculative thoughts and iterative questioning, which enabled an emotional and sensory response to the enquiry. This resulted in interpretating the students' views into five creative concepts which could be incorporated into the everyday clothing of the target demographic. These were then evaluated through student focus groups. The concepts were intended to both raise wearers' awareness of their personal stress, and promote mindfulness and bio-feedback using non-binary formats. The samples sought to determine the types of feedback that wearers would find acceptable in terms of light, sound, haptics or a combination of approaches. They enabled the identification of which familiar gestures wearers would be comfortable with actioning. For example, pulling up a zip, pulling up a hood, self-hugging or stroking (similar to a keeping warm gesture), fidgeting with drawstrings or squeezing pompoms on hoodies. Textile e-wearables were considered from three stress-related perspectives: (i) raising self-awareness, (ii) self-monitoring and managing, and (iii) prevention.

Mind maps, visual metaphors and concept mapping (Lardjane 2018) are known to bring useful visual expression to research (Butler-Kisber and Poldma 2011) and these methodologies were also utilised to create a concept map (Figure 2). *"What if…?"* scenario-based questions (Rosson and Carroll 2009) were created as part of the methodology framework and informed the starting point for each of the five concepts. These questions suggested possible future activities for self-managing stress through the affective touch of textiles. These were interpreted as conceptual prototypes with a playful element. Relevant scientific principles and technologies were explored to support the functionality of the designs. Engaging with playful activities supports subjective wellbeing (Killick and Allan 2012). Textile research into dementia (Treadaway et al. 2014) shows how this approach can be useful in textile and health contexts. The concepts designed in this present research study were intended to celebrate the joy of engaging with textiles and introduce a sense of fun alongside purpose. They presented an opportunity to observe the surprise

Table 1. Concepts mapped to student feedback, purpose, measurement, input, and output

Purpose	Aspect of questionnaire feedback addressed	Concept name	Measuring & input	Output
Stress Management	• Clnching & fidgeting as a stress response • Simple feedback • Self-management • Visualising feedback • Self-management	Boading Ball (Textile Sample) Pulse Pom (Textile Sample) Breathing Patterns (Textile Sample)	Piezoresistive Change (Pressure - Squeeze) Pulse wave modulation (Touch) Heart rate variability (Touch)	• Audio/Haptic Inc. frequency & vibration • Visual Pulsing Light • Light Colour Changing
Stress Awareness	• Sub-conscious stress • Stressful environments	Zip it (Virtual Sample)	Potentiometer (Sliding scale)	• Audio (Delayed)
Stress Prevention	• Low mood • Ease of use	Mood Hood (Textile Sample)	SAD – Blue Light Therapy (non-contact via eye)	• Visual Fibre Optic Light

and delight of wearers experiencing a textile that acknowledged and supported their wellbeing. The names of each concept, the tactile nature and form of the samples, and the type of action required to activate them collectively created the playful narrative and encouraged "magical thinking" (Wilde and Andersen 2009) amongst the participants. These magical elements were not intended to make light of a sensitive subject, but rather to provide an accessible introduction to participants engaging with the sensors and the subject matter, and to gain their confidence.

Table 1 identifies the purpose of each concept and how it responded to issues raised in the questionnaire; the concept name; what was being measured and how it was being measured and outputted. The following sections examine each of the five concepts and describes the *"What if"* scenarios; what is being measured and how this is outputted; the scientific principles relating to the measurements, and how each concept was constructed.

Concepts

Concept 1 – Baoding Ball

Baoding Ball "What if?"

> "What if you could hear your stress levels by squeezing your clothing and have your clothes de-stress you haptically?"

The idea for Baoding Ball was inspired by Chinese boading balls which were an ancient tool for health and wellbeing. Squeezing fists

