

Keeping the Data within the Garment: Balancing Sensing and Actuating in Fashion Technology

Lianne Toussaint
Utrecht University
Utrecht, The Netherlands
l.toussaint@uu.nl

Marina Toeters
by-wire.net
Eindhoven, The Netherlands
marina@by-wire.net

ABSTRACT

Fashion technology designs typically combine sensing technology and actuators to register and respond to information about the environment and/or the human body. The ways in which designers use and integrate these data into garments, however, varies on a scale from highly theatrical and outward-oriented designs to subtle and inward-oriented applications. This pictorial presents five garment designs created between 2013 and 2020, that occupy the more utilitarian and inward-oriented end of the fashion technology spectrum (Fig 1). We visualize and analyze how these five designs combine sensing and actuation, highlighting the benefits of direct biofeedback and of keeping the personal data within the garment. The pictorial aims to show that striking the right balance between sensing and actuation is pivotal to realizing the physical, functional, social and ethical wearability of fashion technology design.

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for components of this work owned by others than ACM must be honored. Abstracting with credit is permitted. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee. Request permissions from permissions@acm.org.
DIS '20, July 6–10, 2020, Eindhoven, Netherlands.
Copyright is held by the owner/author(s). Publication rights licensed to ACM.
ACM ISBN 978-1-4503-6974-9/20/07...\$15.00.
<https://doi.org/10.1145/3357236.3395577>

Authors Keywords

Fashion technology; clothing design; personal biofeedback; balancing sensing and actuation.

CSS Concepts

• Human-centered computing~Collaborative and social computing~Empirical studies.

INTRODUCTION

For over two decades, designers have been exploring the possibilities of integrating technologies into clothing [e.g. 2, 16, 19, 21, 22, 23, 24, 29, 30]. The resulting garments, here referred to as 'fashion technology', typically combine sensing technologies (e.g. respiration, galvanic skin response or motion sensors) with actuators that translate the collected data into some kind of output (e.g. light, sound or vibration) [27]. This pictorial presents five fashion technology designs created within the past ten years. We combine a short description of the technical specificities and functionality of each design with a brief reflection on the design process and the qualitative (interview and survey) data of some of the most significant wearer test results. We then use these insights combinedly to analyze how each design establishes a different biofeedback loop between the wearer and the garment, which is visualized in schematic representations [18]. The aim is to show how the balance between sensing and actuation impacts the 'wearability'

of fashion technology designs [7, 8, 33] in terms of physical, functional, ethical and social dimensions.

With the physical, functional, ethical and social wearability of fashion technology we mean that a garment can only be considered truly wearable if the wearer finds it to be suitable for wear on four levels: (1) it is physiologically comfortable and has a fitting shape, weight and form; (2) it serves practical or functional needs such as safety or warmth; (3) it fits its practical purpose, social context and socio-cultural identity of the wearer [3, 6, 11] and; (4) it is ethically acceptable in light of its environmental impact [12], as well as privacy-related issues such as data sharing and access [1].

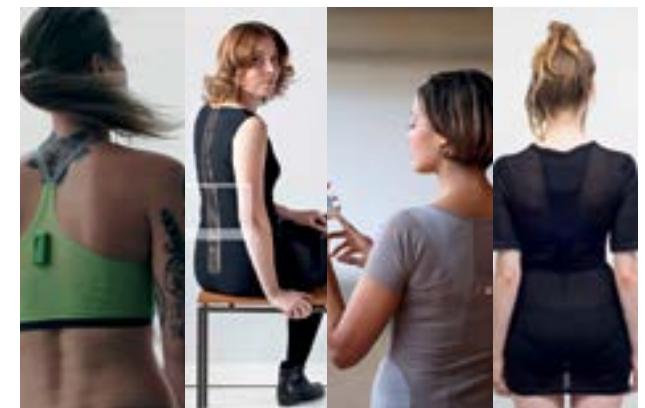


Figure 1. 4 fashion tech designs, nr. 5 work in progress.

ANALYSIS: 5 FASHION TECHNOLOGY PROJECTS

The five fashion technology projects described in this pictorial have all been (co-)developed Marina Toeters, by one of the authors. We selected this particular set of design projects because it illustrates a development from an approach mainly focused on designing for physical or functional wearability, to a broader approach that also considers social and ethical dimensions.

All of the design projects presented here combine sensing and actuation, yet the type and amount of actuation differs from inward-oriented to more outward-oriented applications. A purely inward-oriented design approach limits the use of data [17] to direct personal biofeedback given to the wearer only. More outward-oriented designs, on the other hand, (also) allow wearers to share the collected data with their social environment or even the outside world (Fig. 2).

The five projects analysed in this pictorial provide insight into how the decision to actuate data inward and/or outward is inextricably connected to the 'wearability' of the garment on all four levels. Whereas project 1 to 4 have already been realized and tested, the fifth and final project represents work in progress. In addition to providing photographs and technical drawings of the designs, we present schematic visualizations of how each garment translates the incoming data from the sensors into visual or sensorial output for wearers and/or their surroundings. See legend to these schematic visuals in Fig. 2.

