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# In-Situ exploration of emotion regulation via smart clothing: an empirical study of healthcare workers in their work environment

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**ABSTRACT**

Healthcare personnel suffer from an increased risk of stress, burnout, and depression due to the challenges of the COVID-19 pandemic. Studies show that interactive smart textiles help people alleviate their emotions. In this research, we investigate how to utilise interactive textiles to help healthcare workers mitigate their negative feelings. We have designed a smart t-shirt that encourages its wearers to perform body movements to enhance their positive emotions, stimulated by vibrotactile and audio feedback mechanisms. We demonstrate our smart t-shirt's utility by asking healthcare workers (including physicians and nurses) to use it for five consecutive days. Our prototype design supports using it anywhere, including work, home, and other places. We evaluated our smart t-shirt prototype for emotion regulations at work for healthcare workers through an in-situ user study conducted at three hospitals. Results show that using the smart t-shirt positively impacts the healthcare workers' immediate emotion regulation when they experienced emotion fluctuation and provided a more positive attitude towards their work. We conclude by analysing the potential factors that influence emotions and outline the design space of e-textiles for emotion regulation in real-life use.

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Interactive textile; E-textile; emotion regulation; healthcare workers; in-situ research

## 1. Introduction

Research shows healthcare personnel are more prone to stress, burnout, and depression, especially during the pandemic (Spoorthy, Pratapa, and Mahant 2020). Healthcare workers are often confronted with heavy workloads, irregular working hours, and their work often consists of long periods of high tension and intensity. In addition, previous research has indicated that female healthcare workers were more likely to experience psychological burdens (Lai et al. 2020). Although the problem was well recognised and described, little research has explored the possible intervention methods to help healthcare workers to cope with stress, burnout, and depression issues. Some measures, such as psychological support, exercise, online-push messages for mental health issues, provision of rest areas, have been used, but the uptake of these interventions has been limited and the effects of these interventions were often unevaluated (Sriharan et al. 2020). We think introducing motion and touch is a readily accessible but under-explored strategy among these emotion regulation strategies. Moreover, motion can be easily captured using smart textiles.

E-textile qualities such as conformity to the body and flexibility increase the intimate relationship between interactive textiles with the human body, leading to the wearer more opportunities for sensing and actuation. These features have the potential to lead to new interactive possibilities concerning emotion recognition, emotion communication, and emotional engagement. Recently, studies have investigated the theme of interactive textiles and emotion regulation in an early stage. For example, several researchers have attempted to regulate emotions through altering users' sensory feedback, among which vibrotactile feedback and tactile feedback are the two most frequently used ones (Lemmens et al. 2009; Bordegoni, Ugur, and Carulli 2012; Giannoulis and Sas 2013; Mazzoni and Bryan-Kinns 2015; Paredes et al. 2015; Foo et al. 2018; Ghiasi et al. 2019; Tajadura-Jiménez, Väljamäe, and Kuusk 2020). Other emotion adjustment methods, such as social connection (Wang, Nagai, and Yuan 2017), introducing narrative (Palaigeorgiou et al. 2019), changing recognition (Costa et al. 2017), and introducing motion and touch (Davis 2019), have emerged in interactive textiles studies in the past three years.

Psychological experiments have revealed that the relationship between body movement and emotion is bidirectional (Damasio 1999), and as a result, our

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body movements may impact our emotional state. In a previous study, *E-motionWear* (Jiang et al. 2021), was built on the somatic marker hypothesis (Damasio 1999). It was an interactive shirt that aims at enhancing the user's positive emotion by motivating them to do specific body movements (elbow flexion/extension, shoulder flexion/extension, open and closed arms, neck flexion/extension) with three movement feedback mechanisms (audio, visual and vibrotactile). To determine the effect of potential interactive movements and feedback mechanisms, they carried out the lab experiments to validate each factors' impact. Findings suggested that body motion does have the potential to regulate emotion in interactive textiles. However, there is still a gap between wearing experimental wearable devices in the laboratory and real-life, especially for emotion-related issues due to the following reasons: (1) participants in lab experiments are not necessarily those who are most in need of emotion regulation; (2) emotion regulation experiments are mostly conducted in labs through emotion induction methods, while real-life emotions at actual work environments may not be easily induced; (3) in a laboratory setting, researchers and participants, being isolated, inevitably have a specific impact on user emotions. In light of this, we redesigned an interactive t-shirt prototype. The purpose of this prototype is to explore this bidirectional relationship between body movement and emotion beyond the lab setting.

In this research, we aim to evaluate the usability of our smart t-shirt prototype with healthcare personnel in their work environments. To achieve this, we recruited six physicians and nurses from three hospitals who volunteered to participate in our experiment for nine days. Our primary focus is to investigate the impact of using our interactive smart t-shirt prototype to regulate their emotions at work. We make the following contributions: (1) basic detailed instructions for smart textile designers to build interactive smart t-shirt prototypes to regulate emotions; (2) insights into how to support emotion regulation using a smart t-shirt prototype; and (3) understanding the factors that could have an influence on the design of movement-based interactive textile for emotion regulation in real-life use and its implications.

## 2. Motivation and related work

### 2.1. Movements conducive to emotional well-being

The principles of the movement-based emotion regulation approach have been discussed in Damasio's somatic marker hypothesis (Damasio 1999). It intimated that the role of body motion and emotion is mutual, emotion can be expressed through body movements, and bodily movements may directly activate emotional experiences (Gross 1998; Strack, Martin, and Stepper 1988; Niedenthal et al. 2005; de Rooij 2014; Shafir 2016). For example, Yoga and Taiji movements can bring different feelings to people, which are often used to balance their body and mind (Winters 2008; Francis and Beemer 2019; Shafir 2015). Thus, one of the strategies to achieve emotion regulation is through voluntary changes to one's posture and movements (Shafir 2015, 2016). Several empirical psychological studies have confirmed this. For example, Briñol, Petty, and Wagner (2009) suggested that people in 'confident' positions (like sitting with their chest out) experienced a more positive mood and increased confidence in their abilities, while 'doubt posture' (back curved) led to the opposite effect. Cacioppo, Priester, and Berntson (1993) found that arm gestures can affect their appreciation in the process of evaluating neutral objects. Arm gestures that are generally associated with an approach-motivational orientation (generally toward the body) led to a more favourable judgment of the neutral objects than arm gestures associated with an approach-withdrawal orientation (generally away from the body). Similarly, the research of Neumann and Strack (2000) and Casasanto and Dijkstra (2010) showed that moving objects with upwards facing hands facilitated the retrieval of positive emotions, whereas downwards hands led to faster retrieval of negative emotions. They interpreted the results as supporting theories of metaphorical mental representation; that is, the activation of the implicit mental metaphor 'Good is Up'.

In addition, game-based research explored motion-based design to generate emotions in players (Bianchi-Berthouze and Isbister 2016). Melzer et al. (2010) and Isbister, Schwekendiek, and Frye (2011) developed this approach by looking at how body movements may affect the emotional component of the gaming experience. Their studies found that games that encourage body movement lead to higher emotional arousal levels than those that use a standard controller. Gerling et al. (2012) investigated the full-body motion-based game interaction with older adults. They found that full-body motion-based games could positively affect older adults. They also reported that their participants enjoyed the experience of playing the game by indicating a more positive affective state.

### 2.2. Interactive textiles for emotion regulation

Interactive textiles possess unique advantages for emotion regulation. First, interactive textiles can get close contact with the human body to obtain the required

information, such as physiological signals, movements, and sounds (Lemmens et al. 2009; Giannoulis and Sas 2013; Costa et al. 2017; Ghiasi et al. 2019; Stylios and Chen 2020). Second, interactive textiles can be enhanced with electronically controlled feedback methods to present different types of feedback and create additional sensory experiences to wearers (Lemmens et al. 2009; Giannoulis and Sas 2013; Mazzoni and Bryan-Kinns 2015; Paredes et al. 2015; Costa et al. 2017; El Ali et al. 2020; Stylios and Chen 2020). Third, smart textiles can be used as a dynamic interactive interface to interact with users (Bordegoni, Ugur, and Carulli 2012).