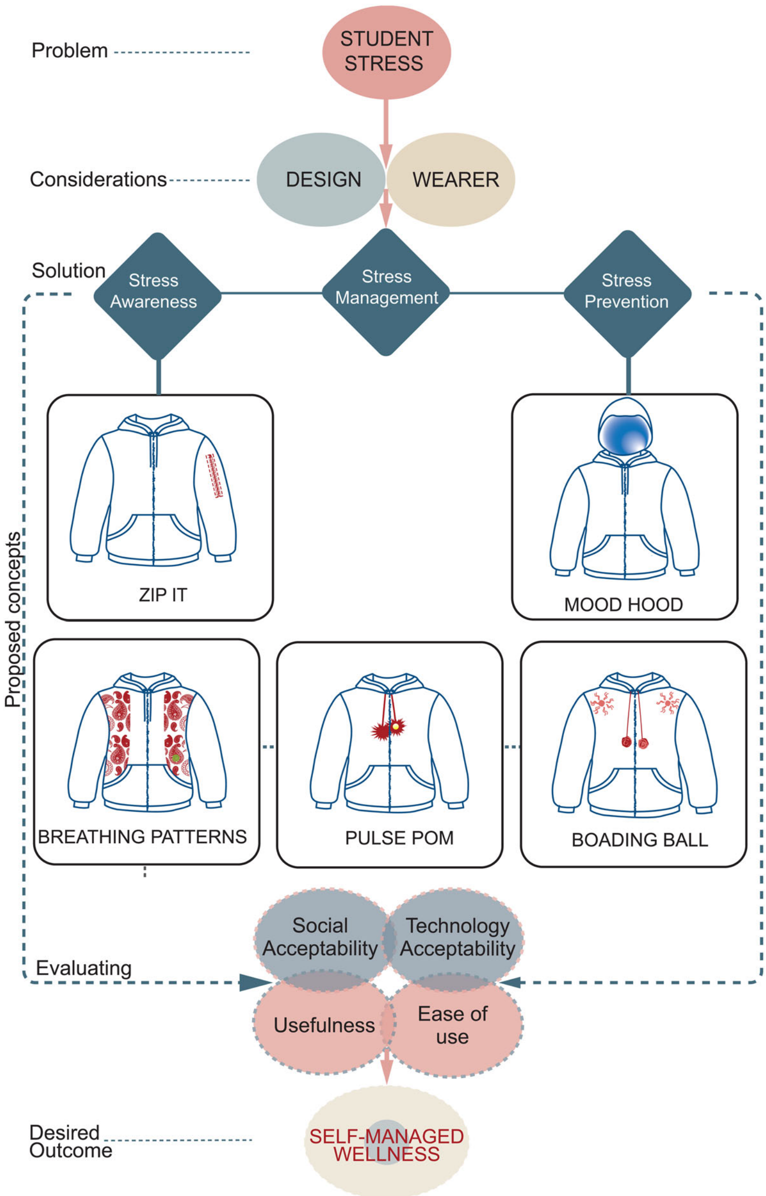

Figure 2
Concepts mapped to research themes.

is a response to stress, and fidgeting with textiles or clothing can be a self-regulating mechanism. The use of gestures such as squeezing and fidgeting in relation to stress had been highlighted in the survey outcomes. Squeezing stress balls is also a mechanism to reduce anxiety (Hudson et al. 2015). "Soft research" suggests that squeezing a stress ball may help the body to release tension in stressful moments, acting as an aide to encourage muscles to relax. Fist clenching and releasing is a useful component in mental health and wellness programs for adolescents (Khanna et al. 2007) and the technique is popular in holistic relaxation therapies (Jamison 2006; Everly and Lating 2019; McKay 2018; Hughes et al. 2019) note the benefits of clenching and releasing fists in the management of anxiety.

A range of e-textile balls was created to serve as textile capacitive sensors activated by squeezing, manipulating and fidgeting with them. These could be added to the drawstrings of hoodies. The idea was that by squeezing the ball in moments of stress audible feedback would be activated which increased in frequency relative to wearer stress. This would bring attention to the wearer who might be sub-consciously stressed and had paid little attention to an increasing stressful situation. The more tightly a fist is clenched around the ball, the higher the pitch of the audible feedback. When the threshold is exceeded the feedback tack is changed. The ball stops offering audible feedback on stress levels and activates haptic feedback via vibrating mini motors which act as a self-soothing cue for the wearer to engage with personal bio-feedback to counter the stress.

Capacitive Sensing

The technology utilised in the Baoding Ball sample was capacitive sensing which detects changes in pressure. In this instance the pressure was brought about by pressing, pushing or squeezing the conductive textile ball which acted as a sensor to measure changes in the resistance of the electrical characteristics of the textile. The textile capacitive sensors blended conductive and non-conductive materials and the non-conductive materials acted as a separator for the conductive materials. When a small electrical charge is applied to the textile, the act of applying pressure through squeezing brings the conductive materials together and changes the resistance. This is then mapped to an e-textile circuit board (Adafruit Playground), coded (Arduino software) and outputted as audible sound and haptic vibration.

Baoding Ball Design

Figure 3 shows the schematic design for Baoding Ball. Figure 4 shows how eight felted ball sensors were constructed using different methods. Some were wound around a donut template; some were constructed by dry needle felting; others were wet felted and then dry needle punched with steel fibre in lattice patterns. One ball was crocheted and stuffed with a mix of conductive and non-conductive batting and another was a wound construction which was tied in a net and boil washed in a washing machine. Each was made from a combination of wool yarns mixed with varying compositions of nickel, steel fibre and copper. Figure 5 shows the circuit construction being tested with different balls.

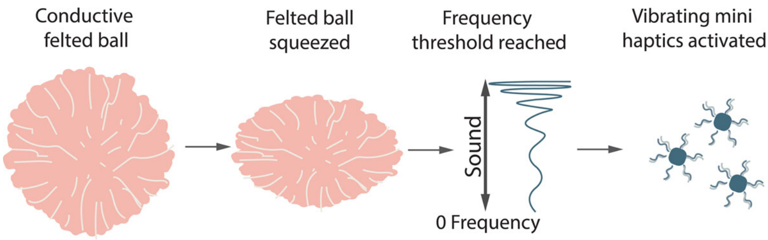

Figure 3
Baoding Ball design schematic. Capacitive sensing: Input-output sequence.

