# *Magic Lining*: Crafting Multidisciplinary Experiential Knowledge by Changing Wearer's Body-Perception through Vibrotactile Clothing

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## Abstract

Our complex and rapidly changing world presents us with profound societal challenges, but also offers tremendous opportunities for new technology to respond to those challenges. Several recent EU initiatives have enabled participants from a diverse array of disciplines to engage in common spaces for developing solutions to existing challenges and to imagine possible futures. This includes collaborations between the arts and sciences, fields which have traditionally contributed very different forms of knowledge, methodology, results and measures of success. They also speak very different languages.

*Magic Lining* is a collaborative project involving participants from the fields of e-textile design, neuroscience and human-computer interaction (HCI). *Magic Lining* combines the findings of their respective disciplines to develop a 'vibrotactile' garment utilising soft, interactive materials and is designed to alter the wearer's perception of their own body. Here we explain the process of designing the first prototype garment—a dress that produces in its wearer the sensation that their body is made of some of other material (stone, air, etc.) and in turn elicits various perceptual and emotional responses (feeling strong, feeling calm, etc.). We reflect on the collaborative process, highlighting the multidisciplinary team's experience in finding a common space and language for sharing cognitive and experiential knowledge. We share our insights into the various outcomes of the collaboration, giving also our views on the benefits and on potential improvements for this kind of process.

### Keywords

Multidisciplinary Collaboration; E-Textiles; Body-Perception; Embodiment; Multisensory Perception.

Today we are experiencing a period of profound socio-ecological change. Multidisciplinary engagement in research is essential if we are to overcome the challenges posed by this change. The tools for such collaboration are in continual development. A number of European Commission initiatives under the umbrella of 'STARTS' (Science, Technology and the Arts) are seeking to foster and explore the potential for common spaces in which arts and sciences can co-create. As part of this initiative, the *Magic Lining* project focuses on the experiential knowledge, opportunities and difficulties arising from a multidisciplinary space that merges the expertise of fashion and textile design and technology (known as e-textile), human-computer interaction (HCI) and cognitive neuroscience. In order to understand this space, we entered into a collaborative process (as recommended by Ingold, 2013) to create knowledge, build environments and transform lives through making. The project aims to create fashionable clothing that focuses on making people feel good about their bodies instead of the usual focus on having their bodies look good for others. To this end, we merged fields in order to ground e-textile development in recent developments in the fields of cognitive neuroscience and HCI, thereby showing the potential for changing personal body-perception through the use of technologies that provide multisensory bodily feedback. In this article, we share our motivations and the background to this experimental project, noting also the potential for this multidisciplinary collaboration to feedback into our respective disciplines. We describe our reasoning and the knowledge shared within our team throughout the life of the project.

## Background and Related Work in Fashion, E-Textiles, and HCI

Fashion affects many aspects of our lives and plays an important role in shaping consumer culture (Sassatelli, 2007). It connects symbolic and aesthetic expressions with the cultural meanings that objects carry (Pan, Roedl, Blevis and Thomas, 2015). Clothing in fashion attempts to balance two contradictory aims: it focuses on our attractions while protecting our modesty (Kawamura, 2004). It is a symbolic product; and its meaning is determined by time (Kaiser, 1996). However, the biosocial aspects of fashion have been largely overlooked, and this is especially apparent when we consider the plenitude of studies in fashion aesthetics (van Busch, 2018).

Our goal with *Magic Lining* is to create fashionable clothing that considers this overlooked biosocial element, by focusing on making people feel good about their bodies for themselves instead of having their bodies look good for others. To this end we combine the fields of e-textile development, cognitive neuroscience and HCI.

E-textiles, as materials connecting textile softness with electronic properties (Hertenberger *et al*., 2014), are obviously a promising material for interactive clothing. They allow technology to become almost imperceptible in close proximity to the body, and to weave or knit components into the textile structure itself. In this way, clothing can begin to play a role in supporting the body in ways that are beyond the vision current fashion trends. For example, the knitted cardigan *Vibe-ing* (M Bhömer, Jeon and Kuusk, 2013) offers vibration therapy for rehabilitation through vibrating elements integrated into the pockets, which are constructed using a standard knitting machine. This sort of e-textile invites the use of touch to enhance stimulation, whereas *Vigour* (ten Bhömer, Tomico and Hummels, 2013) enables geriatric patients, their family and physiotherapists to gain insight into exercise and the progress of rehabilitation by monitoring the movement of the upper body. *MVO* sustainable and supportive garments for hospitals (Toeters, 2016) are aimed at nurses and caregivers themselves, helping them to maintain healthy postures and working environments: the garments include a posture sensor, a gas sensor and a supportive under layer. The neuro-rehabilitation concept *Mollii* (2019), a close-fitting suit that is already successfully on the market, provides rehabilitation electrotherapy programmed for the particular needs of the individual. The suit reduces unwanted reflexive movements and muscular stiffness in people with spasticity or other forms of motor disability, thereby enabling the wearer to improve their posture and enhancing their range of motion and functional ability. Fitness wearables (Adidas, 2018; OMsignal, 2018; Owlet, 2018; Sensoria, 2018) and monitoring devices (Zoll, 2017) are also increasingly becoming an integral part of our everyday clothing.