In recent years, there has been emotion-related research where interactive textiles were used for different research aims. Many of these were designed for emotion recognition using e-textile and physiological signal sensors, for example, in the field of affective computing (Picard 2000). Some cases also present emotional information through different sensory feedback mechanisms, which are used for emotion expression, emotion communication, or self-emotion reflection (Neidlinger et al. 2019; Woodward et al. 2018; Davis et al. 2013; Huisman, Frederiks, and Heylen 2013; Iaconesi 2010). In some cases, it has been tried to influence or regulate user emotions through interactive textiles (Lemmens et al. 2009; Bordegoni, Ugur, and Carulli 2012; Giannoulis and Sas 2013; Mazzoni and Bryan-Kinns 2015; Paredes et al. 2015; Wang, Nagai, and Yuan 2017; Foo et al. 2018; Ghiasi et al. 2019; Palaigeorgiou et al. 2019; Tajadura-Jiménez, Väljamäe, and Kuusk 2020).

Furthermore, several distinct design strategies were adopted using interactive textiles for emotion regulation. (1) Create a sensory experience. One of the frequently used methods is to regulate emotions through sensory experience, especially vibrotactile feedback or tactile feedback (Lemmens et al. 2009; Foo et al. 2018; Tajadura-Jiménez, Väljamäe, and Kuusk 2020). For example, *Skin Deep*, *Hand MUFF* (Bordegoni, Ugur, and Carulli 2012), *VibeRate* (Giannoulis and Sas 2013), *Moody* (Mazzoni and Bryan-Kinns 2016), *Synestouch* (Paredes et al. 2015), *CUFF* (Ghiasi et al. 2019), were all e-textile based designs aimed at altering users' experience with various tactile feedback. (2) Social connection. Other emotion regulation methods were explored, such as bringing social connection into e-textiles (Wang, Nagai, and Yuan 2017), wearing interactive clothes between couples were found to have emotional influence. (3) Introducing narrative. The narrative was introduced in wearable e-textile, Palaigeorgiou et al. (2019) found the narrative clothes evoked more emotions when participants identified with the characters. (4) Changing recognition. Costa et al. (2017) designed *EmotionCheck*, a bracelet to regulate user's anxiety. They reported it was possible to regulate user's anxiety by providing false feedback of a slow heart rate. (5) Introducing motion and touch. Motion and touch were used in emotion regulation methods and have recently emerged in interactive textiles studies (Davis 2019; Jiang et al. 2021). For example, in textile expression research with *FELT* (Davis 2019), looking at and touching textile texture brought people different emotional experiences. Besides, a fashionable smart scarf (Jiang, ten Bhömer, and Liang 2020) was designed as preliminary research of touch-based interactive textile design for emotion regulation, and *E-motionWear* (Jiang et al. 2021) was a body movement-based interactive textile designed for emotion regulation in a lab setting. From the *E-motionWear* (Jiang et al. 2021) study, its facial expression, SAM (Self-Assessment Manikin), and interview results showed shoulder flexion/extension, open and closed arms movements significantly enhanced positive emotion.

### 2.3. Affective E-textile design evaluation - target group, location

Textiles and wearable artefacts appear in in-situ research for their wearability and creative data collection and representation potential in recent years. For example, the hankie probe project used a handkerchief as a medium for mobile user experience studies (Leitner et al. 2012). Three wearable prototypes were used for training technology probes in Yoga, circus, and weightlifting training (Turmo Vidal et al. 2020). However, most of the interactive textiles for emotion regulation studies were tested and evaluated in lab settings; very few are carried out beyond the laboratory. Lopes and Campos (2019) designed *SCAARF*, a scarf prototype for anxiety relief facilitation. The users under higher anxiety levels used the prototype in their daily lives for three weeks and then reported their feedback with a semi-structured interview. The scarf works with a mobile application for audio feedback and records anxiety levels before and after performing interactions using the prototype. Even so, the participants' user experience was not collected in-situ or in other natural settings. Previous work that examined interactive textiles for emotion regulation studies often relied on user testing methodology to evaluate the interventions. We believe gender, identity, in-situ user experience is essential factors for e-textile prototypes. However, in these studies, the target group was seldom considered during the experiments. Most participants are usually typical university students.

There are a few exceptions. For example, Foo et al. (2018) studied the emotional effects of on-body compression used all male participants with qualitative

interviews to explore user experience. Palaigeorgiou et al. (2019) used e-textiles as a narrative mediator for enhancing empathy in moral development. They invited grade 6 students to participate in the design evaluation as the target group and got positive feedback. In a similar way, Profita, Roseway, and Czerwinski (2015) designed *Lightwear* for people with seasonal affective disorder symptoms. For their study, they recruited users with symptoms and have Bright Light Therapy experience. Their results were useful and showed high user acceptance of the prototype.

We also want to evaluate the effectiveness of e-textile for emotional well-being in users' daily lives with specific target groups. Therefore, we presented iterated the smart t-shirt prototype and invited healthcare workers to participate in the in-situ experiment. The in-site experiment validated the positive emotional impact of wearing the smart t-shirt prototype for five consecutive days and investigated the healthcare workers' feedback while using it during their regular working schedule.

### 2.4. Emotion assessment methods in E-textile studies

Moment-to-moment fluctuations in affective experience have always been of interest. There is a variety of emotion recognition approaches in the literature (Mauss and Robinson 2009). Design studies on interactive smart textile for emotion regulation have often used quantitative analysis on the design impact of emotions. Of these studies, the Self-Assessment Manikin (SAM) (Bradley and Lang 1994) (including the ones that used emotional valence and arousal aspects) is the most used method for self-emotion assessment (Lemmens et al. 2009; Mazzoni and Bryan-Kinns 2015; Paredes et al. 2015; Mazzoni and Bryan-Kinns 2016; Ghiasi et al. 2019; Davis 2019; El Ali et al. 2020; Tajadura-Jiménez, Väljamäe, and Kuusk 2020). Other methods were adopted in a few studies, like Kansei engineering eight-way split model (Wang, Nagai, and Yuan 2017), anxious level score (Costa et al. 2017; Lopes and Campos 2019), or physiological signals like Electroencephalogram (EEG) (Stylios and Chen 2020). In other studies, on healthcare workers' emotional issues, the validity of the Job-related Affective Well-being Scale (JAWS) has been proven to be effective (Van Katwyk et al. 2000), and the Geneva Emotion Wheel (GEW) was also used in recording self-assessment emotion (Scherer 2005).

### 2.5. Visual data collection methods

Measuring emotional and user experience is critical but challenging in in-situ and long-time studies. Individuals' emotions frequently vary during the experience journey and difficult to recall. Multi immediate emotion data collection tools emerged from in-situ experiment practices. For example, *PAM*, is a Photographic Affect Metre for users to select the one which suits their current emotion best (Pollak, Adams, and Gay 2011). Besides, Probe is a useful method, especially for in-situ data collection (Gaver, Dunne, and Pacenti 1999). It is typically used for design inspiration. Participants are usually given a range of visual data collection materials, such as a diary, camera, postcards, questionnaires. However, it was also utilised as the experience data collection method in some cases. (Sundström, Ståhl, and Höök 2007) built a mobile emotional messaging system, *eMoto*, and invited participants as *in situ informants*, to enter and explore the subjective and distributed experiences of *eMoto* in daily use. Participants were provided with a probe kit consisting of a notebook, postcards, a disposable camera as a visual collection tool. The in-situ research inspired behaviours that they could not have envisioned in the laboratory setting, and the visual data collection method with the diary and questionnaires recorded the user experience generated in their daily lives.

