Therapeutic Touch: Reactive Clothing for Anxiety

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ABSTRACT

The emotional and physical health benefits that come by being touched in safe ways are well established. Therapeutic touch has been used for conditions such as Autism Spectrum Disorder, Attention Deficit Hyperactivity Disorder, Sensory Processing Disorder and Dementia as a calming agent. Smart clothing and textiles have the potential to not only sense, monitor and collect data (inputs) but also to act on the body with embedded actuation capabilities (outputs) such as promoting mechanical, electrical and thermal tactile stimuli. Thus far, the emphasis in the design of wearables, including smart clothing, has been on inputs, with comparatively little research on the responsive output capabilities. This research presents design requirements for development of a user-friendly wearable product for compression therapy and reports development of a reactive undershirt with embedded textile-based pneumatic actuators that deliver tactile stimulation in response to change in emotional state to calm anxiety. The proposed design can offer novel ways of complementing care to empower people with dementia in everyday situations because of its ubiquitous nature and its affordance.

KEYWORDS

Anxiety, Compression, Smart Clothing, Pneumatic

ACM Reference format:

Gozde Goncu-Berk, Tara Halsted, Ruoyu Zhang, Tingrui Pan. 2020. Therapeutic Touch: Reactive Clothing for Anxiety. In *14th EAI International Conference on Pervasive Computing Technologies for Healthcare (PervasiveHealth '20)*, May 18–20, 2020, Atlanta, GA, USA. ACM, New York, NY, USA, 4 pages. <https://doi.org/10.1145/3421937.3421962>

1 Introduction

Touch is fundamental in sensing the world and in human interaction. Affective touch is also a powerful force in human development throughout the whole lifespan. The emotional and

physical health benefits that come by being touched in safe ways are well established. Research showed that therapeutic touch increases the activity in the parasympathetic division and lowers the activity in the sympathetic division of the Autonomic Nervous System, decreases the galvanic skin response and promotes the production of calming neurotransmitters [1].

Therapeutic touch has been used for conditions such as Autism Spectrum Disorder, Attention Deficit Hyperactivity Disorder, Sensory Processing Disorder and Dementia as a calming agent. World Health Organization estimates that people living with dementia worldwide is currently at 50 million and will almost triple by 2050. With no cure available currently, innovation into improving the quality of life of people with dementia and their care givers is essential. Characterized by progressive memory and cognitive degeneration, people who are affected by dementia often have reduced physical activities and social engagement leading to anxiety and depression. Design-based, non-pharmacological interventions are increasingly recognized as having great potential to help. Smart clothing and textiles with tactile stimulation abilities especially can offer novel ways of complementing care to empower people with dementia in everyday situations because of its ubiquitous nature and its affordance.

Wearables are body mounted technology that can come in forms of accessories and clothing worn on the human body. A more specific subgroup of wearable technology, smart clothing can be distinguished from other worn accessories such as bracelets and watches. In this specific subgroup, electronic textiles (e-textiles) become the building blocks of smart clothing, referring to fibers, yarns or fabrics with embedded electronic functions that offer flexibility that is not existing in traditional electronics. Smart clothing offers the comfort of everyday clothing with the potential to detect and react to wide range of data about the wearer due to the close proximity to the whole body as opposed to smart watches and wrist bands which are limited in scope.

Smart clothing and textiles have the potential to not only sense, monitor and collect data (inputs) but also to act on the body with embedded actuation capabilities (outputs) such as promoting mechanical, electrical and thermal tactile stimuli. Thus far, the emphasis in the design of wearables, including smart clothing, has been on inputs or sensing health and fitness data, with comparatively little research on the responsive output capabilities. It is important and significant to conduct research on reactive smart clothing that could respond to changes in vital signs of the body and potentially contribute to management of many medical conditions closely related with ageing populations.

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<https://doi.org/10.1145/3421937.3421962>

Textiles act as second skin to protect and nourish our bodies and therefore hold a strong potential to function as interfaces for therapeutic touch. Tight-fitting compression clothing, weighted vests and blankets have been utilized to provide relief in many medical conditions. With the development of technology that allows embedding electronics in textiles, it is possible to develop context-aware clothing that can react to arousal in multiple ways through tactile textile actuators.