While audio-visual cues have tended to dominate feedback and communication strategies, tactile or haptic cues represent a good complimentary channel and in some cases provide a necessary alternative (for example, in space and underwater environments): 'Tactons', or 'tactile icons', are structured, abstract messages that can be used to communicate non-visually (Brewster and Brown, 2004); and new forms of interface that exploit ultrahaptics have opened up the development of tactile surfaces by offering mid-air haptic feedback development (Shakeri *et al*., 2018; Ultrahaptics, 2018; Obrist *et al*., 2015). Tactile sensations can be delivered by electric stimulation, which has already been used in the rehabilitation of movement disabilities (Inerventions, 2019). *Teslasuit* (2018), is a bodysuit that utilises fine-tuned location-specific electric stimulation of the skin to deliver haptic feedback directly to the entire body. *Hardlight VR suit* (2017) follows the same whole-body concept, but instead using a force feedback approach. *Versatile Extra-Sensory Transducer* (Eagleman *et al*., 2017) can take in diverse types of real-time data—from sound waves to help the deaf, to flight status, even stock market trends—and translate this data into dynamic patterns of vibration in its motors (Keller, 2018).

Fig 1. Magic Lining concept photos representing sensory-feedback, integrated in the inner layer of the garment, changing the perceived "material" of the body.

These technologies have already begun to enter the market, but the potential of the experiences they can deliver is still largely unexplored. While the prototypes and products mentioned thus far focus on developing the technologies and materials they use, there is also a need for understanding the psychological effects of these tactile sensations on the wearer. What potential is there for giving the wearer the feeling that they are made of some different material? Will they feel fitter? More relaxed? Happier? Our interest is the peculiar link that smart textiles may be able to form between our bodily sensations and cognition. Specifically, *Magic Lining* (Figure 1), aims to find meaningful, affordable solutions in the space between neuroscience research on body-perception, HCI and body-centred smart textile applications.

## Neuroscience and the Use of Sensory Feedback to Alter Body-Perception

Neuroscientific research has shown that the way people perceive their body appearance or their physical capabilities is not something fixed. These body-perceptions change continuously in response to sensory signals relating to one's body (Botvinick *et al*., 1998). Research has shown that these body-perceptions impact on the way people interact with their environment, as each individual must continually keep track of the configuration, size and shape of their various body parts when performing actions (Maravita and Iriki, 2004). Moreover, body-perceptions are basic in forming our self-identity (Longo *et al*., 2008) and are tightly linked to self-esteem (Carney *et al*., 2010) and social interaction.

Recent studies in this area have shown the potential of using bodily, sensory feedback (or manipulating body signals) to alter body-perception (Tajadura-Jiménez et.al., 2015; Botvinick et.al., 1998; Azañón *et al*., 2016; Haggard *et al*., 2007; Maravita and Iriki, 2004; Tsakiris, 2010; Tajadura-Jiménez *et al*., 2017; Vignemont *et al*., 2005; Tajadura-Jiménez *et al*., 2012; Longo *et al*., 2008; Tajadura-Jiménez *et al*., 2018; Maister *et al*., 2015). For example, presenting discrepant visual and tactile cues, or visual and proprioceptive cues about the body can lead to a change in one's body-perception, such as the perception that one's arm is longer than it actually is and corresponding errors in physical coordination (Kilteni *et al*., 2012; Vignemont *et al*., 2005). More recently, research has also shown that aural feedback can be used to alter body-perception. So, for example, one may also get the perception of having a longer or a stronger arm, if, when tapping one's hand on a surface the sounds produced are heard from a farther distance or louder than expected; and this will also influence one's subsequent arm movements and even one's emotional state (Tajadura-Jiménez *et al*., 2012; Tajadura-Jiménez *et al*., 2015; Tajadura-Jiménez, 2016).

Beyond these effects on body-perception, other works have shown that similar sensory feedback alterations can be used to alter the perceived material one's body is made of. If, for example, when an object hits one's hand it sounds like it is hitting marble rather than flesh, one's hand may feel stiff and heavy as though made from that material (Senna *et al*., 2014). Other studies have shown that shifting the frequency spectrum of the sounds made when rubbing one's hands together may make one's skin feel smoother or dryer (Jousmäki & Hari, 1998). Another study suggested that one's body may feel as if "robotized" or made of mechanic components, if, when moving one's limbs one receives vibrotactile feedback and sound from recordings of real robot articulations (Kurihara *et al*., 2013). Our project was inspired by all of these findings.