## 3. System design

The design of our smart t-shirt aims to achieve the following three goals: 1) allowing body movements to regulate emotions, 2) providing two different kinds of feedback to the user, and 3) producing a lightweight, stretchy, flexible, and even washable prototype. We use a closed-loop design; thus, our prototype does not require a mobile phone or a computer. The user can turn on/off the prototype at any time. Moreover, the electronic components are covered with waterproof glue, and the mainboard is easily detachable from the t-shirt. In this section, we summarise the design and building process of the smart t-shirt prototype.

### 3.1. Interaction movements

In most cases, research on using movement to regulate emotion has focused on the joints in the human body, such as the flexion/extension of the shoulder (Cacioppo, Priester, and Berntson 1993) and neck (Shafir 2015), and open and closed arm movements (Rossberg-Gempton and Poole 1993). All these movements are proven effective in emotion regulation (Jiang et al. 2021). However, users with cervical spine conditions have difficulties performing the flexion/extension of neck movement (Jiang et al. 2021). Therefore, to help the user regulate their emotions more effectively, we only consider shoulder flexion/extension and open and closed arms in our design.

### 3.2. Feedback mechanisms

Previous work has shown that the feedback mechanism can motivate users to perform interactive movements to help regulate their emotions (Salminen et al. 2008; Tajadura-Jiménez et al. 2015). Most recently, Jiang et al. (2021) reported that vibrotactile and audio feedback mechanisms received more positive responses than visual feedback from their users when they were asked to do movement-based interaction with a smart textile prototype for emotion regulation. We adapted their recommendations into our prototype so that it supports audio and vibrotactile feedback mechanisms for shoulder and open/closed arms movements.

### 3.3. Fabric materials

Our smart t-shirt consists of three types of materials: 1) non-conductive, lightweight, breathable, stretchy, knitted sports jersey fabric (100% cotton) to facilitate user movements; 2) Eeonyx Stretchy Variable Resistance Sensor fabrics[1] to capture movements; and 3) stainless-steel conductive thread[2] to secure connections. We use three pieces of Eeonyx sensor fabrics (dimension: 1 cm x 6 cm) to capture movements. While two sensors are machine stitched both the front and back joints of the trunk and shoulder to monitor the open and closed arm movements, one is fixed underarm seam to capture the flexion/extension of the shoulder. We use conductive stainless-steel thread (12 µm, 9 ohms/m) in zigzag sewing stitches to secure the connections.

### 3.4. Electronic components

The sensor fabric has a resistance of 180 kilo-ohms while relaxed and 400 kilo-ohms when stretched. Each sensor fabric has a total resistance of approximately 268 kilo-ohms. The resistor we use in the corresponding series circuit is $R = \sqrt{R'max \times R'min}$ where R'max is the maximum resistance and R'min minimum resistance. Each sensor fabric is connected to the analog to digital pin of an Arduino Nano microcontroller board. We use two coin motors (8 mm width and 2 mm thickness) to provide vibrotactile feedback and a DfPlayer Mini module with a TF card and a speaker (8 ohms, 0.5W) in music mode for audio feedback. Figure 1b shows the circuit diagram of the electronic components. The coin motors are stitched at positions (front side of the chest and neckline side of the shirt) where they cannot be easily dragged while moving; thus, users can always feel the vibrotactile feedback (see Figure 1a). The music module is fixed on the Arduino Nano and is placed in the lower pocket of the t-shirt. We use a 2-bit dip switch is to change between vibrotactile and audio feedback modes. The vibration intensity and music volume increase with the flexion/extension of the shoulder and open and closed arm movements, respectively. A 5000 mAh lithium polymer battery (93×25×22 mm), which is placed on the lower side of the t-shirt, is used for power.

## 4. In-Situ experiment

The objective of this study was to investigate how to use a wearable smart textile to help healthcare workers mitigate their negative feelings. The chosen healthcare workers were asked to wear our smart t-shirt prototype during their working hours. Their emotional fluctuations were analysed during a nine-day experiment.

### 4.1. Participants

Six full-time female healthcare personnel (3 doctors and three nurses) working in three different hospitals

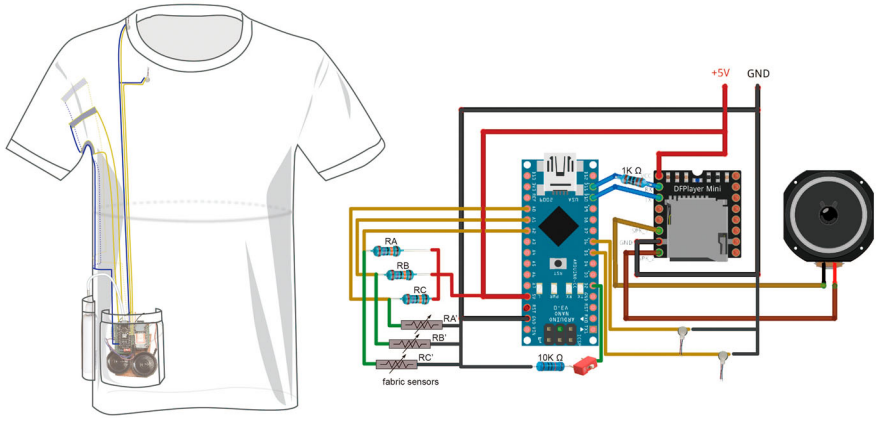


**Figure 1.** (a) a picture of the smart round neck t-shirt prototype, and (b) a diagram of the electronic components.

**Table 1.** Summarises the details of the participants.

| Participant ID | Age | Career | Hours (h) per week | Department |
|---|---|---|---|---|
| N1 | 23 | Nurse | >66h | Hospital ward |
| N2 | 24 | Nurse | Around 50 h | Emergency ward |
| N3 | 25 | Nurse | Around 60 h | Surgery room |
| D1 | 28 | Nephrologist | Around 47 h | Urology department |
| D2 | 29 | Radiologist (part-time PhD student) | 60-70 h | Hospital laboratory |
| D3 | 32 | Rheumatologist | Around 50 h | Rheumatism department |

across China volunteered to participate in this study. All of them are working in different departments and recruited using a social media platform. Only one participant is in her early 30s, while others are in their 20s at the time of the experiment (average age 26.8). None of our participants has fixed working hours because they worked based on shifts. On average, they work nearly 55 h a week. Despite the busy working hours, one participant is also pursuing a part-time PhD in a local university. None of our participants has any professional or personal acquaintance with each other before, during, or after the experiment. All participants are identified using the prefixes N for the nurse and D for the doctor, followed by a number. Table 1 summarises the details of each participant.

### 4.2. Data collection

The measures recorded during the in-situ experiment included questionnaires, interviews, and logged data.

1. We used the JAWS form to understand healthcare workers' emotional attitudes towards their professional careers. This form consists of 20 different kinds of emotions that are often used to evaluate the individuals' emotions at work (Van Katwyk et al. 2000).
2. Each healthcare worker's emotions were self-evaluated before and after using the prototype with the SAM scale (Bradley and Lang 1994). The emotional response measures of SAM appear to be structured along specific dimensions (Mauss and Robinson 2009), it may help us to capture and quantify the instant emotion traits.
3. We measured participants' feelings with a standard GEW scale using the emotion diary pages (Scherer 2005). GEW scale consists of 20 typical emotion types, which could help participants to recall their feelings in the daily emotion diary.

### 4.3. In-situ experiment kit

Our in-situ experiment kit consists of seven components. The experiment kit was delivered to each participant prior experiment. Figure 2 below presents the components included in the kit.

