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Vibe-ing: Designing a smart textile care tool for the treatment of osteoporosis

Abstract
Vibe-ing is a care tool in the form of a garment, which invites the body to feel, move, and heal through vibration therapy. The merino wool garment contains knitted pockets, equipped with electronic circuit boards that enable the garment to sense touch and vibrate specific pressure points on the body. With this design we aim to inform a multi-disciplinary audience about the opportunities of integrating textile and vibration for healthcare applications. We show how new manufacturing can lead to new possibilities in garment design and the integration of electronic components. With an example of dynamic behavior we demonstrate how the vibration therapy of the garment can be tailored to individual treatment needs. This design serves as a start. We plan to further investigate the effects of vibration therapy combined with textile design and electronics for the treatment of osteoporosis.

Keywords
Smart textiles, wellbeing, customization, product behavior.

1 Introduction

Vibration has three positive therapeutic applications: (a) for the improvement of bone density and muscle strength [1]; (b) for the attenuation of delayed-onset muscle soreness [2]; and (c) for an increase of the speed of the blood flow through the body [3]. Vibe-ing is a care tool in the form of a garment, which invites the body to feel, move, and heal through vibration therapy. The aim of this design is to contribute to the treatment of osteoporosis, particularly for women who are most at risk of developing osteoporosis in the post-menopause period [1, 3] and therefore supporting the need for their wellbeing. The textile from which Vibe-ing was constructed has been produced using a fully-fashioned knitting machine. This technique allowed us to create digitally designed, pre-shaped pieces for the garment. The textile contains pockets in which circuit boards with sensors (touch sensors) and actuators (vibration motors) can be placed (shown in Figure 1). Throughout the textile power and communication lines are integrated that connect the pockets with each other. This modular system enabled us to program the exact areas and the way of stimulation on the body depending on the specific person's need for rehabilitation and healing.

By developing this prototype we aim to trigger a multi-disciplinary audience to consider the opportunities of integrating textile and vibration for healthcare applications. We hope to bridge the disciplines of fashion, technology and healthcare. Further, we highlight the possibilities of integrating textile and electronics using modern manufacturing techniques. Finally, we will show how a body-worn decentralized network of vibration and touch modules enabled us to add a dynamic behavior to the garment, tailored to the needs of the person wearing Vibe-ing.

Fig. 1. Left: front of Vibe-ing with two rows of pockets. The white circles visualize the vibration of the modules. Right: back, with the pockets containing the vibration and touch modules on the spine and shoulders. The silver lines are the connection lines between pockets

2 Textile and technology for healthcare

Relating to the integration of textile and technology for osteoporosis applications there are some design choices we would like to emphasize. These design choices show the challenges within the different levels of the design process. We choose for merino wool as textile fiber because of a number of attributes and beneficial properties. These properties include a resistance of chemicals and dirt, absorbency, insulating capabilities, resilience, positive tactility [4] and versatility [5]. For the textile design we used two layered knitting and felting techniques to produce a textile with a voluminous shape, soft and bulky surface. This surface invites the wearer to stroke and touch the fabric and the body. For the integration of technology we choose for vibration actuators that are integrated in the textile pockets. This combination enables the application to have a healing effect on the muscle density of the people wearing the garment. In the garment design we placed the pockets to align with critical pressure points on the body (Figure 1 shows the specific placement of the modules on the body of the wearer). For example, the shoulder area is a difficult location to perform surgery when fractured. Noninvasive treatment, such as vibration on this location could increase the bone density and relief shoulder pain. The lumbar region on the back is often associated with a sedentary lifestyle, and a source of chronic pain for many older people.

Vibration could relieve the pain by increasing the blood flow in this specific area [1]. By rotating the garment (back to the front, top to the bottom) we can further stimulate pressure points on the front of the body. This can offer stimulation of the hips and the ribs. These two areas are often affected by decreasing bone density in the post-menopause period [1, 3]. Simultaneously, flexibility in wearing the garment in different ways enables different treatments with the same garment, limiting the amount of textile, electronics and energy. In conclusion, these aspects – merino wool properties, the knitted soft surface and vibration actuators embedded in the pockets in the garment – could contribute to the feeling of physical-emotional comfort as a noninvasive therapeutic treatment of osteoporosis.