## Crafting Common Space for Sharing Experiential Knowledge

Our team of three brings together expertise from each of our respective fields: e-textile design, cognitive neuroscience and HCI. This meant facing not only the challenge of learning about our respective fields, but also coming to terms with our different ways of working, acquiring and sharing knowledge. Our team consists of individuals with unique experiences, skills and motivations. We now introduce each actor of the study and their involvement in the project.

Kristi Kuusk, an e-textile designer, has the role of *artist* in our project. Kristi has a BSc in Information Technology and MA in Fashion Design, and her PhD thesis is entitled "Crafting Sustainable Smart Textile Services" (Kuusk, 2016). Her goal is to apply theoretical and scientific content in a new way, combining this with her passion for developing alternative sustainable futures for textile and fashion, and proposed to design a garment that would provide its wearer with a variety of sensations.

A multidisciplinary researcher in the fields of HCI and Cognitive neuroscience, Ana Tajadura-Jiménez has the role of *neuroscientist* in our project and is the principal investigator of the *Magic Shoes* project. Her research focuses on the use of sensory feedback for altering body perception and its applications for health. Her goal is to inform the design of novel body-centred and wearable technologies to support people's emotional and physical health needs and to effect behavioural change.

Aleksander Väljamäe an *HCI researcher*, is also a partner in the *Magic Shoes* project. He is focused on contributing to concepts and expertise in physiological computing. Among his research interests are somatic practices and soma-based design in relation to the work of actors and dancers. Specifically, creating an IT communications loop between body and mind for health and well-being, whereby vibrations provide information about the cognitive and emotional states of the user.

For all three members of our team, 'craft', as a way of thinking through material (Nimkulrat, 2012), was implicit in our practices in the *Magic Lining* project. We believe that this craft attitude has been essential in enabling us to share our experiential knowledge and engage with one another's disciplines. The team respects the "enduring, basic human impulse, the desire to do a job well for its own sake" (Sennett, 2008, p. 9), and we challenge one another to strive toward it continuously. We believe that by alternating between cognitive and sensory inputs throughout the collaboration we have been freed from our typical roles (as artist and scientists) and that this allowed each of us to contribute our distinct experiences, knowledge and skills.

## Developing *Magic Lining*—A Collaborative Process

To obtain first-hand experience of the potential of soft vibrotactile materials, our team proposed to develop a dress capable of changing the wearer's perception of their own body. We followed an iterative design process, producing three prototypes and two user studies on the effects of various textile vibration patterns on body-perception (spatial haptic metaphors). This led to the production of a fully functioning prototype garment (Figure 2).

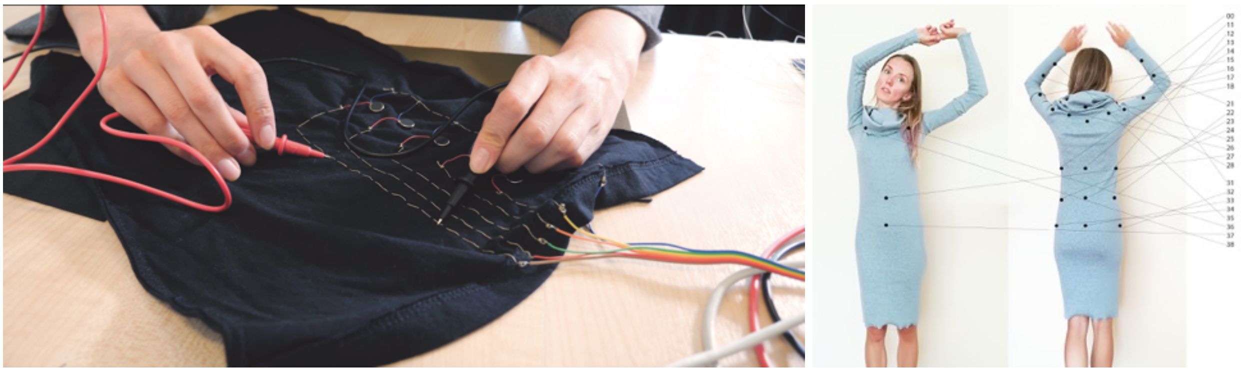

Fig 2. Left: first prototype of *Magic Lining*, allowing the user to experience a series of vibration motors delivering sensation patterns to the body through textile. Right: The vibration motor positioning on the final prototype. For a video describing the project and process: https://vimeo.com/289294125

The team members were each based in different countries, so communication was mainly via e-mail and Skype calls. In addition to these virtual meetings, we met for a workshop in Tallinn University, Estonia and for two residencies in Carlos III University of Madrid, Spain.