Figure 4
Baoding Ball variations on textile sensor construction.

Figure 5
Baoding Ball being squeezed and tested with multiple haptic motors.

Concept 2 – Pulse-Pom

Pulse-Pom "What if?"

"What if your clothes could visualise your heartbeat and help you to moderate it in stressful situations?"

The idea behind the pulse-pom was to bring an awareness to the wearer of unnoticed stress. Heart rates are elevated in times of stress, and by interacting with the crocheted pompom, the wearer's heartbeat can be visualised through *"pulse-and-fade light"* to mimic a heartbeat. The wearer can then consciously work on slowing down her own breathing and receive positive biofeedback that her heartbeat is lowering, visualised by the corresponding slower pulsation of light. A pulse is the number of times that a heart beats per minute. This is measured by pulse wave modulation (PWM) which is controlled by digital signals. These signals have two default positions of either on or off, however the amount of time that the signal reads high compared to low can be altered. These outputs can simulate an analog result by applying short bursts of voltage in a pulsating fashion. Pulse can be detected using light with a process known as photoplethysmogram (PPG). Changes in blood volume associated with arousal or stress can be detected at the peripheral level of circulation optically. Green light placed close to the surface of the skin can travel through the tissues and is more readily absorbed by red blood than the surrounding tissues. Figure 6 shows a tiny sensor placed next to the micro LED green light. It can sense changes in light which corresponds to even the tiniest changes in blood flow. The sensor output (PPG) was mapped to the pulse wave modulated light (PWM) by programming an e-textile circuit board.

Pulse-Pom Design

A pompom was crocheted in wool with the end use intended for the draw strings of a hoody or knitted hat. The top and bottom of the pompom were left open at both ends so that a pulse sensor could be embedded and positioned to be visible from the outside through a small opening at its bottom. The opening at its top enabled the technology to be inserted into the pompom. It was lightly stuffed with light-diffusing wadding and the output was visualised with a micro-LED, programmed to pulse light which diffused through the pompom. When activated by a tiny push switch embedded in a french-knitted drawstring, the pompom could be pressed very lightly on the back of the wrist below the line of the thumb or the forefinger to measure the heart rate. It was important that the forefinger rather than the thumb came into contact with the sensor as the artery in the thumb can make it harder to count accurately.

Once the hardware and software was tested it was then further developed into the Pulse-Pom sample. Figure 7a and b shows a

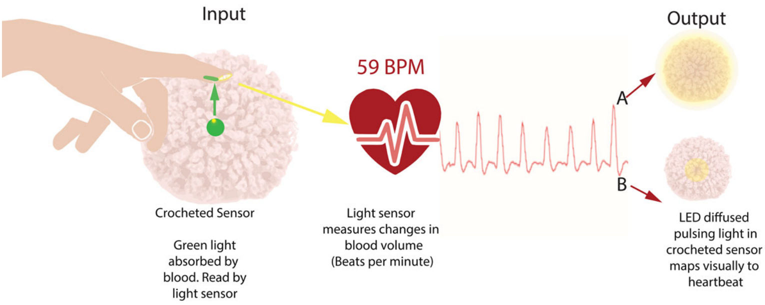

Figure 6
Crocheted Pulse-Pom schematic. Photoplethysmogram (PPG). Pulse sensing with light.

Figure 7
(a, b) Crocheted sensor. Pulse wave modulation (PWM) visualised through light.

second version of the Pulse-Pom mapped to colour which changed according to heart rate, dependent on whether breathing was rapid or controlled.

Concept 3 – Breathing Patterns

Breathing Patterns "What if?"

"What if the patterns on your clothing could conceal and reveal your increasing levels of stress through micro-light, and then help to moderate them?"

Feedback from the survey revealed a preference for discreet and simple feedback related to personal stress. Biofeedback directed at heart rate variability (HRV) has been associated with managing stress and anxiety (Prinsloo et al. 2013). Similarly to the Pulse-Pom sample, the Breathing Patterns sample relied on bio-feedback to bring about a positive response to stress. The outputs and changes in Breathing Patterns however, differed in that they were visualised by micro LEDs hidden in the pattern of a garment which changed colour relative to the level of stress experienced by the wearer.