1. *Smart t-shirt prototype*. Two pieces of suitable size smart t-shirt prototypes were given to each participant (see Figure 2a).
2. *Introduction card.* This card explains the functionalities of the smart t-shirt prototype, including the supported movements and feedback mechanisms and how to use it to monitor their emotions (see Figure 2b).
3. *JAWS form.* It consists of 20 statements that describe different emotions that a work environment can make a person experience (see Figure 2c).
4. *Emotion tracker cards*. These custom-designed cards consist of a pictographic SAM scale on both sides. In addition, each card has sections to record the details such as place, time, feeling, and emotional fluctuations on the *Before Use* side. The movement information, feedback mechanism, feelings, and suggestions regarding the prototype can be recorded on the *After Use* side of the card (see Figure 2d). Each in-situ experiment kit included 20 emotional tracker cards. Participants can use these cards whenever they have emotional fluctuations. We use the dimensions of the standard size of a regular business card to design these cards. Thus, it can be easily carried in their work uniform.
5. *Emotion diary pages*. These diary pages comprise a GEW scale, feedback questions for the prototype. The GEW scale provides 20 specific emotional options (see Figure 2e). The page also includes the questions such as wearable comfort, interaction method, and aesthetics of our prototype.
6. *Emoji stickers*. We included these cute emoji stickers to encourage our participants to record their emotions in an interesting way in the Emotional Diary Pages (See Figure 2f). Our participants were familiar with these emojis because they were the same as the ones from the most popular social media platform that they would daily to talk with their friends.
7. *Pen*. We also provided a pen to each user to record their emotions in the given forms (see Figure 2g).

### 4.4. Procedure

The whole experiment process included three stages for each participant: introduction, pre-experiment measures, and in-situ experiment. During the in-situ experiment, they were instructed to complete the given Emotion Tracker Cards and Emotion Diary

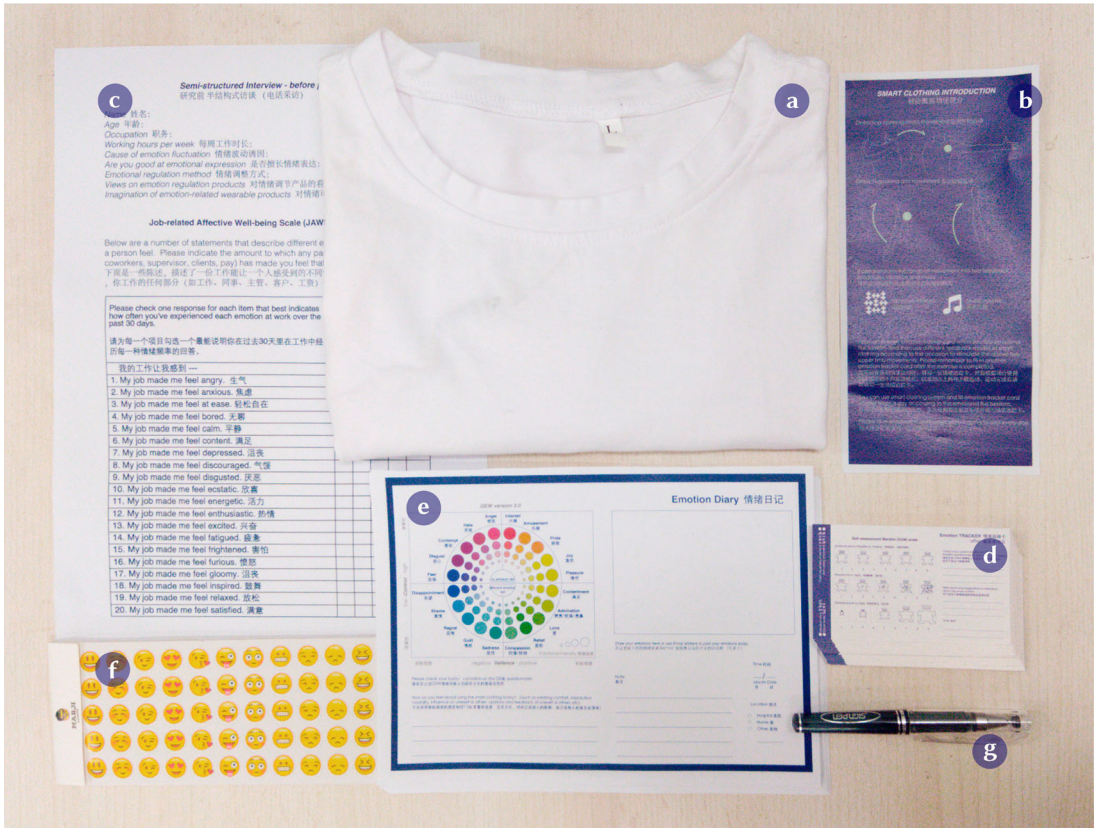


**Figure 2.** Our in-situ experiment kit includes (a) two pieces of smart t-shirt prototype; (b) an introduction page; (c) 3 JAWS forms; (d) 20 Emotion Tracker Cards; (e) 9 Emotion Diary Pages; (f) Emoji stickers; and (g) a pen.

Pages without wearing the prototype during the first and last two days of the 9-day study; thus, they were only asked to wear the prototype for five consecutive days. In addition, they were not asked to video-record their daily routines to avoid any inconvenience and address privacy concerns. The entire process of the experiment was explained to each participant via a series of individual virtual meetings (3 meetings x 6 participants = 18 meetings). Each meeting lasted about 60 min for each participant and took place before the 9-day in-situ experiment. Figure 3 illustrates the entire timeline of the experiment process and the data collection methods.

#### *4.4.1. Introduction*

Participants were introduced to the purpose and the process of the experiment via individual virtual meetings. We collected their demographic and work information during these initial virtual meetings. In addition, we also collected their clothing measurements to prepare the prototypes.

#### *4.4.2. Pre-experiment measures*

In the second stage, we had semi-structured virtual interviews with each participant about their (1) the perceived source of emotional fluctuation, (2) emotion regulation methods, (3) opinions on emotion regulation products, and (4) thoughts on emotion-related wearable products. At this stage, a JAWS online questionnaire was also given to each participant to collect their emotional state before the in-situ study. Next, we shipped the tailor-made kit to each participant. Upon receiving the kit, we explained to each participant the in-situ experiment process, components in the kit, and the procedure to record their feelings using the given kit via virtual meetings. We clarified the participants' questions at this stage, like the prototype usage, battery charging, cleaning, and information filling. Participants received online Behavioural Observation Training (BOT) focusing on emotion observation and reflection. This session lasted for about 30 min.

#### *4.4.3. In-situ experiment*

All participants were instructed to complete Emotion Tracker Cards and an Emotion Diary Page every day during the in-situ experiment. On the first two days, they only practiced recording their daily emotions with the Emotion Tracker Card and Emotion Diary Page without wearing the prototype.

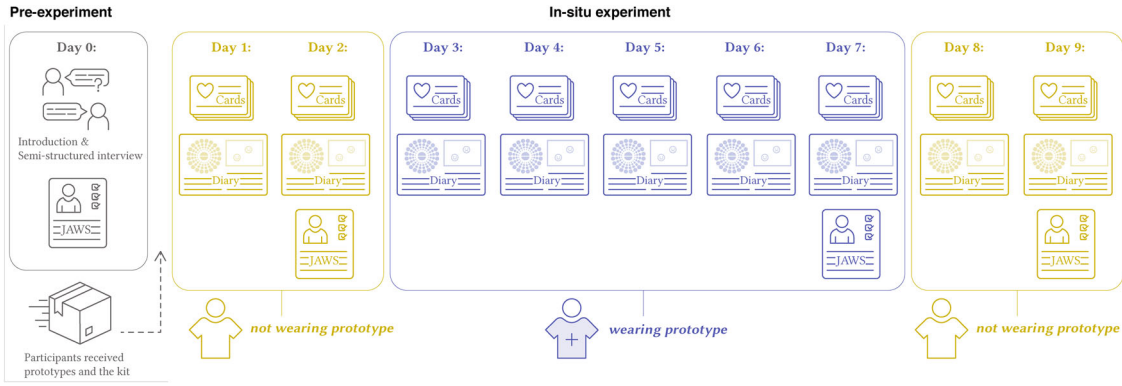


**Figure 3.** The timeline of the experimental procedure.

From the third day to the seventh day, they wore the smart t-shirt prototype for five days. In the last two days, they did not wear the prototype again, as we would like to know how their emotional attitude changed without wearing the prototype. Besides, participants were required to fill in four JAWS questionnaires on the second day, the seventh day, and the ninth day. The JAWS forms completed on these days represented their phased career emotional states. After the nine-day in-situ experiment, all our participants returned the prototype, the completed forms, and questionnaires back to us. Figure 4 shows some of our participants using the smart t-shirt prototype at their work.