To kick-off the *Magic Lining* project, each team member presented their research at the World Usability Day event organized in Tallinn University. The scientists, Ana and Alexander, also visited Kristi's studio in order to get a better understanding of her work as an e-textile designer. During that meeting, Ana explained her work in neuroscience and proposed several keywords to provide focus for the project: "self-esteem", "body appearance", "physical strength", "body flexibility" and "body agility". This meeting coincided with a two-day workshop, which brought together around 20 people of multidisciplinary backgrounds and with a common interest in the project area. The group engage in an ideation process, to discuss the keywords and the ways in which they might guide the process of technological design. This sparked the first proposals for beginning the practical collaborative work.

Five weeks later, the first two-week residency at Carlos III University of Madrid took place. During this residency the team brainstormed ideas for a first prototype garment. Our team proposed to place small vibrating motors in the inner part of a fabric sleeve. These motors would connect to an Arduino microcontroller board, enabling them to be programmed with various patterns to stimulate the wearer's skin. The team discussed the possible mappings of vibrating patterns to sensations: which pattern could help convey the sensation of being stronger, or more flexible, or build self-esteem? How would these sensations be varied by the integration of the motors into different kinds of fabrics? Could a smoother fabric help the wearer to feel sensations and emotions associated with a soft embrace? Could a harsh, coarse surface trigger sensations associated with aggression, which would in turn make one feel more powerful or strong? A large part of the residency period was dedicated to addressing ideas relating to questions like these, and to introducing each team member to relevant work in one another's respective disciplines. Through these discussions, new ideas and practical considerations came into play, and in this way a common space for sharing experiential knowledge began to take shape.

The first vibrotactile prototype consisted of five vibration motors placed in a line (Figure 2, left) and allowed the team to explore the basic idea and the sensations the vibrating movement could potentially create. As we aimed to create more sophisticated patterns of vibration, we then proceeded by developing this into a sleeve that could transmit the vibrations across larger areas, creating sensations around the arm or on the back. We also wanted to explore the possibility of having the pattern of vibrations move gradually about the body. To achieve this, our next step was to create a 3 x 7 matrix of vibrotactile material.

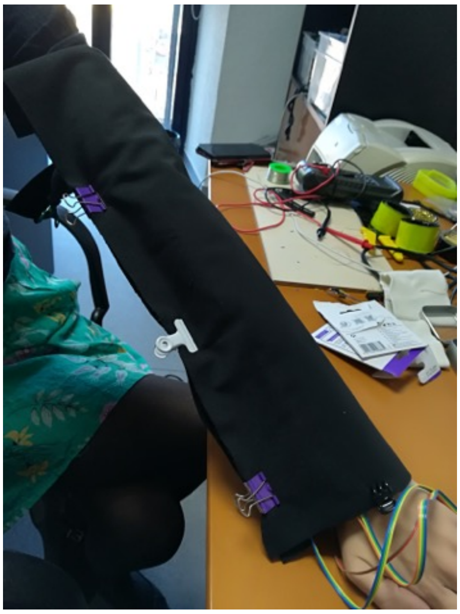

Fig 3. The second prototype of *Magic Lining* allows the user to sense vibration movements from one end to another, inside out and outside in, on the back and around the arm.

After solving several technical issues in programming the second prototype (Figure 3) and connecting the electronics, the team began looking deeper into vibration patterns and behaviours. The team studied papers in experimental neuroscience to understand how sensitivity to tactile stimuli differs across various body parts (e.g. Nolan, 1982), how vibrations have already been used on the body (e.g. Amemiya 2013 and 2016), and what kind of vibration patterns have been used (e.g. Deroy *et al*., 2016; Harris, *et al*. 2017). They also looked at the spacing between each motor and the duration of vibrations. We do not elaborate on those insights here, and they are covered elsewhere (Tajadura-Jiménez *et al*., in preparation).

Having first experienced the second prototype for themselves, applying it to different body parts and with vibrations passing in various directions and movements, the team began preparing a wider user study to test systematically the effects of the different vibration movements and locations on people's body perceptions. According to the initial tests on team members, the conditions with the greatest potential were: a wave moving from the fingers to the upper arm; a wave from the upper arm to the fingers; a wave moving vertically from the centre of the back towards the upper and lower back; a wave moving vertically from the upper and lower back towards the centre of the back; a wave moving horizontally from the centre of the back towards the sides of the back; and a wave moving horizontally from the sides of the back towards the centre of the back.