This study aims to determine the needs and preferences for wearable products that use textiles as an interface for therapeutic touch applied within health and wellbeing. We employ netnography method [2] in public online communities to collect data on user and caregiver feedback about existing products that provide therapeutic touch and review of the interdisciplinary literature to collect data on feedback about prototypes developed in different fields. Ultimately, through identifying the design requirements for textile-based wearable products, we develop a user-friendly reactive undershirt with embedded pneumatic textile actuators and electronic-textile based sensing capabilities that can react to change in Heart Rate Variability (HRV) and Galvanic Skin Response (GSR) to simulate human contact and bring about the health benefits of affectionate touch during an arousal.

Different fields including clothing and textiles design, product design and human-computer interaction (HCI) approached wearable product design with tactile stimulation capabilities from different perspectives. In HCI researchers attempted to embed tactile stimulation through vibration, temperature change, pneumatic compression into accessories and clothing to act as a nonverbal, asynchronous communication tool [3], [4], [5], [6], [7]. Interdisciplinary teams of researchers from design, textiles and engineering developed wearable products with actuation capabilities targeting rehabilitation and healing [8], a wearable with sound output to aid elderly in rehabilitation exercise [9], compression vest with shape memory alloy (SMA) springs that contract on command when heated for children with Autism Spectrum Disorder (ASD) and ADHD [10]. Another study explored the tactile textile surfaces incorporated in a pillow that can produce cause and effect upon touching through light and heat [11]. The research focused on elderly population whose sense of touch is deteriorating to enhance and encourage their sense of touch.

2 Method

2.1 In-Depth Research on Tactile Actuation Needs

Products in the form of weighted vests and blankets, tight-fitting clothing, tactile toys and accessories for individuals with wide range of disorders from Autism Spectrum Disorder (ASD) to Dementia are abundant. Therefore, there is vast amount of data available on the Internet which has not been systematically analyzed to understand the needs of users based on existing experiences with these traditional products.

With the goal to understand the needs of individuals who can benefit from tactile body actuation from multiple perspectives and to ground the design decisions for the reactive undershirt, first we employed “netnography” method to analyze the online data [2].

We conducted an exhaustive internet search using keywords such as “compression therapy”, “compression clothing”, “deep touch pressure”, “sensory clothing”, “occupational therapy”, “Dementia”, “Alzheimer’s”, “Autism Spectrum Disorder”, “Sensory Processing Disorder”. Our search included broad e-commerce websites such as “Amazon.com”, niche company websites such as “funandfunction.com”, a brand that focuses on products for special needs, and public online forums in which care takers and people with related disorders shared their coping mechanisms and recommendations about products, interventions and therapies. Based on these analyses, we documented the positive and negative feedback about tactile products for our target audience and developed a framework of design requirements to ground the development of the reactive undershirt for anxiety.

2.2 Development of Textile Based Pneumatic Tactile Actuators

Based on the design requirements, we developed ideas and prototypes for dynamic textile based tactile actuators to provide compressive tactile sensations. Materials and fabrication methods to laminate textiles to design airtight bladders, which would function as the pneumatic soft actuators, were determined. Appropriate locations and sizes of these pneumatic soft actuators on the wearer’s body were identified by considering the physical size and surface curvatures of the human body.

2.3 Embedding Sensors in Textiles for Automated Tactile Actuating Based on Emotional State

E-textile-based heart rate variability (HRV) and galvanic skin resistance (GSR) sensors were integrated in the reactive undershirt at designated locations to detect the emotional state of the wearer. We developed an Arduino based prototype of the control mechanism that uses input from HRV and GSR sensors to trigger an automated tactile actuation output using a mini air pump.

3 Discussion

3.1 Design Requirements

Focusing on textile-based wearable products that provide compression therapy to calm and comfort the user with gentle compression, we identified three product categories as weighted, stretch and inflatable products which ranged from vests, jackets to hats and shawls. The benefits of current products are that many users find them effective in helping the wearer relax and calm down as they simulate a gentle hugging sensation. They are regarded as versatile and can be worn in many situations, as the calming effect can help the wearer stay quiet in appropriate situations, stay focused on work, sleep through the night, and self-regulate from a meltdown.