## 5. Result

We analysed 91 Emotion Tracker Cards (out of given 120 cards), 54 (6 personnel x 9 days) Emotion Diary Pages, 24 (6 personnel x 4 days) JAWS forms, and 6 interview questionnaires from the 6 healthcare participants. Our results include each healthcare worker's perceived source of emotional fluctuation, SAM, JAWS, GEW scales, feedback, and suggestions.

### 5.1. Perceived source of healthcare workers' emotional fluctuation in the semi-structured interview

Table 2 summarises the perceived source of our participants' emotional fluctuation before the 9-day in-situ experiment. All our participants mentioned that their emotional fluctuation mostly comes from the high workload and interpersonal relationships at work.

Our participants dealt with their emotional fluctuations in various ways, including weeping, sleeping, relaxing, watching tv, going outside, being with friends, taking pictures, doing make-ups, eating sweets, and playing with pets. For instance, N2, N3, D2 prefer to go outside, take long walks, and have fun with friends to cope with their emotional fluctuations. While four of our participants believe massage products/supplies make them feel better, the other two participants either have no clue about these products or doubt their efficacy. These two users believe that emotion regulation is purely based on personal character and self-will, and external products have a very limited role in helping them improve their emotional fluctuations. However, on the other hand, most of our participants believed that wearable devices, such as a smart t-shirt, can potentially help them monitor their

(a) (b) (c) (d)

**Figure 4.** Pictures of our participants working in the hospital while wearing the smart t-shirt prototype. (a) N1 in the office; (b) N2 in the hospital ward; (c) D1 in the hospital; (d) D2 in the hospital lab.

**Table 2.** Summarises the details of the perceived source of healthcare workers' emotional fluctuation.

| Participant | Perceived Source of Emotional fluctuation |
|---|---|
| N1 | People from work and work itself |
| N2 | Excessive workload, the working environment is chaotic |
| N3 | Heavy workload and pressure |
| D1 | Work and the doctor-patient relationship |
| D2 | Unsuccessful environment, tiredness, pressure from the group meeting |
| D3 | The doctor-patient relationship, Children education |

emotional state to regulate their emotions when they have emotional fluctuations automatically. In particular, N2 expressed her interest in using stylish smart t-shirts daily to regulate her emotional fluctuations.

### 5.2. Perceived source of participants' emotional fluctuation during the in-situ experiment

To analyse the participants' feedback, we performed the open-coding analysis of the texts recorded on the Emotion Tracker Cards following an iterative, inductive thematic analysis process (Downe-Wamboldt 1992) and according to the emotion incentive types. The thematic analysis result was established independently by participants, verified by the same group, and got majority agreements. We analysed a total of 91 valid Emotion Tracker Cards from our 6 participants during the 9-day in-situ experiment. Among these, 65 cards were filled in during their working hours in the hospital, 18 cards at home, and only 8 cards in other places. The time of the day to complete these cards ranged between 06:00 and 23:30 h, with different peaks at 11:00, 16:00, and 20:00 h.

It is clear that most of the healthcare workers' emotional fluctuation arose during their working hours. There were many reasons for this, including problems with patients, excessive workload, difficulties in work, and work pressure. In addition, there were also factors such as collaboration with colleagues, dissatisfaction with work policies, job burnouts, and annoyance from work meetings. Notably, four of our participants (two nurses and two doctors) highlighted that their negative emotions mainly came from their work hours. In contrast, they felt calm, relaxed, and pleasant while they were at home. Among them, the neurologist and rheumatologist encountered more problems in the doctor-patient relationship. The source of some of these problems includes their patients' incomprehension, poor compliance, and poor communication. The three nurses expressed their worries regarding the workload, difficulties faced at work, and unbalanced relationships with their senior colleagues (see Table 3).

**Table 3.** Descriptive statistics of the perceived source of participants' emotional fluctuation.

| Place | Perceived source | Note | Number |
|---|---|---|---|
| Work | Social relationship | With patient | 21 |
| | | With colleague | 5 |
| | Workload | | 16 |
| | Troublesome situation | | 12 |
| | Pressure | | 10 |
| | Policy | | 5 |
| | Career burnout | | 4 |
| | Meeting | | 4 |
| | Environment | | 2 |
| Home and other | Social relationships | With relatives, or friends | 3 |
| | other | Sleep, pet, environment, etc. | 4 |

### 5.3. SAM results

Our participants used the smart t-shirt prototype for 5 consecutive working days (from Day 3 to Day 7). During this time, they recorded a total of 57 entries for the SAM scale on the Emotion Tracker Cards. We found that open and closed arm movements were recorded for 74.6% (vs. 26.4% of the flexion/extension of the shoulder) of the cards and 71.2% reported vibrotactile feedback mechanism (vs. 28.8% of the audio feedback). The Cronbach's Alpha and the Keiser-Meyer-Olkin (KMO) were calculated to determine the inter-item reliability and validity (Cronbach's alpha = 0.87, KMO = 0.757).

Figure 5 presents the results from a paired t-test on the valence, arousal, and dominance data of the SAM scale before and after using the smart t-shirt. We conducted paired t-tests on three groups of data and found that the emotion valence data showed differences before and after interacting with the prototype. The analysis also shows that there is a significant difference between valence 1 and valence 2 ($t$=−4.477, $p$=0.000) and that the average value of valence 1 (4.06 ± 1.88) is significantly lower than that of valence 2 (6.13 ± 1.26). Emotional arousal also showed a significant difference before and after the interaction ($t$=−3.184, $p$=0.006 < 0.05). Furthermore, the mean value of Arousal 1 (4.94 ± 1.29) was significantly lower than that of Arousal 2 (6.19 ± 1.22). However, there was no significant difference in emotion dominance.

### 5.4. JAWS results

Figure 6 shows the spider chart of the distribution of the emotion data from the four JAWS forms completed on Day 0 (pre-experiment), Day 2, Day 7, and Day 9. The Cronbach's Alpha and the KMO were calculated to determine the inter-item reliability and validity

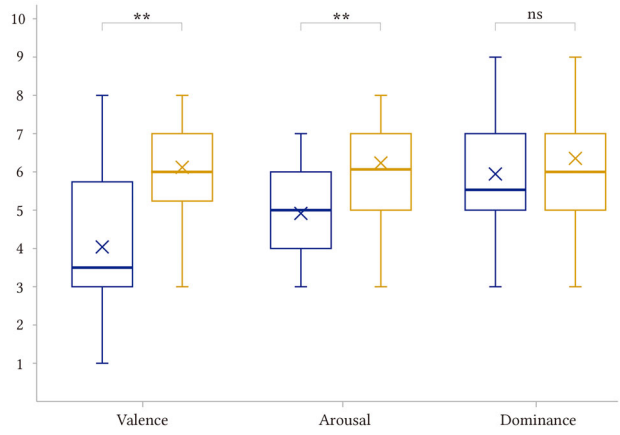


**Figure 5.** Paired T-test of SAM data before and after using the prototype (**$p$<0.01, ns = no significance).

(Cronbach's alpha = 0.658, KMO = 0.529). Unsurprisingly, very similar results were recorded before using our prototype on Day 0 and Day 2. Notably, the negative emotions such as angry, anxious, furious, and gloomy were decreased after using the smart t-shirt prototype at work. On the other hand, our data showed little fluctuation in the positive emotions between using the prototype and without it.