For the user study, the team changed the look and feel of the initial prototype to something more robust and comfortable, and with the vibration motors hidden from view. In order to quantify user responses, we developed a questionnaire based on previous cognitive neuroscience and psychology papers and on HCI papers (e.g. Tajadura-Jiménez *et al*, 2015; Longo *et al*, 2018; Stroyer *et al*., 2007). The questionnaire asked participants to report the bodily sensations they experience immediately before the test session and then the experience of each vibration pattern on their body. It also asked whether they felt quicker/slower, heavier/lighter, stiffer/more flexible, harder/softer, and so on. In this way, we created a starting point for understanding whether the vibrations could affect the way people feel about their environment or their own body composition (e.g. wood, water, rocks etc.).

To allow us to programme a wider range of patterns and with more detail, our third prototype resembled a spider's web (Figure 4), with 38 vibration motors placed in lines that cross at the centre.

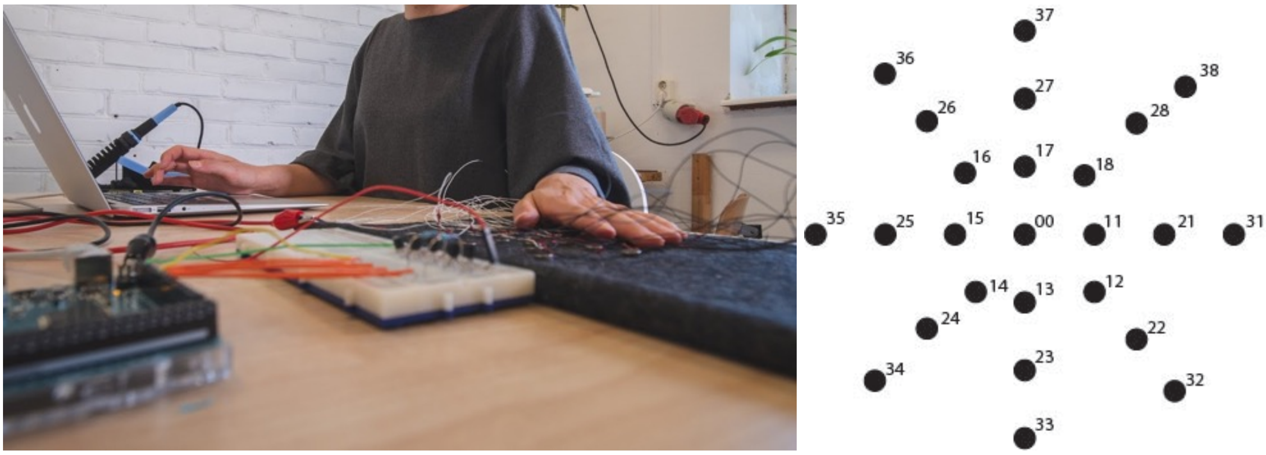


Fig 4. The third prototype of *Magic Lining* allows the user to sense vibration movements under his/her hand. The aim is to create body sensations that relate to materials.

During the second two-weeks residency, which took place in the seventh month of the project, the *Magic Lining* team explored further ideas about sensations, movement, vibration and textile materials. Once the "spider's web" electronic circuit was set up, the team created patterns that allowed us to check all the motors individually and in groups. We then started to explore with patterns that moved with different strengths, speeds and directions.

To create the patterns, one of our external collaborators developed a "pattern generator"—a software programme that allowed us to set the sequence and duration of each individual vibration motor, thereby generating code for the Arduino controller. This allowed us to freely experiment with many more patterns and intensities, which we again tried first on our own bodies.

After trying various patterns and analysing the results from the previous user tests, we identified some interesting directions for our project. We decided to focus on simulating the touch of three, very different, materials and then set to work developing a series of vibration patterns, intensities and different material surfaces that would simulate as closely as possible our idea of how a cloud, water and concrete should feel (see Figure 5). We began by thinking about how best to characterise these three phenomena and between the three of us came up with a list of keywords that would define the sensations we were aiming for. For example, "cloud" made us think of these keywords: air, calm, cuddle, cosy, comfortable, gas, warm, temporary, soft, white, light (i.e. weight), sun, flexible, fluffy, slow, light (i.e. colour), round, and loose. Parallel to this process, we sought the most appropriate material surfaces in which to embed the vibration motors. We looked at around 40 sample materials of varying characteristics and evaluated their influence on the sensations produced by the vibration movements. Again tested each material sample for themselves, this time with each of the three patterns, and selected the two samples that seemed the most extreme in relation to each other. Material sample 1 was a soft, fluffy, white unwoven polyester of the type normally found inside warm jackets, and sample 2 was a black, structured, woven waffle polyester that could be used for light jackets, skirts or trousers.