As depicted in Figure 1, positive and negative feedback we gathered are color coded where blue designates location and amount of compression, red identifies useful conditions for

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Compression Therapy Products	Examples	Positive Feedback	Negative Feedback
Weighted Wearable Products	<ul style="list-style-type: none"> • vest • blanket • hat • jacket • scarf 	<ul style="list-style-type: none"> • Weights on shoulder area or across back of neck are comforting • Weights on head area help prevent wearers from hitting their heads on objects as a meltdown response • Feeling of pressure helps to relax • Good for sensory and self-regulation • Helps to sleep through the night 	<ul style="list-style-type: none"> • Uncomfortable when the weight at the bottom of the vest or jacket pulls down on the shoulders • Not breathable • Not stylish for adults
Negative Ease Stretch Wearable Products	<ul style="list-style-type: none"> • shirt/undershirt • pant • sock • bedding 	<ul style="list-style-type: none"> • Hugging feeling helps with attention • Helps to sleep through the night 	<ul style="list-style-type: none"> • Uncomfortable fabric, seam, tag textures • Too restrictive • Not breathable • Not stylish for adults • Sizing issues • Donning-Dooffing Difficulty
Inflatable Wearable Products	<ul style="list-style-type: none"> • Vest • Jacket • Pod 	<ul style="list-style-type: none"> • Safe feeling for during a meltdown 	<ul style="list-style-type: none"> • Does not provide as much pressure • Has to be self-inflated by squeezing • Issues with seams not being air tight, air leaking • Not breathable • Not stylish for adults

Blue: Location of Compression/Pressure
 Red: Useful Conditions for Compression/Pressure
 Green: Product Features (Material, Amount of Compression/Pressure, Use, Size, Style)

Figure 1: Summary of findings from netnography on compressive tactile stimulating wearable products.

compression, and green identifies product features such as material, size, use experience, comfort and style. Based on this, it is possible to conclude that compression therapy itself is evaluated positively but the products that are designed to deliver this type of therapy by different means (i.e. weight, stretch, inflation) have flaws and are evaluated negatively. Therefore, there is a need and opportunity for a user-friendly and innovative design that can make change in people's lives.

Departing from analysis and coding of the feedback on existing products, we identified four design requirements which we discuss in relation to findings from our in-depth Internet research. **Location and amount of compression** are important factors in effectiveness of the compression therapy and also in other aspects of the product comfort such as mobility, thermal and tactile properties. Products that distribute a gradual compression over the back and sides of torso and the shoulders avoiding body core area were evaluated more positively. Similarly, one study also suggested that location of actuation effects how pleasantly it is perceived. Same study reported that women prefer gentle actuation whereas it is the opposite in men [7]. Another study reported gradually increasing compression are perceived more pleasant than sudden changes [12].

Product Comfort is a critical design requirement as most of the negative feedback on available products were related to its features. Tactile and thermal comfort, mobility and sizing are the sub requirements under product comfort. Feedback we gathered suggests that lack of breathability and restriction of movement are concerns because they can cause panic attacks and meltdowns. It is crucial that the garment can be worn in different weather conditions without causing the individuals to overheat. In addition, it was commonly reported that bulky seams in tight clothing rub uncomfortably against skin. Finally, finding the right size for compression to function was defined as another challenge.

Visual Style refers to how the compression clothing looks in comparison to a regular daily clothing. Aesthetically, many users have concerns wearing garments that might be perceived as different by their peers. The findings demonstrate that individuals

want compression clothing that blend in with their wardrobes and style rather than appearing to be coping tools that draw attention.

Use experience relates to donning and doffing, initiating and controlling the compression (i.e., placing weights, pumping air). The findings brought up contradicting results related to donning doffing, while in some cases where small children are involved self-donning/doffing was a negative factor whereas with older population ease of donning and doffing due to tight fitting structure of these clothing was highly needed. Currently available products rely on wearer put the weights or pump air to initiate the compression application or the compression is constantly available embedded as a negative stretch in a tight-fitting garment.