### 5.5. GEW results

Our participants completed the GEW scale using the Emotional Diary Pages for each of the nine nights. We superimposed 56 GEW choices of our 6 healthcare personnel into a scale. The different experiment periods Day 1–2 (without wearing a prototype), Day 3–7 (wearing the prototype), Day 8–9 (without wearing the prototype) are distinguished with different colours. Figure 7 illustrates the results from the GEW scale. By examining the figure, we can easily identify the differences in the emotional state from the different experiment periods. However, there was no statistical significance.

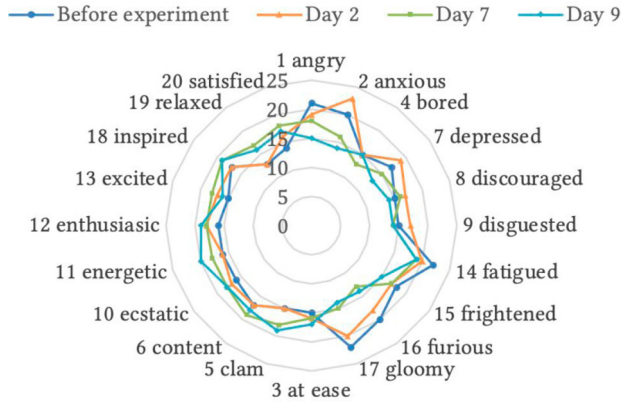


**Figure 6.** The spider chart of JAWS questionnaires.

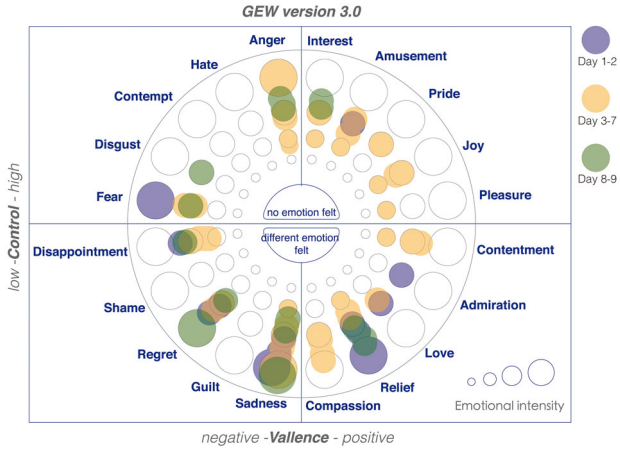


**Figure 7.** The GEW scale result from the Emotion Diary Pages.

### 5.6. User experience with the smart T-shirt prototype

To better understand the healthcare workers' experience of using our smart t-shirt prototype to regulate their emotions data was collected using emotion tracker cards and emotion diary pages, and we discovered several interesting details.

Given the explicit nature of the interaction movements, it made sense that our participants preferred not to perform these in the presence of others, particularly their patients. Unsurprisingly, the two doctors preferred the open and closed arm movement over the flexion/extension of the shoulder. As mentioned by D1, the open and closed arm movement made her feel positive and helped her relieve fatigue, and it was more convenient to perform during working hours. We also found that our participants were in favour of vibrotactile over audio feedback mechanism. In particular, D2 highlighted that the sensitivity of the vibrations was higher in the open and closed arm movements and was very useful than the other mode. She also added that it was challenging for her to pay attention to audio feedback while she was occupied with other activities in the hospital.

When reviewing our participants' emotional changes while using our prototype, we were encouraged to find that our prototype helped them regulate their emotions at work. For instance, N1 described how our prototype helped her calm down to avoid an argument with her patient that could have turn somewhat ugly, whereas N3 noted her dependence on our prototype to regulate her emotions after using it for a week.

## 6. Discussion

Our in-situ experiment with healthcare workers' using our smart t-shirt prototype produced useful insights

about how participants performed interaction movements that were supported by our prototype to regulate their emotions at work. As documented by Kinman and Jones (2005), we also found that the reasons that lead to negative emotional issues at the workplace are diverse, including the professional relationship with colleagues, social relationship with patients, challenging situations, workload, and work policies. Our user group includes both physicians and nurses. We also found differences between these two users, involving emotion fluctuation incentives, work scene, emotional state, and emotional needs. It is important to note that different working scenarios would lead to diverse emotional responses. We recommend understanding the user requirements and their working conditions when designing interactive smart textiles for emotion regulations.

From the non-verbal pictorial assessment scale, SAM, we found that healthcare workers' emotional valence was significantly improved after using our prototype. While there was also improvement in emotional arousal, no significant change was found in their emotional dominance (see Figure 5). Our findings align with the lab-based experiment on interactive textiles for emotion regulation (Jiang et al. 2021). We also found from JAWS results that some negative emotions of the healthcare workers improved after using the prototype (see Figure 6). Interestingly, the improvement was sustained even without using the prototype in the last two days of the in-situ experiment. Even with the short time, participants developed a sense of dependence on the prototype to regulate their emotions at work. However, due to the workload, the fatigue of our participants remained high during the experiment period.

The results of the GEW scale did not indicate clear diversity in different stages. The possible reason could be that the GEW scale tends to reflect the real-time emotional state of users. Most of the time, because they filled them at home in the evening, participants' emotional state may have changed by the time they arrived home. Some users also expressed the possibility that they could not fully express all their feelings when filling in the GEW scale, and there were too many options, so they did not pick any choice when they did not find the corresponding option. This was not the case for the SAM scale because they could always make the corresponding choice regardless of the emotion.

We believe the SAM scale is more effective and convenient for tracking the real-time emotional changes of users. The JAWS scale is also a useful tool to capture long-term work feelings. It should be noted that several short-term emotional fluctuations during working hours would influence healthcare workers' overall feelings, particularly at work. This, however, introduce challenges to support healthcare personnel to improve their emotions while under work burnout, fatigue, or in a prolonged negative mood. We recommend that designers consider these rapid emotional fluctuations while designing interactive smart garments for emotion regulations, resulting in less negative feelings towards their work. As the SAM and JAWS results show, our smart t-shirt prototype successfully helped our users reducing their negative emotions. However, it is challenging to precisely know whether the interaction movements or feedback mechanisms or both were responsible for reducing their negative feelings. It should be noted that the usage scenario determines the choice of interaction movement(s) and the feedback mechanism(s).

The smart t-shirt prototype was tested with our healthcare participants for a period of 30 days (6 personnel x 5 days) in total. Our prototype was used approximately 300 h by 6 different people who also provided early feedback during that time. Prior studies investigated the use of interactive textiles for emotion regulation in the lab environment with one or two prototypes for a few minutes (Mazzoni and Bryan-Kinns 2015; Paredes et al. 2015; Costa et al. 2017; Jiang et al. 2021). In contrast to the lab experiment, we produced 12 smart t-shirt prototypes for six different healthcare workers. Our participants wore this custom-built prototype for a week. As such, this study provides a deeper understanding of long-time emotion variations, wearability and usability concerns, user behaviour of a specific target group, and various working conditions. Participants provided valuable information for the design of smart t-shirts for emotion regulation in actual use cases. For example, our users expressed their concern about performing these movements with the prototype in front of other people or in a public place with many onlookers.

Furthermore, our prototype was designed to be worn inside the healthcare workers' official uniform at work. Because of the nature of the physicians' loose and oversized uniforms, they felt more comfortable using our prototype than nurses. Even though our users were in favour of both vibrotactile and audio feedback mechanisms, they expressed their interest to have customisable options like music type, volume control, vibration intensity, and vibrotactile position. We also observed that our fabric sensors, components, and connections did not get damaged even after washing it few times.

## 7. Limitations and future work

This in-situ experiment involved only female healthcare workers across three different cities in China and used

smart t-shirts with pre-defined interaction movements and feedback mechanisms. Despite our attempts, male healthcare workers showed less interest to volunteer for this study, involving male healthcare workers in using our prototype and investigating their emotional issues at work could help increase the study's validity. However, for an initial evaluation of interactive textiles for emotion regulations at a health-related work environment, considering a single user group is still suitable to identify valuable insights and findings—our study has been able to achieve this. On the other hand, it will be interesting to perform variations of this study, including having other user groups like male healthcare workers and explore any differences in their preferences. While we do not expect significant differences in the possible movements or feedback mechanisms, having other groups would further validate our results and refine any design issues.