To enable the user to experience all three different vibration patterns on the new prototype, we added three, soft-touch, user selection/interface surfaces.

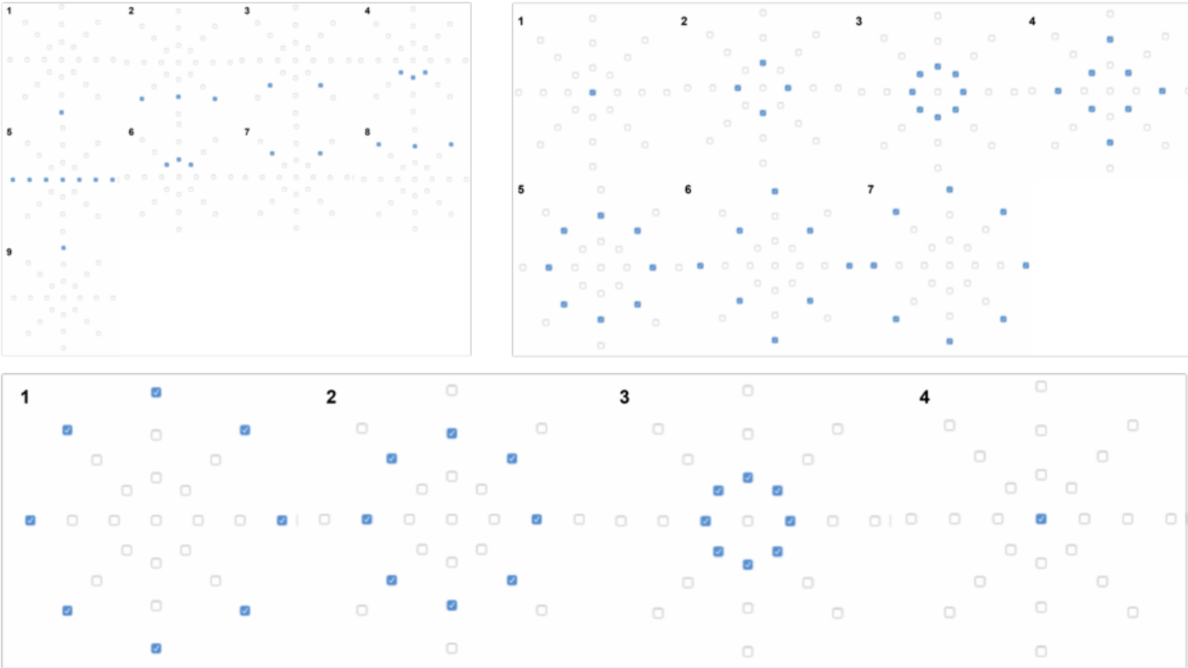

Fig 5. Vibration patterns used to simulate the feelings of water (upper left), air (upper right) and rocks (bottom).

Having got the prototype to a reliable functioning state, we started to experiment with adding sound and movement to enhance the vibration patterns. Drawing from *the Magic Shoes* project, we paired patterns with suitable sound files, which could be triggered by the wearer's hand touching different surfaces. We looked at whether sound enhances the experience of touch, again relating this to each of the various vibration patterns and fabrics.

Before deciding on the final cut and look of the *Magic Lining* garment, we presented the prototype at public events at the Pompidou in Paris and at the International Conference on Movement and Computing in Genoa (Kuusk *et al*., 2018). We produced a second, duplicate prototype (made from a different textile) to enable as many visitors as possible an opportunity to try a *Magic Lining* garment, and asked them each to complete a short questionnaire about the experience. The visitors were able to try all three vibration patterns with two different surface materials. The feedback from these events informed our decisions about the final prototype.

## *Magic Lining*: altering body perception through e-textiles

Our final wearable prototype is a dress with 38 integrated vibration motors. The motors are distributed along the body and guided via an Arduino controller. The placement of the vibration motors follows the spider's web structure of the third prototype and the logic that it would be possible to experience movements over both arms as well as around the body (Figure 6 right). Since the vibration is placed on the outer side of the arms, it can give the sensation of embracing the wearer and move around her.

The cut and material of the dress was selected based on the following criteria. For the vibrations to be felt as intended, the garment needs to be tight and close to the body. At the same time, the dress has to be flexible to allow the wearer to move freely. Jersey tubular dress with tight sleeves allows both.

This prototype invites the wearer to experience three very different materials: strong, fast, rhythmic vibration resembles a cold, rough surface, such as rocks; smooth, moving, medium vibration reminds the wearer of a flowing stream of water; and soft, distributed, slow vibration allows the user to forget him/herself in a soothing sensation of air or cloud.

Fig 6. The inside layer of the final prototype of *Magic Lining* allows the user to feel as if she/he is made of three different materials: air, water, rocks. A professional dancer is shown experiencing the prototype in these photographs.