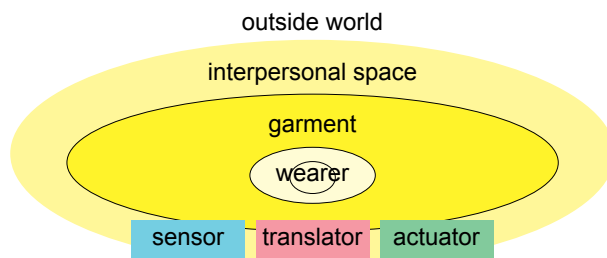


Figure 2. Legend to schematic visuals

Project 1: Closed Loop Smart Atleisure Fashion

This project consists of a collection of women's sportswear that uses heart rate, acceleration and respiration sensors to measure the wearer's health, performance and stress level (Fig. 3). The heart rate and respiration sensors have been printed and laminated directly onto the textiles, allowing for unobtrusive, comfortable and flexible integration into the garment (Fig. 4). The hardware (battery, communication, and acceleration sensor) is placed in a tiny removable container in between the wearer's shoulder blades (Fig. 5).



Figure 3. A bra from the biosensing sportswear project.



Figure 4. Printed electrodes on TPU foil to measure heart rate and respiration.



Figure 5. The hardware (battery, communication, and acceleration sensor) in a tiny removable box on the back.

The biometric data collected through the sensors are processed and visualized with the help of a fitness app that wearers can access on a mobile device. The data of heart rate, breathing and movement are visualized in three separate graphs (Fig. 6).

First of all, twelve wearer tests conducted during the design process proved that the technology embedded in this sportswear collection is *physically wearable* in the sense that it is small and lightweight enough to be worn comfortably while exercising [9]. Moreover, the printed electronics allow the sensors to remain in constant touch with the moving body, assuring accurate measurement and registration.

As a tool for self-care, however, the designs offer limited *functional wearability* as their feedback is perceived indirectly (i.e. through the app) and visually. Wearers can only effectively benefit from the functionality of the design



Figure 6. The app shows the data in 3 graphs.

if they constantly keep an eye on the app that 'translates' and visualizes the raw data from the sensors into three graphs (Fig. 6). In order to be able to read and use the data, wearers thus have to disconnect themselves from their physical surroundings while working out, which increases the risk of hinder, distraction or even accidents [30]. Moreover, the app that visualizes the data requires wearers to first interpret them before they can actually make an impact on their behaviour, sports performance or health. Neither the garments nor the app provide active instructions or direct feedback to the wearer based on the input from the sensors. This implies that the meaning ascribed to the visual output in the app is variable and may lead to confusion, misinterpretation or even undesirable effects on the health and stress level of the wearer [11]. The functionality of the design is thus compromised by the fact that it actuates the data in an outward-oriented way (Fig. 7).

Wearer tests pointed to another interesting aspect of this design project. Wearers indicated that they wanted the technology to be visible to their environment, which shows that physical and functional elements such as the placement of the technology are also connected to the *social dimension* of fashion technology.

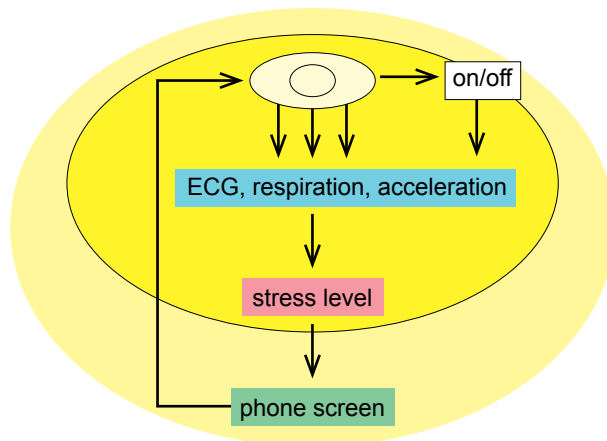


Figure 7. Schematic visualization biosensing sportswear.

Project 2: Spine-Warming Dress

The second fashion technology project we want to analyse is a dress containing a band of conductive copper on the back, which gives tiny pulses that gradually warm the spine towards a comfortable temperature (Fig. 8). The conductive non-woven material has a low resistance, the copper ribbons a very high resistance, and they spread the current vertically while the non-woven in the middle warms up when current passes through (Fig. 9).

As the previously discussed project, this design is comfortable (i.e. *physically wearable*) to wear and integrates the sensing technology in a subtle way. The main difference is in the actuation, which is tactile and inward-oriented rather than visual or screen-based. The changing temperature of the copper band gives direct and active biofeedback to the wearer and continuously adapts to signals it gets from the body. No translation, visualization or interpretation of the data is thus needed. In fact, the results of our in-depth interviews with test wearers prove that the temperature rise caused by the dress is gradual enough to not distract or actively call for the attention of the wearer [31].

The spine-warming dress showcases the potential for fashion technology to actuate data in a purely inward-oriented manner, allowing the data to remain within the garment and to direct the actuation at the wearer only. Following our elaborated definition of wearability provided in the introduction, the garment is *ethically wearable* in the sense that the wearer remains the sole owner of the data and is in full control of how they are collected and shared. No one else but the wearer can notice the gradual change in temperature, which eliminates the risk of privacy violation [1, 13, 14, 15] or negative psychophysical effects [7]. Moreover, wearer tests indicated that the *social wearability* of this dress, i.e. how socially comfortable the wearer feels while wearing the technology [8, 31], is high because actuation is tactile and inward-oriented. The only visual and aesthetic expression of the embedded technology inside the garment is the copper band placed on the spine. Since this band does not actively communicate anything

to the outside world, the feedback loop between sensing and actuation remains within the garment and with the wearer only (Fig. 10).