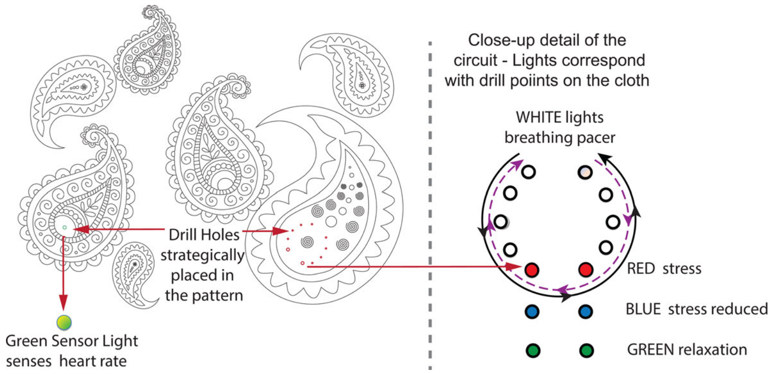

Figure 8
Schematic of Breathing Patterns concept. Changes in heart rate variability outputted in coloured micro-LED.

Breathing Patterns Design

A paisley patterned design was drawn in Adobe Illustrator with drill points strategically incorporated into the design and then laser etched on to a wool, felt-based cloth. Figure 8 shows a schematic of the paisley design and illustrates how the concept works. At times of perceived stress, only the wearer would know the position of the sensor within the pattern, which measured heart rate variability. Threshold variables of increasing stress mapped to colour and discreetly displayed through the pinholes would indicate the level of stress, relative to increased heart rate. Rapid breathing associated high stress was indicated with red micro-light. As the wearer actively slows down her breathing, the colour of the light changes to blue, and as a complete state of relaxation is achieved through slowing down breathing the light patterned turns to green (Figure 9 – stills taken from video footage). These confirmations of physiological change affirm the wearer's positive action and further contribute to overall sense of de-stressing. (The reference for the coding was based on a heart-rate variability sensor tutorial from Adafruit.com).

Concept 4 – "Zip It"

Zip it "What if?"

"What if your zip was a proxy for absorbing your 'silent screams' in situations where you can't show your stress outwardly?"

"Zip It" was a virtual concept and its potential was left open to interpretation by the wearer to encourage discussion from individual perspectives in the focus groups. The idea was loosely based on stress and anxiety, and how a wearer might modify behaviour relative to her environment. It sought to acknowledge states of wearer anxiety in social settings where it would not be appropriate for her to freely

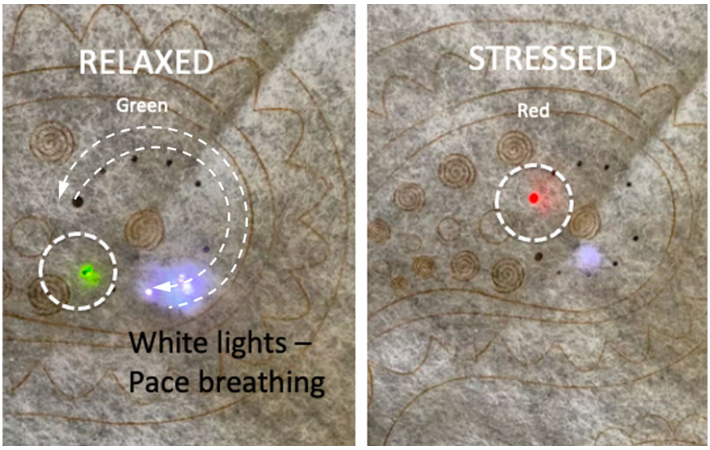

Figure 9
Laser cut patterned fabric revealing micro-LEDs. Green (relaxed) and Red (stressed). Stills from video footage.

express this, for example at a meeting or in class. It was an idea to give a voice to a "silent scream." The concept raised further questions that were posed to the focus group who were asked to consider if elapsed time might enable the wearer to calm down; if it was important to recognise how stressed the wearer felt in-the-moment; if it would be useful to acknowledge a silent emotion without feeling negative physiological effects, and upon reflecting later, what effect their yelling might have on others.

A study into stress in adolescents by (De Anda et al. 2000) found that yelling was used as a maladaptive coping strategy as reported with high frequency by a substantial percentage of adolescents in their study. However, yelling has a negative impact on the brain and can have both the psychological effect of increasing anxiety, and the physiological effect of increasing blood pressure and heart rate (Tomoda et al. 2011). Other research suggests mentally yelling *"stop*," is a useful stress management tool (Donovan and Kleiner 1994), while (Hrvatin 1997) uses the phrase *"Silent screams"* to explain a self-embodied emotion that people cannot talk about for a variety of reasons.