We invited an acting professional dancer to experience the sensations the dress evoked in her (Figure 6). She expressed clear sensations of feeling calmer or more nervous when the vibration patterns were switched. This was reflected in her way of speaking, the tonality of her voice, speed of movement and body language. She described mental images of composers and pieces of music that specific vibration patterns brought to mind.

We continue to develop the project and to explore this idea in new directions, including: the use of multisensory stimulation (where vibrotactile feedback is paired with other sensory feedback such as sound, light or smell); a closed-loop bio- or neuro- feedback system; and social interaction settings. We would now like to provide some insight into our experience of this multidisciplinary shared project, and to discuss its possible implications for future collaborations of this kind.

## Discussion

Departing a little from Tim Ingold's claim that *"It is the artisan's desire to see what the matter can do, by contrast to the scientist's desire to know what it is"* (Ingold, 2013, p.31), we instead discovered both "artisans" and "scientists" in all of our team members. It is our willingness to let go of the authority of our respective areas of expertise, our established methods, and to reach out into the unknown, that has enabled us each to listen and learn from each one another's experiences. Over the course of the project, the e-textile designer had the opportunity to conduct formal user studies, while the neuroscientist could reflect upon the tactility of various materials. All three of us sewed, soldered and programmed. We continued as experts in our fields, but conducted this work using unfamiliar methods and tools.

As art, the goal of the project was to create through our garment a sensation of air, water or some other perceived substance, flowing through the wearer's body. With the structure and knowledge provided by the scientific participants, the concept developed into something far from a fashion statement and gained real insight into people's body perception. Through user studies, as artists we learned to seek test our ideas and intuitions. The additional technologies we began to look at during the project (e.g. the use of sound) opened further avenues for future exploration.

As science, the goal was to open up a space for designing multisensory wearable interfaces that act on bodily sensations and emotional experiences, by practical experimental application and reflecting on existing research, in order to find alternative directions, concepts and methods for further research. From the scientific point of view, the artist brought a new, alternative approach to the work, and three new lines of future research unfolded during the collaboration: (i) a new way of thinking about materials (e.g. a cloud, rocks) as sensations relating to the definition of body perceptions (e.g. being light or heavy); (ii) the potential for the interaction between vibrotactile patterns and textile surface to induce various bodily sensations; and (iii) new ways of changing one's body perception from within a garment—i.e. a form of stimulation that is both invisible and entirely intimate to the user.

The project produced a series of prototypes that enable the public to experience bodily sensations that suggest the material substance of a cloud, of water, or of rocks, thereby affecting the wearer's perception of their own body. The sensory-feedback technology developed from those prototypes is integrated into the inner part of the final prototype haptic dress, *Magic Lining*.

The work has benefited and inspired both our artistic and scientific partners. We have presented the project, its process and results, internationally: World Usability Day at Tallinn University (one art/design presentation, two science presentations, and a two-day workshop); Vertigo Residencies day at Centre Pompidou (presentation and demonstration); International Conference on Movement and Computing (demonstration and scientific paper); and the textile futures seminar at Tallinn Design Festival (presentation). Further, interest from commercial industry.

It is because all three team members shared all of the project tasks—generating ideas, prototyping, conducting user studies, analysis, experimenting with and experiencing the prototype technology, planning, reflecting, writing, etc.—that we were able to contribute our specific knowledge and experience most effectively. Although some tasks may have been performed more quickly had we allocated them exclusively to an 'expert' team member, we learned by working together—seeing directly the results of one another's work, but also submerging ourselves fully into every aspect of the process with the guidance of someone for whom this was a daily practice. We believe that this shared approach has led to insights we would not have gained otherwise. It required that we all step away from the comfort of our own discipline and accept the challenge of viewing a task from each other's discipline and perspective. In this way, we each took the opportunity to experience with fresh eyes the work and concepts that had already been central to our own work for some years. As Sennett (2008, p. 220) points out: *"Though much can be lost in moving from one language to another, meanings can also be found in translation."*

The following insights, ways of exchanging ideas and co-creating, emerged from our experience of developing *Magic Lining* as a multidisciplinary team. We experienced a shift in perspectives, "thinking out of the box", and cross-pollination between our areas of expertise. Following the approaches and methods of scientific practice gave structure to the artistic practice and, conversely, the artistic approach enabled moments of creative "chaos" to inspire the scientific practice. All three participants appreciated the common co-creative space and have seen its benefits for their daily work. We had to allow a generous period for getting for know each other, to gain a mutual understanding and find a common language. We achieved this through taking the time to present our ideas to one another, through creative drawing sessions, and by exploring materials. We kept a daily log of activities, including notes and photographs, that helped us to maintain our focus and continue to progress the project.