Figure 8. The spine-warming dress.

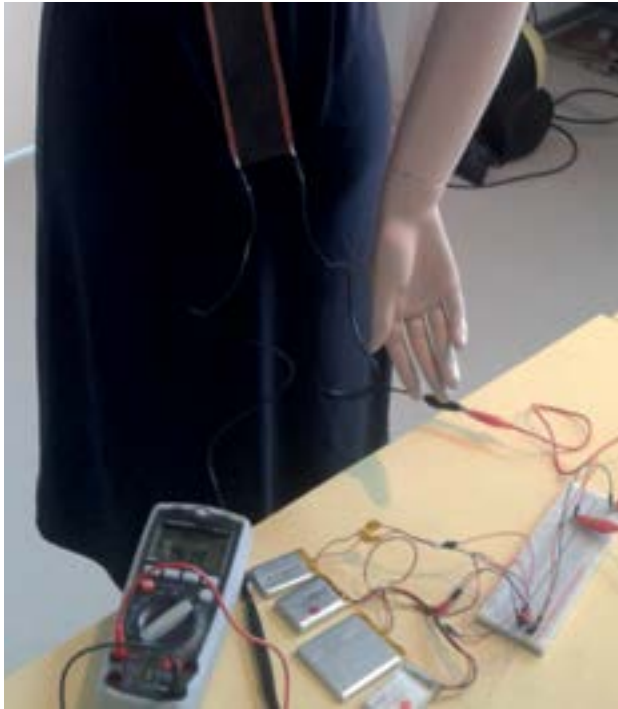


Figure 9. Technology development of the heating system. The power is guided via the copper ribbons.

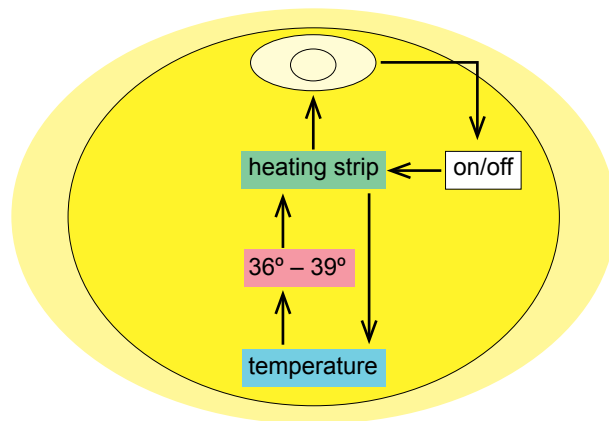


Figure 10. Schematic visualization Spine-Warming Dress.

Project 3: Smart and Supportive Garments for Caregivers

The next and third fashion technology project is a collection of workwear for caregivers and nurses [28]. The undergarment provides health professionals—who perform a very physical job—support to the shoulders, lower back and knees by pattern construction and choice of fabric (Fig. 11).

The outerwear is equipped with an anti-bacterial coating, which helps reduce the risk of bacterial contamination. Electronic ‘wearables’ (Lumolift) in the garments can issue a warning signal when the posture trackers register overload or unbalanced postures.

This project is unique for its focus on designing garments that can take better care of caregivers and stimulate them better take care of themselves. Combining indirect feedback through data visualization and statistics (Fig. 12) and inward-oriented personal biofeedback (vibration), the garments offer both direct and indirect stimuli for posture correction (Fig. 13).

Whereas the spine-warming dress and biosensing sportswear focused on either outward or inward-oriented actuation, this design project for caregivers represents the potential and pitfalls of combining both. Elaborate testing with healthcare professionals from hospitals and a home care organization showed that the direct biofeedback through vibration is relatively unobtrusive and subtle enough to be physically and socially wearable [4, 8]. In terms of functional wearability, several test wearers indicated that some of the activities were wrongly marked as ‘damaging’ by the technology while they are simply part of the job.

That the garments also collect and store data in an outward-oriented way potentially violates the privacy of the health professionals. Especially when power relations such as those between employees and employers are involved, there is a risk of undesirable use [5]. As the smart garments for caregivers expand the feedback loop between sensing and actuation beyond physical and personal (i.e. inward-oriented) space, the issue of

ethical wearability thus resurfaces. This illustrates the importance of an on/off option that allows wearers to control if, when and how their personal data are collected or shared.