"Zip It" Design

The idea of "Zip it" was that when a wearer was feeling stress in an environment where it is not possible or appropriate to express this audibly, she can record the intensity of her stress using a Likert scale zip which is actioned by pulling it up to silently visualise the intensity of her stress. Stitching tiny conductive fabric strips to the teeth of the zip at increments creates an electronic Likert scale. The zipper pull acts as a linear potentiometer, which is a sensor that measures displacement. In this instance, the displacement is the wearer's state of

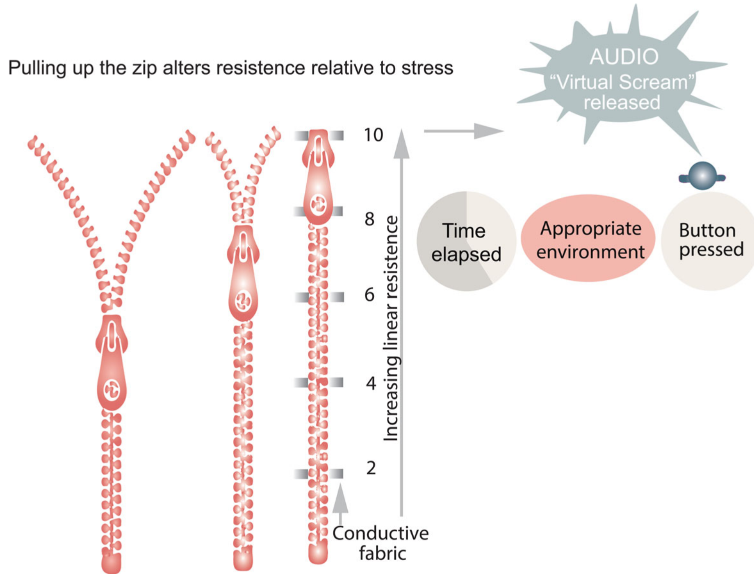

Figure 10
Concept for "Zip it" – resistive sensing.

mind from "not stressed" to "increasingly stressed." This is mapped to increasing sound frequency which is inaudible (a silent scream), and stored to a mini sewable speaker. Later, in an acceptable environment of the wearer's choosing a button on her garment acts as a trigger and releases the anxiety through the speaker as an augmented scream, at an audible frequency commensurate with the level of anxiety registered by the zip (Figure 10). This enables the wearer to have greater understanding of her "in-the-moment" stress and retrospectively reflect upon this.

Concept 5 – Mood Hood

Mood Hood "What if?"

> "What if you could improve your 'Winter Blues' without sitting stationary in front of a SAD lamp, by pulling up your hood as you journey to Uni?"

The use of light in treating depression was first proposed by (Rosenthal et al. 1984) who contended that mood lowering effects of stress can be countered by light therapy. Blue wavelengths in particular increase effectiveness and improve cognitive function and positive mood (Roehlecke et al. 2013). It offers antidepressant benefits more rapidly than medical intervention (Alotaibi et al. 2016). Seasonal Affective Disorder (SAD) is most commonly treated by sitting in front of a light box that emits simulated daylight. This is inconvenient and can be a poor use of time in the mornings when users are preparing for the day ahead. Although light source of 10,000 lux

Figure 11
Participant interacting with Mood Hood. © P. Marshall.

is recommended, recent studies have shown that blue light is effective at only 200 lux (Phillips et al. 2019). These findings meant that blue light fibre optic had the potential to be considered as a viable option for a blue light textile accessory. Fibre optics are flexible and can be effectively woven into fabric, making them a possible material for wearables. They have the distinct advantage of utilising less light and less power than other illuminating sources.

Mood Hood Design

Light therapy is effective and safe when entering the eye via peripheral vision (Levitt and Lam 1999; Pail et al. 2011; Brouwer et al. 2017). A hood which is an everyday socially acceptable component of a garment with an established self-identity and a large display platform offered an ideal medium to explore a blue light, fibre optic hood. The hood was engineered to extend beyond the natural line of the face and was lined with organza woven with blue light fibre optics to enable blue light to enter the retina via peripheral vision. Fifteen minutes of exposure to blue light in the mornings is the optimal requirement to enhance mood and the premise of the “Mood Hood” was that the wearer can pull the hood up around her head in the morning while going about her normal morning routine. After testing different fibres and base cloths, a side emitting fibre optic fabric on a grey base was selected as it gave optimal output when illuminated. It was slightly abraded by manipulating the fabric to partially break down its structure, causing more light to escape across the area of the fabric. The outer cloth was made from an opaque and breathable fabric with a cotton, bamboo and elastane blend to ensure comfort. The hood also featured magnets to fasten and position it to maximise the placement of the blue light towards the retina. Figure 11 shows a participant interacting with Mood Hood. The materials all complied with Photobiological Safety Standards (Anon 2013) which ensured protection against retinal photochemical injury from chronic blue-light exposure.

Evaluation of Concepts

E-health wearables are increasing in popularity, however, little is understood of the value that they bring to wider society and ongoing research seeks to establish this (Maksimović and Vujović 2017; Leung and Chen 2019; Guo et al. 2020; Papa et al. 2020; Bakhshian and Lee 2022). With the exception of evaluating fitness wearables (McCallum et al. 2018; Talukder et al. 2018), there is limited evidence to quantify how wider society desires or values e-health products. Without personal endorsement wearers' are unlikely to accept e-health wearable garments as a self-administered help strategy. In the context of this research a focus group methodology was selected to establish if e-textile accessories and garments were acceptable to a student demographic as a self-help intervention for wellbeing.