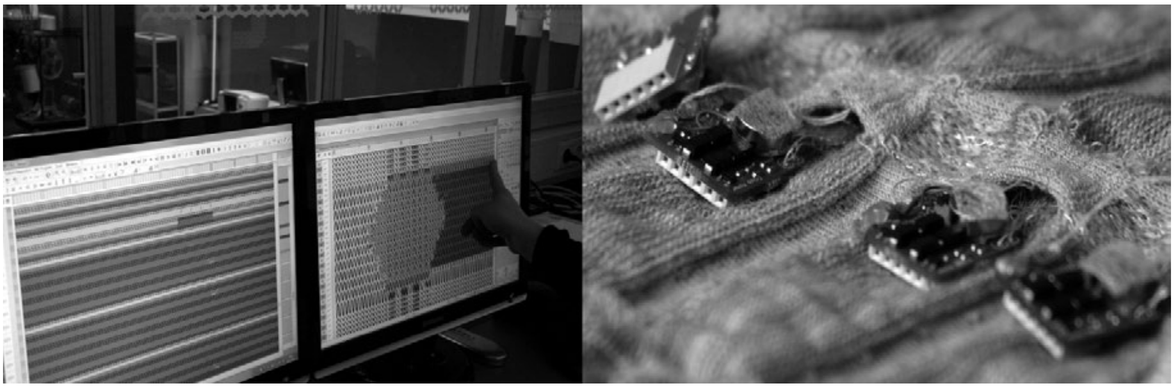

Fig. 2. Left: the computer interface to design the pockets. Right: the bottom of the pockets, showing the touch sensitive fabric, the connection lines and the electronic modules

3 New manufacturing possibilities

Besides showing the potential for healthcare, the design of Vibe-ing is also an exploration of the possibilities to bring the manufacturing of textile and digital design tools closer to each other. Modern manufacturing techniques, such as fully-fashioned knitting, make it possible to produce a garment without the need of additional cutting and sewing (the left picture in Figure 2 shows the digital tools used to design complex textile complete garments). These techniques will enable designers to produce in smaller quantities, customized to the users needs, shape of the body, and aesthetic preferences, thus reducing waste compared to traditional mass production of garments [6]. At the same time, this allows for more complex structures that make it possible to integrate technological elements into textiles. This perspective expands the design discourse in terms of how garment design is more integrated with body consciousness, which links to a sense of physical wellbeing. We will illustrate these new possibilities with examples from Vibe-ing. During the design process the merino wool was knitted using a jacquard pattern to create a bulky structure after being felted. The garment can be customized to different body shapes, while the placement of the vibration modules can be modified to the needs of the individual user. The pockets in the garment contain specially developed modular electronic circuit boards with actuators and sensors on it (the modules are shown on the right picture in Figure 2). Connected by power and communication lines, these modules provide the therapeutic vibration. The knitted construction of the pockets consists of a combination of different yarns. In the bottom of the pocket a mix of a soft conductive yarn and an elastic yarn to function as a stretchable touch sensitive surface (showed on the right picture in Figure 2). Because of the conductive yarns it becomes possible to measure the body capacitance of the skin touching the fabric, creating a basic touch sensor. The copper yarns knitted in the textile, provide the power and communication throughout the garment, while in the pocket they run freely to make them accessible for connecting to the circuit board.