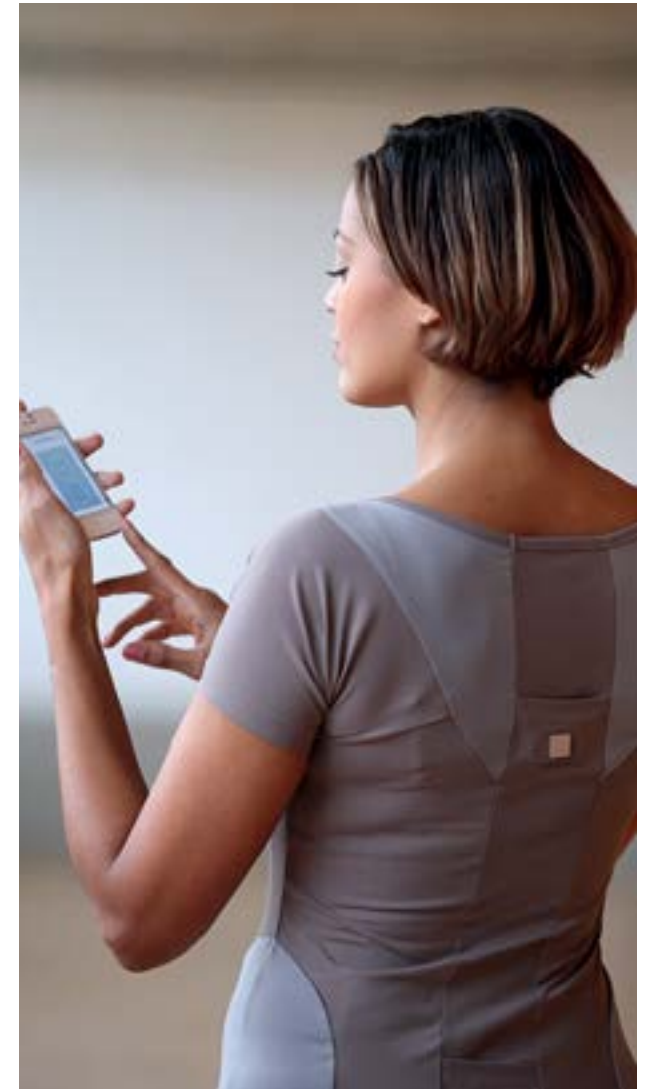


Figure 11. Underwear from project 3.



Figure 12. The Lumolift app.

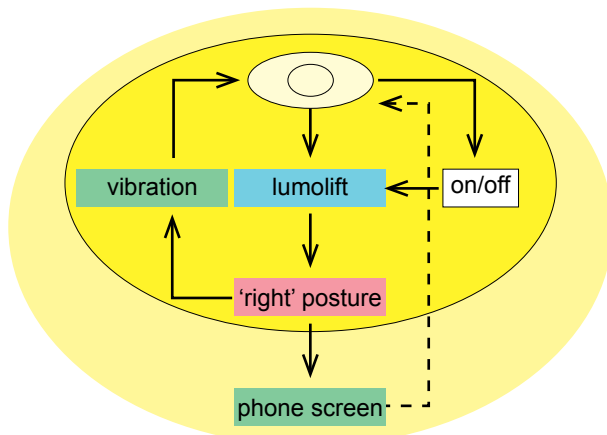


Figure 13. Schematic visualization of project 3.

Project 4: NazcAlpaca, Stress-reducing Shirts

The fourth design project presented here consists of a collection of knitted alpaca yarn shirts that contain wearable technology geared towards avoiding work related stress issues (Fig. 14). Most visuals of this project can be found on the next page of this pictorial.

These biomonitoring shirts (Fig. 15) contain an ECG sensor, accelerometer and a breathing sensor, and give the wearer direct inward-oriented feedback via a tiny vibration in the upper back (Fig. 16). In addition, the collected data are communicated outward via a wireless Bluetooth Low Energy chip that connects to a phone. A specially developed iOS app allows wearers to adjust the sensors' settings, start training and check their data history (Fig. 19, 20). The training application visualizes the data using three icons that represent the data input (for example, the wave-icon indicating breathing would slowly fade in and out) and an indicator. A representation of the wearer changes expression based on 4 pre-defined states ("normal", "rest", "stress", and "active") (Fig. 17). The input provided by the biomonitoring sensors is thus actuated as inward-oriented haptic biofeedback (the "massage" function) (Fig. 16) as well as translated into outward-oriented visual screen-based output that can be accessed on a mobile device (Fig. 20).

First, the physical wearability of this particular design is characterized by the lightweight technology and 3D-printed casing (Fig. 18) that offer a perfect fit between hard and soft materials [20, 30].

Second, test users noted the design is functionally wearable for how it gently and literally massages healthier behavior into the wearer. This biofeedback system also functions without the visual display of the data, but the possibility of sharing and communicating about one's biometric data through the app adds a level of social wearability [8] to the collection of the data. It illustrates how data measured via integrated technology can be used on the body itself as an inward-oriented tool for personal training and self-care, and/or as an outward-oriented display for social interaction and interpersonal communication [25, 26].

Finally, the option to store and access these highly personal data again highlights the delicate topic of ethical wearability. It illustrates how data measured via integrated