Full ethics approval was granted by the university to conduct the focus groups. The application was carefully constructed and mindful of the sensitive nature of the research to ensure the welfare of participants. Appropriate protocols were put in place to provide support to participants should they become distressed during or after the research and this included links to mental health support counsellors. Students who had completed the online questionnaire and were interested in further contributing their views to the research through a focus group were invited to submit their email addresses at the end of the online questionnaire. A convenience sampling method was used to draw a focus group cohort. This type of sampling is common in healthcare studies where participants meet the inclusion criteria (Acharya et al. 2013). The inclusion criteria were female students aged between 19 and 34. These were based on previous research which investigated how age profiles affect the global burden of disease attributable to the mental health of young people (Whiteford et al. 2013) and how females are more predisposed to mental health issues such as anxiety and depression than males (McManus et al. 2009; NHS 2020; NHS Digital 2021). 16 students who had responded to an open invite and registered an interest in being involved with the study were invited to participate in focus groups. Focus group 1 was drawn from design students and focus group 2 were medical students, all of which fitted the inclusion criteria. This provided a balance of student perspectives across design and health. Due to covid related issues at the time 11 female university students were able to attend the focus groups. Both quantitative and qualitative data was collected during the workshops. Bespoke Starfish Likert scale pro-formas were adapted from the Mental Health Evaluation Recovery Star (MacKeith and Burns 2010; Briggs-Goode et al. 2016) with a Technology Acceptance (Davis 1986) context to suit this research. The Likert scales collected participants perceptions

Table 2. Cumulative average scores of the e-textile concepts visualised

	Baoding Ball	Pulse-Pom	Zip It	Breathing Patterns	Mood Hood	Average
Social	77%	53%	80%	60%	73%	69%
Tech.	69%	62%	84%	65%	85%	73%
Ease	100%	85%	80%	80%	98%	89%
Use	84%	76%	60%	78%	91%	78%
Aesthetics	95%	65%	95%	77%	100%	86%
Average	85%	68%	80%	72%	89%	79%

The cumulative averages for each concept were extremely positive with three of the five scoring over 80%. The total cumulative average was 79% which strongly indicated their likelihood to be adopted by the target demographic.

of: (i) perceived usefulness; (ii) ease of use; (iii) technology acceptance; (iv) social acceptance and (v) aesthetics of each concept. The concepts presented explored different ways to playfully integrate technology with textile. Participant interaction with the concepts and casual dialogue between them was recorded. The elements of fun and surprise that the students expressed was tempered with sensitive conversations of sharing their own wellbeing narratives. The students then independently scored each concept and were encouraged to elaborate on their scores with commentaries and these were collated after the workshop. Oral and written comments were transcribed. This enabled identification and coding of common themes and perspectives. The quantitative data from the returned Likert scores was analysed in a database and average scores across all participants were recorded in percentages. This established where there was consensus on which concepts were acceptable in terms of the technology used; and socially acceptable as a 'self-help' intervention in a daily lifestyle context.

Results

Each of the 11 participants provided a score for each of the five elements associated with technology acceptance (Davis 1989) across all five samples giving a return of $n = 55$ scores for each concept. Table 2 summarises the average score for each element (horizontally), and for each sample (vertically), and their respective cumulative scores. The overall average score for **technology acceptance** was 73% and was calculated by taking the 11 participants average score across all of the concepts. Discussions with the students uncovered that the technology was appealing in that it was simple to use with clear analog output, was not data driven and did not require the support of an app. The average **social acceptability** score was 69%. PulsePom lowered the average score as it was not considered discreet enough, otherwise the results for social acceptability were encouraging. This suggested that there would be a reasonable likelihood that the e-textile wearables presented would be socially accepted as an early intervention for the self-management of student