4 Behavior of the garment

With this design we would like to show the possibilities of a body worn network of sensors and actuators integrated in the garment. We see more and more examples of intelligent systems consisting of different nodes, for example in living rooms [7], lighting systems [8] and textile applications [9]. These make it possible to extend the functionality of separate products, and can transform previously static products into products with a dynamic behavior. In Vibe-ing we distributed multiple modules in the garment, corresponding to different locations on the body. With this configuration it became possible to program the exact areas and form of stimulation on the body, depending on the specific person's need for care, rehabilitation, and healing. The modules in the garment are programmable using the Arduino platform, enabling designers to quickly adapt the functionality and behavior of the garment. As demonstration of this platform we designed an initial behavior for the garment that is based on a ripple pattern (similar to a wave in the water or sound travelling through air). A vibration would start in the pocket which was touched by the person wearing the garment. Then, slowly the vibration would transfer to the surrounding pockets, until it faded away after a certain period (this dynamic movement of vibration is visualized by the white circles on the left picture in Figure 1).

5 Further research

The work we presented in this short paper is still preliminary and serves as a trigger to open further research. The garment has been designed as a platform to explore different behaviors of the vibration motors. The implemented “ripple behavior” is one of the possibilities but has not yet been verified for the treatment of osteoporosis. Our assumption is that the behavior of the garment could engage the user in the treatment process. For example, by guiding the touch of the person with the vibration motors to specific pressure points, or by gently reminding the person to stimulate the pressure points during long inactivity. As a next step it will be necessary to design these different behaviors in collaboration with practitioners and end-users, and to validate these behaviors with user tests. The placement of the pockets is based on the specific pressure points and has been carefully selected. By further discussing this placement with experts, and conducting user studies with the prototype we hope be able to validate the placement. To treat osteoporosis effectively we will further investigate existing scientific and medical implementations to find out more about the amplitude and frequency characteristics of the mechanical stimulation. Thereafter, it will be necessary to monitor this frequency and let the vibration modules adapt to the right frequency in relation to the location of the pocket on the body. Because of the fully-fashioned manufacturing technique it becomes possible to customize the garment to the preferences of an individual. This opens up new design possibilities and new business models that can be explored. To conclude, in further research it will be crucial to collaborate with medical experts to evaluate our application of vibration therapy and extend it further based on knowledge in the medical field. To explore the possibilities of customization and the design of a personal care tool it will be necessary to involve end-users and manufacturing partners to make sure the garments fits the individual preferences and body shape and measurements of the person.

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7 References

1. Verschueren, S.M., Roelants, M., Delecluse, C., Swinnen, S., Vanderschueren, D., Boonen, S.: Effect of 6-Month Whole Body Vibration Training on Hip Density, Muscle Strength, and Postural Control in Postmenopausal Women: A Randomized Controlled Pilot Study. Journal of Bone and Mineral Research. 19, 352–359 (2003).
2. Lau, W.Y., Nosaka, K.: Effect of Vibration Treatment on Symptoms Associated with Eccentric Exercise-Induced Muscle Damage. American Journal of Physical Medicine & Rehabilitation. 90, 648–657 (2011).
3. Klima, R.R., Weigand, A.H., DeLisa, J.A.: Nerve Conduction Studies and Vibration Perception Thresholds in Diabetic and Uremic Neuropathy. American Journal of Physical Medicine & Rehabilitation. 70, 86–90 (1991).
4. Jeon, E.: Designing enriched aesthetic interaction for garment comfort, Doctoral Thesis (2013).
5. Holcombe, B.V.: Wool Technology and Sheep Breeding: The role of clothing comfort in wool marketing. CSIRO Division of Textile Physics. 34, 80–83 (1986).
6. Larsson, J., Peterson, J., Mattila, H.: The knit on demand supply chain. AUTEX Research Journal. 12, 67–75 (2012).
7. Van der Vlist, B., Niezen, G., Hu, J.: Design semantics of connections in a smart home environment. Design and Semantics of Form and Movement (DeSForM 2010). (2010).
8. Magielse, R., Offermans, S.: Future lighting systems. CHI ‘‘13 Extended Abstracts on Human Factors in Computing Systems (CHI EA ’’13). (2013).
9. Deckers, E., Wensveen, S., Overbeeke, C.J.: PeR: Designing for perceptive qualities. Presented at the Design and Semantics of Form and Movement (DeSForM 2010), Lucerne, Switzerland (2010).