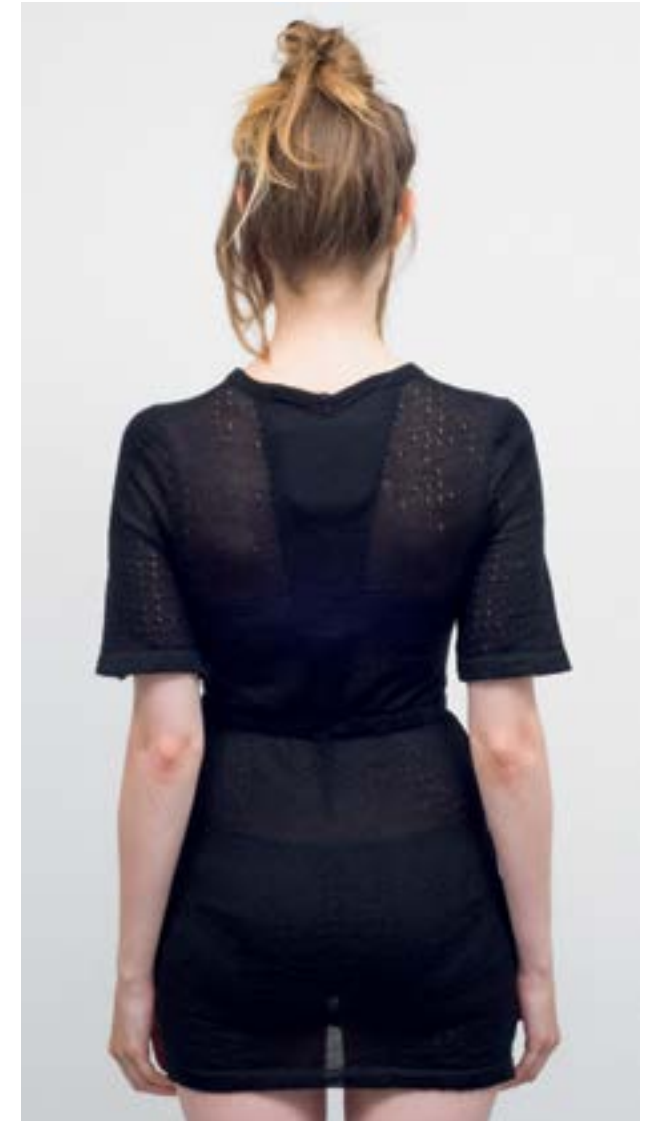


Figure 14. The black stress-reducing shirt

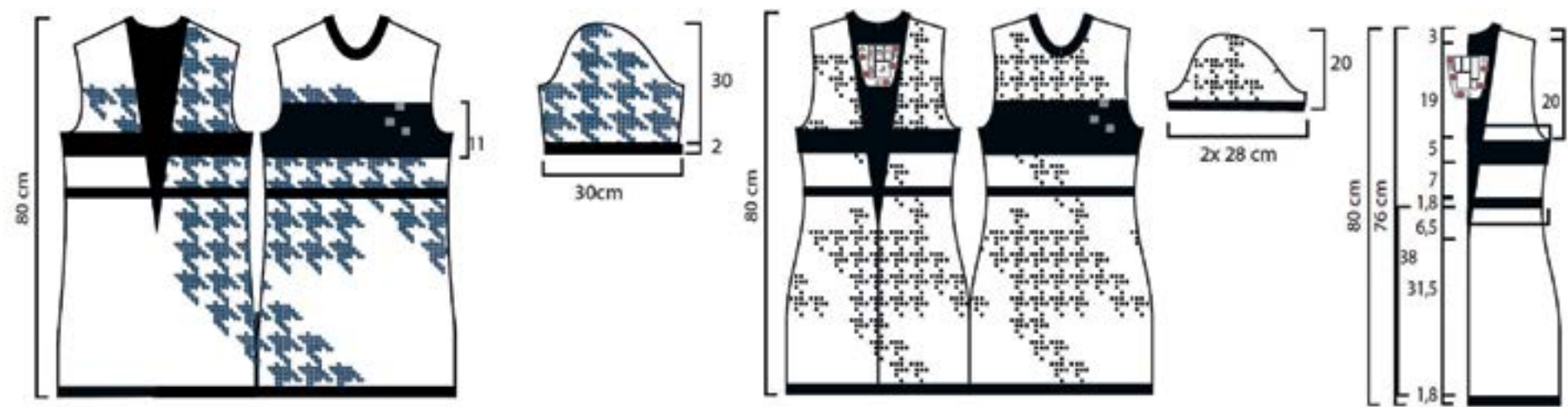


Figure 15. Technical drawing of the front and back, with pied de poule print, male and female version.

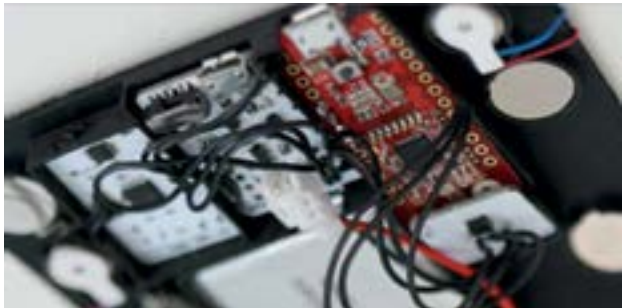


Figure 16. All the hardware, including the vibrators.

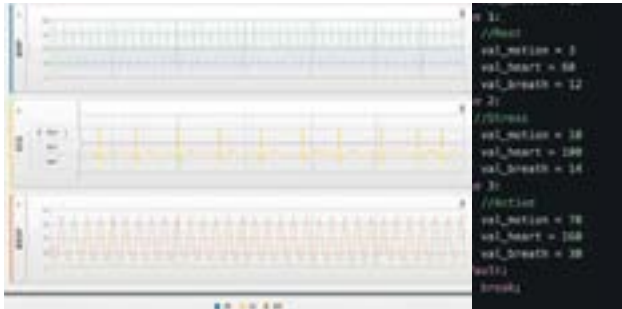


Figure 17. Visualisation of the raw data.



Figure 18. The 3D printed casing connected via magnets.



Figure 19. Screenshots of the training app.

technology can actually be used on the body itself, rather than exist as a static base of knowledge used only for analysis (Fig. 21).

The stress-reducing shirts exemplify the type of fashion technology designed to influence wearers' actions in positive ways by providing meaningful data for self-tracking and self-care. From a more critical point of view, however, they can also become an instrument of social control designed to nudge people into sufficiently healthy, active, productive and profitable behavior [1, 13, 32].