Our collaborative work showed that the use of vibrotactile patterns could induce various haptic metaphors in the wearer. In other words, e-textiles enable one to "wear" different sensations. However, it is important to bear in mind that since the vibrations delivered via textile are still relatively novel, there may be a "surprise" factor at play and wearers may eventually become habituated toward the experience—a phenomenon that is common with tactile actuators (both mechanical and electrical). The effects of long-term usage of this wearable technology need to be studied. Nonetheless, given the specificity of somatosensory stimuli and their role in fight-flight type reflexes, the use of haptic metaphors as tactile icons or "tactons" could be very effective. We are hopeful that the field of somaesthetic research and applications relating to designing for various bodily experiences, such as *Soma Carpet*, (Shusterman, 2008; Höök *et al*., 2016), will benefit from our work. As identified by *Teslasuit*, the personalisation of patterns is probably key to the success of such haptic clothing.

Every project is a new invention, utilising the knowledge gained from previous work, but always solving new challenges in new ways (see also Satomi and Perner-Wilson, 2007), and we discovered throughout the process that e-textile development could be very precisely tailored for a specific purpose and user—everything from the physical garment to the placement of the vibration motor arrays and pattern programming.

Our work *on Magic* Lining has made us wonder about the fashion of the future. Could it become something that is essentially experienced by the individual user rather than seen by others? What would the future catwalk be like? Instead of wearing the latest cuts and patterns of famous fashion designers, could we be wearing designer-emotions, downloaded directly to our second skin?

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**Kristi Kuusk**

Kristi Kuusk is a designer-researcher working on the direction of crafting sustainable smart textile services. She is looking for new ways for textiles and fashion to be more sustainable through the implementation of technology. In 2016 Kristi presented her PhD project on craft and sustainability qualities in smart textile services at the Eindhoven University of Technology in Designing Quality in Interaction research group. The related collaborative design work has been presented in various international exhibitions, shows and conferences. Her PhD work related to Augmented Reality on textiles was granted a patent in 2018 and commercialized by an industrial partner. Today Kristi works as an Associate Professor and researcher in the textile futures direction at the Estonian Academy of Arts. In 2017 her project "Magic Lining" was awarded by the jury of VERTIGO to collaborate with ICT R&D projects with the goal of producing original artworks featuring innovative use-cases of the developed technologies. In 2018 her explorative children clothing brand Spellbound was selected by the jury of WORTH as one of the winning projects for transnational creative collaboration. In 2019 Brooklyn fashion + Design Accelerator nominated Kristi as one of the 23 women leading the world of fashion technology.

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Ana Tajadura-Jiménez is an associate professor at the DEI Interactive Systems Lab at Universidad Carlos III de Madrid and honorary research associate at the University College London Interaction Centre (UCLIC). She graduated in Telecommunications Engineering from Universidad Politécnica de Madrid in 2002 and obtained an MSc degree in Digital Communications and Systems (2003) and a PhD degree in Applied Acoustics (2008), both at Chalmers University of Technology, Sweden. She was a post-doctoral researcher at the Lab of Action and Body at Royal Holloway, University of London (2009-2012) and an ESRC Future Research Leader at University College London, leading the project "The Hearing Body" (2012-2015). Since 2016 Ana is a Ramón y Cajal research fellow in Spain conducting research on multisensory body perception, wearable and self-care technologies at the intersection between the fields of human-computer interaction and neuroscience. She is currently Principal Investigator of the MagicShoes project, which aims to inform the design of technology to make people feel better about their bodies and sustain active lifestyles. This project has taken her to be part of the H2020 STARTS Arts-Science collaboration initiative. Her research has lead to over 100 peer-reviewed publications in international journals and conferences, and 4 book chapters.

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Aleksander Väljamäe received his PhD in applied acoustics at Chalmers University of Technology, Gothenburg, Sweden, in 2007. He has been doing research in Sweden, Spain, Japan, Austria and Russia. During this time he has being active in a number of EU projects: POEMS, PRESENCCIA, BrainAble, TOBI, Future BNCI, CONTRAST, GALA, BrainHack; and acted as an external expert for EC. Since 2016 he is an associate professor in physiological computing at Human-Computer-Interaction group, Tallinn University, Estonia. His current psychophysiology research concerns how audiovisual media influence humans on perceptual, cognitive and emotional levels, with particular stress on health/well-being and new applications (Brain-Computer Interfaces, neurocinema, neurotheatre). He also actively participates in art and science projects, e.g., his technical directing of the “Multimodal Brain Orchestra” performance in 2009, Prague or directing neurotheatre performance "Demultiplexia" in 2017, Brussels. He authored over 30 journal articles and book chapters.