3.2 Prototype Development

Design requirements developed are taken as the point of departure in our functional and aesthetic design choices when creating the reactive undershirt that uses pneumatic compression to mimic the therapeutic touch of a hug. Our research showed that most wearable products such as vests and jackets are geared towards kids and are not necessarily designed to be unobtrusive. We target older adults who can benefit from the compressive tactile actuation to get relief from anxiety that may be associated with conditions like Dementia. This has led us to create a design that is discreet and wearable as an undershirt which can be made in different sizes to accommodate individuals of different body sizes.

To address **location and amount of compression**, we developed a single inflatable bladder that covers back and sides of the torso and the shoulders. The air is pumped into the system from a single point leading to gradual increase in the pressure.

To address **product comfort**, we have inferred that fabric weight, stretch, and softness are crucial considerations in designing a garment that meets the user's comfort needs. Thus, we designed the inflatable bladder using a single jersey cotton blend, stretch knit fabric which was then laminated with TPU membrane to make it air tight while maximizing comfort and minimizing noise. Two layers of laminated knit fabric were heat sealed to form the inflatable bladder in a strategically pleated structure for a full range of movement so that the design is tight but not restrictive. The pleats are created in alternating angles to conform the curvatures of the body. In addition, inflatable bladder is shaped in a racer back form to allow for comfortable shoulder movement and thermal comfort at the under-arm area.

Figure 2: Early prototype of the undershirt showing front, side and back view of the air bladder placement under arm area.

Figure 3: The pleating created at angles that conform with the movement of different body parts when the bladder is inflated.

The patterns of the reactive undershirt are also zoned strategically to use mesh knit fabric in areas of the body that are most likely to sweat to increase breathability and four-way extra stretch fabric on the stomach/chest area to maximize the ease of movement. To reduce bulk and discomfort of seams, we used flat, overlock seams on the knit textiles.

To address concerns regarding **visual style**, the reactive undershirt is designed as an undershirt to make it more discrete and avoid any unwanted attention. On the other hand, the reactive undershirt still has athletic style design with different knit textiles zones and racer back cut if it is to be worn as a single layer in summer months. The reactive undershirt provides a unique **use experience** with a context-aware compression function. The smart undershirt utilized e-textile based GSR and HRV sensors to detect anxiety and trigger the air pump to inflate the air tight bladder. In addition, stretch knit textiles are purposefully selected for easy donning/doffing.

3.3 Technology Development

We used GSR and HRV to detect emotional arousal. Silver coated polyamide yarn was used to embroider the electrodes and the conductive tracks on the inner lining of the undershirt using a CAD embroidery machine. The smart undershirt housed two embroidered GSR electrodes located at the underarm area, an area of skin that contains enough sweat glands to measure the resistance of skin. Two embroidered ECG electrodes were located on the chest.

We calculated the HRV in time domain from the ECG sensor by detecting the fluctuation in the time intervals between adjacent heartbeats. HRV can be calculated in long-term 24 h, short-term (~5 min), and ultra-short term (<5 min). In our design, short-term and ultra-short term HRV were used by calculating standard deviation of the inter beat intervals (IBI) of normal sinus beats (SDNN).

A microcontroller controlled a mini air pump to inflate the air bladder and maintain the inner pressure of air bladder by proportional-integral-derivative (PID) control with pressure sensor. And the microcontroller also dynamically controlled the valve to deflate the air bladder when wearer calmed down.

4 Conclusion

The results of this ongoing study can inform efforts on development of other smart clothing with actuation capabilities. The early prototype of the reactive undershirt shows great potential to be complementary to improving anxiety disorders for people with dementia and beyond by providing a context-aware therapeutic compression. It also exemplifies how smart clothing and textiles can act as a non-pharmaceutical rehabilitation alternative for healthy aging.

Currently, we are in the process of building a high fidelity second prototype and we will be gathering feedback on the developed smart undershirt from people with dementia. We will continue on with clinical trials to measure effectiveness of the reactive undershirt in reducing anxiety using electroencephalogram (EEG) monitoring.

ACKNOWLEDGMENTS

This research is funded by UC Davis Academic Senate, Interdisciplinary Research Grant.

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