Figure 20. Product in use with the screen-based output.

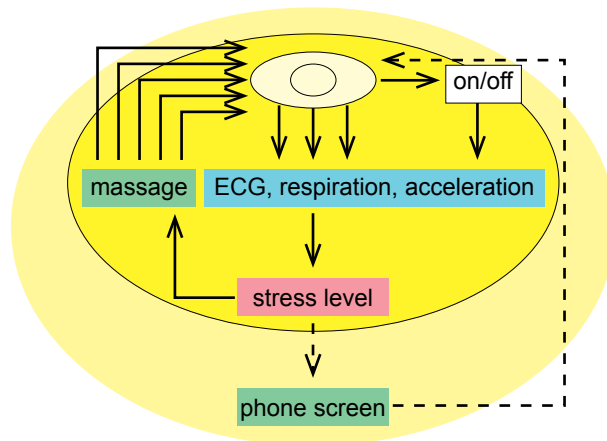


Figure 21. Schematic visualization of project 4.

Project 5 Gesture-sensing Presentation Shirt

The final design project is still work in progress but helps to illuminate how sensing and actuation are related to the overall wearability of fashion technology. The gesture-sensing presentation shirt (Fig. 23) is equipped with hybrid [10] printed micro-electronics (Fig. 23) that sense the wearer's arm gestures via an acceleration sensor to act as a wearable remote controller during presentations.

The shirt is functionally wearable as a direct feedback module that notifies the wearer via a gentle vibration when it senses a recognizable gesture and actuates the movement of the presentation slides. All hardware is positioned locally and unobtrusively on the wrist (Fig. 22, 24, 26), ensuring the shirt's physical [6] and social [8] wearability. It is the ethical aspect of this design project, however, that makes it particularly noteworthy.

Importantly, the gesture-sensing presentation shirt has a control button that allows wearers to 'opt out' of the technological functionality of the garment at any time. Depending on the specific context, wearers may decide to deactivate the technology to prevent the shirt from registering and actuating their gestures. The wearer thus always remains in control of when and what the technology measures, which means that power is carefully distributed and balanced among the human (i.e. wearer) and non-human (i.e. fashion technology) actors involved.



Figure 23. Sketch of the gesture-sensing shirt.

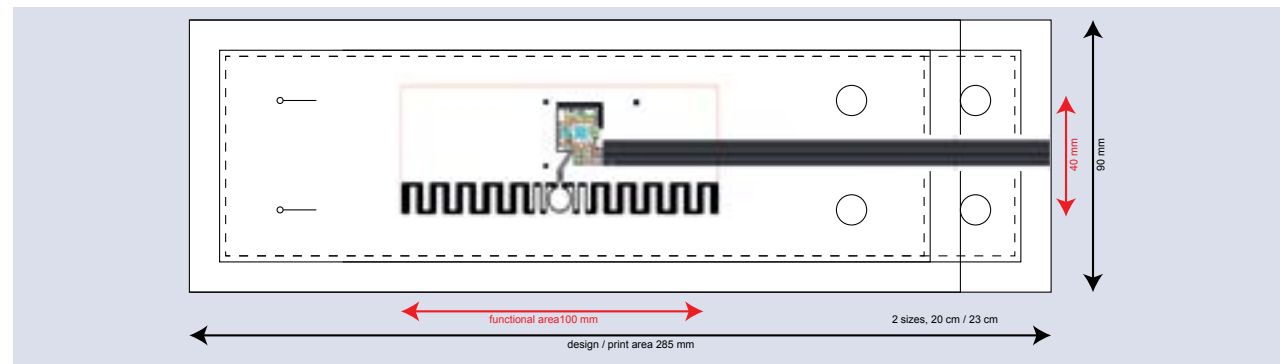


Figure 22. Technical drawing of the cuff with all the hybrid printed sensor, actuator and power technology.



Figure 24. Printing process in progress, first experiment for textile connection.

Although this project is still ongoing it signals the potential of designing fashion technology that consciously combines inward and outward-oriented approaches and aspires to be perfectly wearable on a physical, functional, social *and* ethical level (Fig. 25).

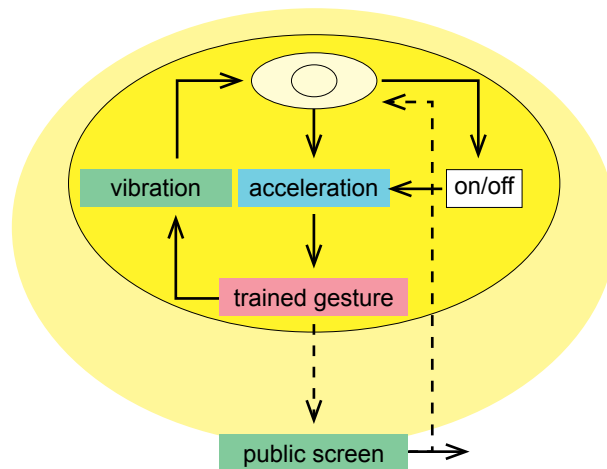


Figure 25. Schematic visualization of project 5.