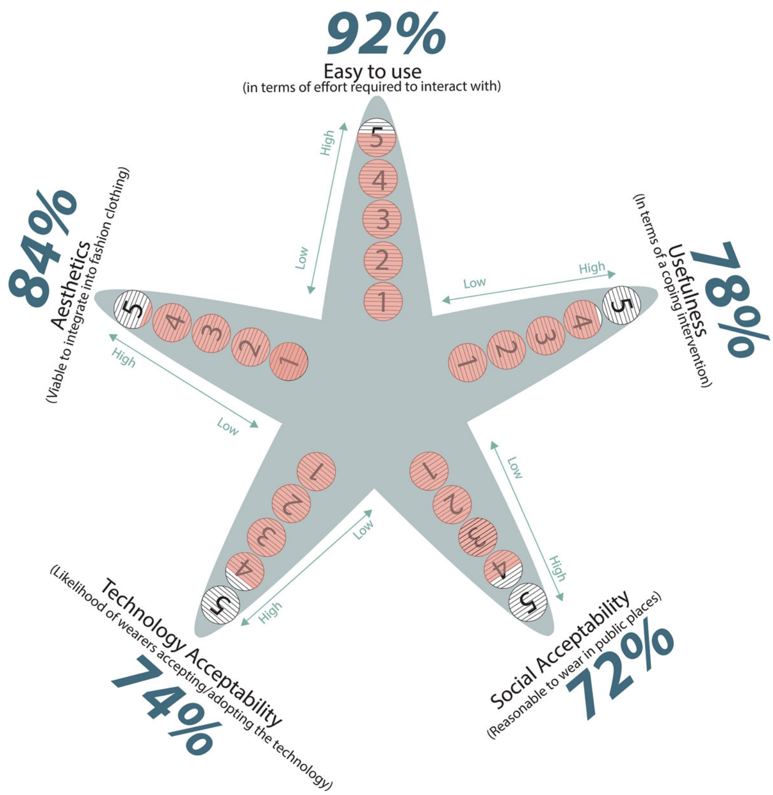

Figure 12
Participants cumulative average scores of the 5 concepts visualised.

wellbeing. Discussions in the focus group reaffirmed the data. Students also revealed their preferences for feedback mechanism in different environments and the results revealed that haptic vibration appeared to be the most socially acceptable method of receiving feedback in any environment, followed by micro-LED in certain environments at the wearers discretion, and audible feedback was not deemed socially acceptable. The average scores **for ease of use and usefulness were** (89%) and (78%), respectively. This suggested that the designs were functionally effective. The average score for **aesthetics** was (86%) providing a strong indicator that the textile concepts were well received in terms of their visual appearance. The samples that were more developed through textiles were best received, in particular Mood Hood. The combined averages for each element of the Starfish Likert scale are visualised in Figure 12.

Written qualitative data and open discussion was important to illuminate and further explain some of the quantitative data. Mood Hood had the highest score across all aspects and this was supported by the student narratives. Baoding Ball also had a high cumulative average score. Its average was lowered by its technology score. Students enjoyed the tactility of the felted balls and fidgeting with them as a stress reliever. The audible feedback was not popular, with a consensus that this drew too much attention to their stress. The students enjoyed the haptic vibration aspect of feedback, and the sample was adapted for focus group 2 where a haptics only version was piloted. Pulse-Pom's lower average was due to the visibility of the pulsing light which again was deemed indiscreet. However, one student had commented that she knew when she was stressed and was interested in this sample as it helped her to address the stress. The students did like the concept, but they just preferred to confine their engagement with it to private environments. Similarly so, with "Breathing Patterns," most students were happy to engage with the textile if they could find a quiet space to do so. They found the ability to change the visible feedback of colour changing lights mapped to their conscious calming thoughts fascinating, however whilst most liked the colour-coding system, a few students remarked they preferred fewer lights and less complexity. The Zip-It sample had a high scoring average, however 60% of students thought that it would not be useful to them. This was the only concept presented as a virtual concept and was deliberately left open to interpretation to encourage debate and this may have had a bearing on perspectives offered. Some of the comments explained the students' thinking:

> "I can be prone to over-dramatise the scale of my stress -something which is moderately stressful could be a 10 out of 10 in the heat of the moment."

> "I wouldn't find this as useful or actionable as the other examples."

> "The zip just looked like a regular zip. I think it can probably blend in easier into a garment than some of the other examples I would be happy to use this in my garments or in any social setting."

The most popular concept across all participants in both focus groups was Mood Hood.

One student remarked that this was her favourite out of all the textiles presented and that it was novel and "easily adoptable" into something that she would wear every day. This was surprising, as there was no actual interaction needed with the accessory and it was the most "obviously lit" of the concepts which was contradictory to the need for discreetness that students had alluded to. Their discussion helped to explain their reasoning, with one student saying that she got a "secure feeling" by pulling the hood around her to create her own private space. This indicated that the hood offered other sensory benefits conducive to supporting stress management which was beyond its intention of combatting seasonal affective disorder (SAD) and low mood. Their comments reinforced their enthusiasm for this e-textile accessory and endorsed its value as being socially acceptable and having acceptable technology:

"It would be something I would wear in public, especially in the winter".

"I would have no issue wearing this in public".

"I feel the hood is subtle enough to be socially acceptable".

"I would wear this into uni".

"I would definitely wear it. Subtle enough to have in a public place. Really great design. Think it would be very useful - slightly mesmerising. Very calming".

The ease of use and the usefulness of the concept suggested that it addressed sensory overload in public places, which is a known source of anxiety and stress, and student comments reaffirmed this:

"I love how it's comforting; a big hood would make it better to shut out the outside world".

"I feel it's very comforting and I immediately felt at ease".

"It feels private and comforting".

"I would find this hood very useful".

"It allows time to focus on yourself".

"I think it would be useful, it would lift your mood and allow you to clear your mind".