We did not investigate user acceptance of the interaction movements and feedback mechanisms for each specific work environment of healthcare workers. Understanding their acceptance (or otherwise) will help improve their design and use that fit each healthcare worker's work processes and usage scenarios. While the inherent nature of healthcare workers' uniforms makes them feel comfortable, developing interaction movements and feedback mechanisms that do not create unnecessary and unwanted attention from others would remain a challenge but is a direction worth exploring. In addition, we conducted the study during the COVID-19 pandemic time. The experiment data collected and analysed only after the experiment period for each user. We did not evaluate the performance of our prototype in real-time during the experiment. Real-time data collection from an in-situ experiment may allow us to understand some subtle, implicit factors that affect movements with smart clothing performed by the healthcare workers.

## 8. Conclusion

This research has explored the use of a smart interactive t-shirt to help healthcare workers manage their emotional fluctuations in their work environments. We focused on healthcare workers because they tend to suffer from an increased risk of depression and burned-out due to their typically high levels of workload. The COVID-19 pandemic has exposed further their risks. We conducted an in-situ experiment of 30 days to evaluate the usability of smart textiles for emotion regulation. We designed an interactive smart t-shirt prototype in which fabric sensors could capture interactive movements while two coin motors and a speaker module provide vibrotactile and audio feedback to the users. Our prototype was used for approximately 300 h by 6 healthcare workers at three hospitals in this study. The results show that using the smart t-shirt (1) enhanced healthcare workers' positive emotions at work and (2) made them feel relaxed and calm in a short time. Through our in-situ investigation, we also derive suggestions for designing interactive textiles aimed at emotion regulations.

## Notes

1. https://www.adafruit.com/product/3669
2. https://www.adafruit.com/product/640

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## References

Bianchi-Berthouze, N., and K. Isbister. 2016. "Emotion and Body-Based Games: Overview and Opportunities." *Emotion in Games* 4: 235–255.

Bordegoni, M., S. Ugur, and M. Carulli. 2012. "When Technology Has Invisible Hands: Designing Wearable Technologies for Haptic Communication of Emotions." In International design Engineering technical conferences and Computers and information in Engineering conference, 581–589. American Society of Mechanical Engineers.

Bradley, M. M., and P. J. Lang. 1994. "Measuring Emotion: the Self-Assessment Manikin and the Semantic Differential." *Journal of Behavior Therapy and Experimental Psychiatry* 25: 49–59.

Briñol, P., R. E. Petty, and B. Wagner. 2009. "Body Posture Effects on Self-Evaluation: A Self-Validation Approach." *European Journal of Social Psychology* 39: 1053–1064.

Cacioppo, J. T., J. R. Priester, and G. G. Berntson. 1993. "Rudimentary Determinants of Attitudes: II. Arm Flexion and Extension Have Differential Effects on Attitudes." *Journal of Personality and Social Psychology* 65: 5.

Casasanto, D., and K. Dijkstra. 2010. "Motor Action and Emotional Memory." *Cognition* 115: 179–185.

Costa, J., A. T. Adams, M. F. Jung, F. Guimbretière, and T. Choudhury. 2017. "EmotionCheck: A Wearable Device to Regulate Anxiety Through False Heart Rate Feedback." *GetMobile: Mobile Computing and Communications* 21: 22–25.

Damasio, A. R. 1999. *The Feeling of What Happens: Body and Emotion in the Making of Consciousness*. New York, NY: Houghton Mifflin Harcourt.

Davis, F. 2019. "FELT: Communicating Emotion Through Textile Expression." *Technology Architecture+ Design* 3: 146–149.

Davis, F., A. Roseway, E. Carroll, and M. Czerwinski. 2013. "Actuating Mood: Design of the Textile Mirror." In Proceedings of the 7th International Conference on tangible, Embedded and Embodied interaction, 99–106.

de Rooij, A. 2014. "Toward Emotion Regulation via Physical Interaction." In Proceedings of the companion publication of the 19th international conference on Intelligent user interfaces, 57–60.

Downe-Wamboldt, B. 1992. "Content Analysis: Method, Applications, and Issues." *Health Care For Women International* 13: 313–321.

El Ali, A., X. Yang, S. Ananthanarayan, T. Röggla, J. Jansen, J. Hartcher-O'Brien, K. Jansen, and P. Cesar. 2020. "ThermalWear: Exploring Wearable On-Chest Thermal Displays to Augment Voice Messages with Affect." In Proceedings of the 2020 CHI Conference on Human Factors in Computing systems, 1–14.

Foo, E., J. W. Lee, S. Ozbek, and B. Holschuh. 2018. "Preliminary Study of the Subjective Comfort and Emotional Effects of on-Body Compression." In Proceedings of the 2018 ACM International Symposium on Wearable computers, 128–131.

Francis, A. L., and R. C. Beemer. 2019. "How Does Yoga Reduce Stress? Embodied Cognition and Emotion Highlight the Influence of the Musculoskeletal System." *Complementary Therapies in Medicine* 43: 170–175.

Gaver, B., T. Dunne, and E. Pacenti. 1999. "Design: Cultural Probes." *Interactions* 6: 21–29.

Gerling, K., I. Livingston, L. Nacke, and R. Mandryk. 2012. "Full-body Motion-Based Game Interaction for Older Adults." In Proceedings of the SIGCHI conference on human factors in computing systems, 1873–1882.

Ghiasi, S., G. Valenza, M. S. Morelli, M. Bianchi, E. P. Scilingo, and A. Greco. 2019. "The Role of Haptic Stimuli on Affective Reading: A Pilot Study." In *VibeRate, an Affective Wearable Tool for Creative Design*. 2013 Humaine Association Conference on Affective Computing and Intelligent Interaction, edited by S. Giannoulis and C. Sas, 594–599. Berlin: IEEE.

Giannoulis, S., and C. Sas. 2013. "VibeRate, an Affective Wearable Tool for Creative Design." In 2013 Humaine Association Conference on Affective Computing and Intelligent interaction, 594–599. IEEE.

Gross, J. James. 1998. "The Emerging Field of Emotion Regulation: An Integrative Review." *Review of General Psychology* 2: 271–299.

Huisman, G., A. D. Frederiks, and D. Heylen. 2013. "Affective Touch at a Distance." In 2013 Humaine Association Conference on Affective Computing and Intelligent interaction, 701–702. IEEE.

Iaconesi, S. 2010. "Wearing Emotions: Physical Representation and Visualization of Human Emotions Using Wearable Technologies." In 2010 14th International Conference information visualisation, 200–206. IEEE.

Isbister, K., U. Schwekendiek, and J. Frye. 2011. "Wriggle: an Exploration of Emotional and Social Effects of Movement." In CHI'11 extended abstracts on human factors in computing systems, 1885–1890.

Jiang, M., V. Nanjappan, M. Ten Bhömer, and H.-N. Liang. 2021. "On the Use of Movement-Based Interaction with Smart Textiles for Emotion Regulation." *Sensors* 21: 990.

Jiang, M., M. ten Bhömer, and H.-N. Liang. 2020. "Exploring the Design of Interactive Smart Textiles for Emotion Regulation." In International Conference on Human-Computer interaction, 298–315. Springer.

Kinman, G., and F. Jones. 2005. "Lay Representations of Workplace Stress: What do People Really Mean When They say They are Stressed?" *Work & Stress* 19: 101–120.

Lai, J., S. Ma, Y. Wang, Z. Cai, J. Hu, N. Wei, J. Wu, H. Du, T. Chen, and R. Li. 2020. "Factors Associated with Mental Health Outcomes among Health Care Workers Exposed to Coronavirus Disease 2019." *JAMA Network Open* 3: e203976–e203976.