RESULTS

This pictorial discussed five different fashion technology projects, which balance sensing and actuation in different (inward or outward-oriented) ways. Our discussion of biosensing sportswear, smart garments for health professionals and stress-reducing shirts showed that the combination of direct and indirect feedback loops allows personal data to travel both within and outside the wearer's personal space. The spine-warming dress, being the only design that keeps the feedback loop within the garment itself, illustrated that the chances at ethical wearability are notably higher when the collected data are directly given back to the wearer in the sense that it avoids common concerns about data security and privacy violation. The gesture-sensing shirt, finally, represents the ambition to design fashion technology that is perfectly wearable for how it allows wearers to switch off or control the balance between sensing and actuation at any time.

Our analyses indicate that the right balance between sensing and actuation can be found when the amount, type and longitude of sensing is carefully weighed against

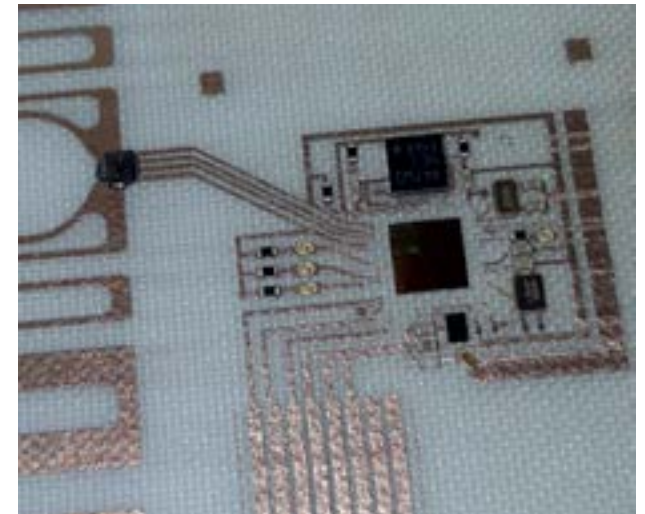


Figure 26. Pick and place project in progress.

how these data are used and actuated. See the arrows in figure 27. In this process, all four and interconnected levels of wearability have to be taken into account. Depending on the particular physical, functional, social and ethical factors at stake, fashion technology designers can decide to only provide immediate tactile biofeedback to the body and/or to also include more outward-oriented applications.

Complementing the notions of physical, functional and social wearability with the concept of ethical wearability, we raised the importance of also balancing the power relations between human and non-human actors in fashion technology design. Automated or programmed technology, such as the immediate actuation of the spine-warming dress or the vibrations of the stress-reducing shirts, may be experienced as beyond control of the wearer even when explicitly presented as a form of self-care or rehabilitation. The gesture-sensing shirt indicated that the integration of an 'opt out' option (e.g. on/off button) into the garment design can help to also balance the sense of 'control' and 'being controlled' among fashion technology wearers.

CONCLUSION

The use of sensing technologies in garments is commonly combined with actuators that translate the raw data into relevant and meaningful inward or outward-oriented output for the wearer. Striking the right balance between sensing and actuation (Fig. 27), as well as carefully distributing power between human and non-human actors, is key to establishing a positive feedback loop between fashion technology and its wearers.

The five projects analysed in this pictorial also provided insight into how the decision to actuate data inward and/or outward is inextricably connected to the 'wearability' of the garment on four levels. The physical, functional, social and ethical dimensions of wearability are all equally important when sensing, collecting and actuating personal data through fashion technology.

REFLECTION

This pictorial argues that integrating all kinds of sensors into fashion technology is one thing, but carefully balancing this with how, why and when the data are actuated is another. We believe that much more research and testing is needed to understand how different

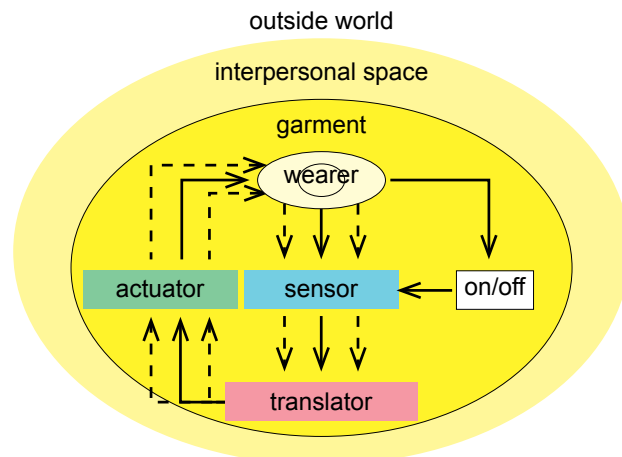


Figure 27. Schematic visualization of the conclusion.

combinations of sensing and actuation impact wearers' experiences and behaviour. We hope that the framework presented here can act as a tool that helps designers and developers to carefully consider all four interconnected dimensions of wearability. In addition, the five projects we presented demonstrate that the active involvement of test wearers in designing for inward and/or outward-oriented combinations of sensing and actuation, can significantly benefit the wearability of fashion technology in the future.

ACKNOWLEDGMENTS

We would like to thank all the partners that collaborated in the 5 different fashion technology projects, including Margreet de Kok – Holst Centre, Melissa Bonvie – Studio Bonvie, Beam Contrechoc, Ralf Jacobs, Matthijs Vertooren, MVO Nederland and the care and textile consortia, Martijn ten Bhömer, Kevin Russell – Domicro, the Domicro team, and many more people that contributed to the projects. And the WEAR Sustain funding from the European Union's Horizon 2020 under grant agreement No. 732098. Thank you all!

Thanks to all the models and photographers. Specifically to Jan Willem Groen, Iztok Klančar, Wetzter & Berends, and Sanne Kortooms.