Limitations of Practice and Future Research

There were a number of limitations to the research. The making processes were organic meaning that it was not possible to accurately calculate the ratio of conductive to non-conductive yarns and how these varied in different combinations. The felting processes, particularly with the machine-washed felted balls meant that it could not be determined how much of the conductive fibre would come into contact with the wearer after felting. The length of conductive yarn attached used in stitched traces and the thickness of ply attached to the felted balls had a bearing on resistance which could only be estimated. Connection traces were hand-stitched to the microprocessors using conductive thread which frayed very easily, leaving the connections less secure. It could be argued that drawing attention to sub-conscious stress has the potential to exacerbate stress and a support action plan was put in place as part of the ethics protocol to mitigate this. A focus group could be perceived as a limitation in itself and raise further research questions about the novelty of e-textiles creating a sense of group excitement or “group think” (Boateng 2012). This of course is a common problem with all focus groups, however with something as sensitive as personal mental wellbeing, affording wearers the opportunity to experience the samples privately and over a longer time period may have had a bearing on results. This is something that will form the basis of future research.

Discussion and Conclusion

The e-textile concepts presented in this paper displayed a unique ability to regulate wearers’ emotions. Their tactile properties encouraged human touch such as stroking which elicited feelings of comfort and self-soothing. By virtue of their conductive properties and their proximity to the skin they were able to glean physiological signs from the body associated with stress, such as chemical changes in the skin or changes in blood volume. The electronically augmented haptics amplified wearers’ feelings of well-being. The e-textile accessories demonstrated their potential to act as a personal barometer which understands dips in mental health. The five samples, with four developed as working prototypes gave the opportunity for the researcher and potential end-wearers to explore their own in-the-moment stress. The *“What if… ”* scenarios were useful in providing an empathic method to transfer an intended experience into the mind of potential wearers, and the questions posed in this research encouraged students to contextualise their feelings around stress to their personal situations. They opened up wider debate about student mental health which highlights the issue on a broader stage. The concepts demonstrated that melding knowledge from design, science and technology can support communities and address social issues such as mental health in an accessible way. Each idea was tethered to a physiological scientific principle (electrodermal activity, skin conductance response, heart rate variability, neuroscience, and seasonal affective disorder) and the textiles played a key role in presenting these to the students in an understandable format, without the need for medical language. The technology-led processes such as pulse wave modulation and capacitive sensing were actioned through the coding of microprocessors and scaffolded around scientific concepts and textile processes. This highlights the exigency for designers to become hybrid practitioners and cross-disciplinary thinkers. It further underscores the need for complex problems to be explored through multi-disciplinary research and collaboration, with a new emphasis on each partner learning across disciplines, rather than offering their own discreet contribution to the research. Such approaches can demonstrate the relevance of the fashion design industry by building hybrid knowledge across un-related fields, and make innovative contributions to solving societal problems such as the escalation of student mental health.

It was clear from the results and the written comments at the focus group workshops that students were receptive to the idea of self-managing the early signs of stress. Their enthusiasm about this being mediated through their own clothing and on their own terms was reiterated by their narratives at the workshops. These were articulated through their preferences for haptic feedback, and it was clear that there was no appetite for audible feedback. The students endorsed light as an acceptable method of feedback provided that it was discreet, with the exception of Mood Hood. The micro-LEDs used in the samples reassured them of discreetness. The decisive factor for students embracing wearable textiles to support their mental wellbeing was the textiles' potential to merge unobtrusively into daily lifestyles. The simplicity of the feedback and minimal distraction to their day appealed to the students. Interacting with the e-textiles brought about playful narratives and an unexpected sense of fun, enjoyed privately by the students. In a wider context, embedding non-binary feedback, in easily understandable formats into wearable textiles brought about a shift in how wellbeing feedback can be physiologically monitored. It moves static monitoring reliant on professionals away from clinical environments, to a more mobile, self-managed alternative. This shift enables wearers to respond to in-the-moment stress in their daily environments and encourages them to take greater responsibility for their mental health.

The research brought a new paradigm to address student wellbeing through tactile interventions. It demonstrated a proof of concept that e-textiles embedded in clothing or textile accessories can offer female students an unobtrusive intervention to support their mental wellbeing whilst respecting their privacy. The research afforded novel ways of reframing affective properties of materials to bring an understanding of physiological data and psychological perception. The exploration through sensory touch, haptic experiences and non-binary biofeedback introduced new forms of non-verbal communication.

The experiential approach taken to conduct the research was pertinent to the success of the outcomes. It easily combined with other overlapping methodologies. Harnessing the researcher's experiential and tacit knowledge, and drawing upon the lived experiences of the participants created new transformational knowledge through design. The author's tacit knowledge and experimental approach embedded in the outputs metamorphosed to articulated knowledge in the outcomes, which bring new value to this researcher and others. Holistically, the work presented enables other researchers to further understand and build upon the positioning of technology within textiles and fashion, and apply it to different lifestyle contexts or communities to support personal wellbeing.

Fritzing software: https://fritzing.org/
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