Leitner, M., G. Cockton, J. Yee, and T. Greenough. 2012. "The Hankie Probe: a Materialistic Approach to Mobile ux Research." In CHI'12 Extended Abstracts on Human Factors in Computing systems, 1919–1924.

Lemmens, P., F. Crompvoets, D. Brokken, J. Van Den Eerenbeemd, and G.-J. de Vries. 2009. "A Body-Conforming Tactile Jacket to Enrich Movie Viewing." In world Haptics 2009-Third joint EuroHaptics conference and Symposium on Haptic Interfaces for virtual environment and teleoperator systems, 7–12. IEEE.

Lopes, L., and P. Campos. 2019. "SCAARF: a Subtle Conditioning Approach for Anxiety Relief Facilitation." In Proceedings of the 18th International Conference on Mobile and Ubiquitous multimedia, 1–5.

Mauss, I. B., and M. D. Robinson. 2009. "Measures of emotion: A review." Other, 23.

Mazzoni, A., and N. Bryan-Kinns. 2015. "How Does it Feel Like? An Exploratory Study of a Prototype System to Convey Emotion Through Haptic Wearable Devices." In 2015 7th International Conference on Intelligent Technologies for interactive Entertainment (INTETAIN), 64–68. IEEE.

Mazzoni, A., and N. Bryan-Kinns. 2016. "Moody: Haptic Sensations to Enhance Mood in Film Music." In Proceedings of the 2016 ACM Conference companion publication on designing interactive systems, 21–24.

Melzer, A., I. Derks, J. Heydekorn, and G. Steffgen. 2010. "Click or Strike: Realistic Versus Standard Game Controls in Violent Video Games and Their Effects on Aggression." In International Conference on Entertainment computing, 171–182. Springer.

Neidlinger, K., L. Toussaint, E. Dertien, K. P. Truong, H. Hermens, and V. Evers. 2019. "Emotional Prosthesis for Animating awe Through Performative Biofeedback." In Proceedings of the 23rd International Symposium on Wearable computers, 312–317.

Neumann, R., and F. Strack. 2000. "Mood Contagion": the Automatic Transfer of Mood Between Persons." *Journal of Personality and Social Psychology* 79: 211.

Niedenthal, P. M., L. W. Barsalou, P. Winkielman, S. Krauth-Gruber, and F. Ric. 2005. "Embodiment in Attitudes, Social Perception, and Emotion." *Personality and Social Psychology Review* 9: 184–211.

Palaigeorgiou, G., G. Vroikou, C. Nikoleta, and T. Bratitsis. 2019. "Wearable E-Textile as a Narrative Mediator for Enhancing Empathy in Moral Development." In *Interactive Mobile Communication, Technologies and Learning*, edited by Michael E. Auer Thrasyvoulos Tsiatsos, 457–467. Cham: Springer.

Paredes, P., R. Ko, A. Aghaseyedjavadi, J. Chuang, J. Canny, and L. Bäbler. 2015. "Synestouch: Haptic+ Audio Affective Design for Wearable Devices." In 2015 International Conference on Affective Computing and Intelligent Interaction (ACII), 595–601. IEEE.

Picard, R. W. 2000. *Affective Computing*. Cambridge: MIT Press.

Pollak, J. P., P. Adams, and G. Gay. 2011. "PAM: a Photographic Affect Meter for Frequent, in Situ Measurement of Affect." In Proceedings of the SIGCHI conference on Human factors in computing systems, 725–734.

Profita, H., A. Roseway, and M. Czerwinski. 2015. "Lightwear: an Exploration in Wearable Light Therapy." In Proceedings of the ninth International Conference on tangible, embedded, and Embodied interaction, 321–328.

Rossberg-Gempton, I., and G. D. Poole. 1993. "The effect of open and closed postures on pleasant and unpleasant emotions." The Arts in psychotherapy.

Salminen, K., V. Surakka, J. Lylykangas, J. Raisamo, R. Saarinen, R. Raisamo, J. Rantala, and G. Evreinov. 2008. "Emotional and Behavioral Responses to Haptic Stimulation." In Proceeding of the twenty-sixth Annual CHI Conference on Human Factors in Computing Systems - CHI '08. doi:10.1145/1357054.1357298.

Scherer, K. R. 2005. "What are Emotions? And how Can They be Measured?" *Social Science Information* 44: 695–729.

Shafir, T. 2015. "Movement-based strategies for emotion regulation." Handbook on emotion regulation: Processes, cognitive effects and social consequences, 231–249.

Shafir, T. 2016. "Using Movement to Regulate Emotion: Neurophysiological Findings and Their Application in Psychotherapy." *Frontiers in Psychology* 7: 1451.

Spoorthy, M. S., S. K. Pratapa, and S. Mahant. 2020. "Mental Health Problems Faced by Healthcare Workers due to the COVID-19 Pandemic–A Review." *Asian Journal of Psychiatry* 51: 102119.

Sriharan, A., S. Ratnapalan, A. C. Tricco, D. Lupea, A. P. Ayala, H. Pang, and D. Lee. 2020. "Stress, burnout and depression in women in health care during COVID-19 Pandemic: Rapid Scoping Review." medRxiv.

Strack, F., L. L. Martin, and S. Stepper. 1988. "Inhibiting and Facilitating Conditions of the Human Smile: a Nonobtrusive Test of the Facial Feedback Hypothesis." *Journal of Personality and Social Psychology* 54: 768–777.

Stylios, G. K., and M. Chen. 2020. "The Concept of Psychotextiles; Interactions Between Changing Patterns and the Human Visual Brain, by a Novel Composite SMART Fabric." *Materials* 13: 725.

Sundström, P., A. Ståhl, and K. Höök. 2007. "In Situ Informants Exploring an Emotional Mobile Messaging System in Their Everyday Practice." *International Journal of Human-Computer Studies* 65: 388–403.

Tajadura-Jiménez, A., M. Basia, O. Deroy, M. Fairhurst, N. Marquardt, and N. Bianchi-Berthouze. 2015. "As Light as Your Footsteps: Altering Walking Sounds to Change Perceived Body Weight, Emotional State and Gait." In Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing systems. doi:10.1145/2702123.2702374.

Tajadura-Jiménez, A., A. Väljamäe, and K. Kuusk. 2020. "Altering One's Body-Perception Through E-Textiles and Haptic Metaphors." *Frontiers in Robotics and AI* 7: 7.

Turmo Vidal, L., E. Márquez Segura, L. Parrilla Bel, and A. Waern. 2020. "Training Technology Probes Across Fitness Practices: Yoga, Circus and Weightlifting." In Extended Abstracts of the 2020 CHI Conference on Human Factors in Computing systems, 1–8.

Van Katwyk, P. T., S. Fox, P. E. Spector, and E. K. Kelloway. 2000. " Using the Job-Related Affective Well-Being Scale (JAWS) to Investigate Affective Responses to Work Stressors." *Journal of Occupational Health Psychology* 5: 219.

Wang, W., Y. Nagai, and F. Yuan. 2017. "Human-centred Design Blending Smart Technology with Emotional Responses: Case Study on Interactive Clothing for Couples." In DS 87-8 Proceedings of the 21st International Conference on Engineering design (ICED 17) Vol 8: Human behaviour in design, vancouver, Canada, 21-25.08. 2017, 051–058.

Winters, A. F. 2008. "Emotion, Embodiment, and Mirror Neurons in Dance/Movement Therapy: A Connection Across Disciplines." *American Journal of Dance Therapy* 30: 84.

Woodward, K., E. Kanjo, S. Burton, and A. Oikonomou. 2018. "Emoecho: A Tangible Interface to Convey and Communicate Emotions." In Proceedings of the 2018 ACM International joint Conference and 2018 International Symposium on pervasive and Ubiquitous Computing and Wearable computers, 746–749.

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