Thanks to our 'shepherd' Iohanna Nicenboim and the reviewers for their in-depth, motivating and actionable recommendations and feedback. Lastly, we would like to thank the DIS organizers and reviewers for doing such a complex job in this time of uncertainty.

REFERENCES

- [1] Segura Anaya, L.H., Alsadoon, A., Costadopoulos, N. et al. 2018. Ethical Implications of User Perceptions of Wearable Devices. *Sci Eng Ethics* 24, 1–28
- [2] Joanna Berzowska. 2005. Electronic Textiles: Wearable Computers, Reactive Fashion, and Soft Computation. *TEXTILE: The Journal of Cloth and*

- Culture*. 3, 1, 58-75. <https://doi-org.proxy.library.uu.nl/10.2752/147597505778052639>
- [3] David Bryson. 2007. Unwearables. *AI & Soc* 22, 25–35.
- [4] Pauline van Dongen, Ron Wakkary, Oscar Tomico, and Stephen Wensveen. 2019. Towards a Postphenomenological Approach to Wearable Technology through Design Journeys. <https://doi.org/10.17028/rd.lboro.9724649.v1>
- [5] Mitchell Dröge and Aniek Lentferink. 2017. Are employees open to wearables in the workplace?. Retrieved January 30, 2019 from <http://qsinstitute.com/are-employees-open-to-wearables-in-the-workplace/>
- [6] Lucy E. Dunne. 2008. Wearability in wearable computers. 12th IEEE International Symposium on Wearable Computers, 125–125. <https://doi.org/10.1109/ISWC.2008.4911605>
- [7] Lucy E. Dunne and Barry Smyth. 2007. Psycho-physical elements of wearability. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '07)*. Association for Computing Machinery, New York, NY, USA, 299–302. <https://doi.org/10.1145/1240624.1240674>
- [8] Lucy E. Dunne, Halley Profita, and Clint Zeagler. 2014. Chapter 1.2 - Social Aspects of Wearability and Interaction. In *Wearable Sensors*, Edward Sazonov and Michael R. Neuman (eds.). Academic Press, Oxford, 25–43. <https://doi.org/10.1016/B978-0-12-418662-0.00026-X>
- [9] Venere Ferraro. 2015. Smart textiles and wearable technologies for sportswear: a design approach. *Sensors and Applications*.
- [10] Bruna Goveia da Rocha, Kristina Andersen, and Oscar Tomico Plasencia. 2019. Crafting soft wearables with and through digital technologies. *Temes de Disseny*, (35), 76-89.

- [11] Noura Howell, Laura Devendorf, et al. 2016. Bio-signals as social cues: Ambiguity and emotional interpretation in social displays of skin conductance. In *Proceedings of the ACM Conference on Designing Interactive Systems* (pp. 865–870).
- [12] Kristi Kuusk, Oscar Tomico, Geert Langereis, and Stephan Wensveen. 2012. 'Crafting Smart Textiles : a meaningful way towards societal sustainability in the fashion field?', *Nordic Textile Journal*, vol. 1, no. 6–15.
- [13] Deborah Lupton. 2012. M-health and health promotion: The digital cyborg and surveillance society. *Social Theory & Health* 10, 3, 229–244.
- [14] Deborah Lupton. 2016. The diverse domains of quantified selves: self-tracking modes and dataveillance. *Economy and Society* 45, 1, 101–122.
- [15] Deborah Lupton. 2016. *The quantified self*. John Wiley & Sons.
- [16] Angella Mackey, Stephan Wensveen, Ron Wakkary, Annika Hupfeld, and Oscar Tomico. 2019. Wearing Digital Shimmers: A fashion-centric approach to wearable technology. In *Proceedings of the 4th Biennial Research Through Design Conference* (pp. 19–22).
- [17] Troy Nachtigall. 2019. Materializing data: craftsmanship and technology for ultra-personalization. Eindhoven: Technische Universiteit Eindhoven. <https://research.tue.nl/en/publications/materializing-data-craftsmanship-and-technology-for-ultra-persona>
- [18] Kristin Neidlinger, Lianne Toussaint, Edwin Dertien, Khiet Phuong Truong, Hermanus J. Hermens, and Vanessa Evers. 2019. Emotional prosthesis for animating awe through performative biofeedback. *Proceedings of the 23rd International Symposium on Wearable Computers (ISWC '19)*, 312–317. <https://doi.org/10.1145/3341163.3346939>
- [19] Marie O'Mahony and SE Braddock-Clarke. 2005. *Techno textiles 2: revolutionary fabrics for fashion and design*. Thames and Hudson.
- [20] Irene Posch, Geraldine Fitzpatrick. 2018. Integrating Textile Materials with Electronic Making: Creating New Tools and Practices. In *Proceedings of the Twelfth International Conference on Tangible, Embedded, and Embodied Interaction* (pp. 158–165).
- [21] Bradley Quinn. 2002. *Techno fashion*. Berg Oxford.
- [22] Bradley Quinn. 2010. *Textile futures: Fashion, design and technology*. Berg Publishers.
- [23] Bradley Quinn. 2012. *Fashion futures*. Merrell London.
- [24] Sabine Seymour. 2009. *Fashionable Technology. The Intersection of Design, Fashion, Science, and Technology*. Vienna: Springer.
- [25] Anneke Smelik, Lianne Toussaint, and Pauline Van Dongen. 2016. Solar fashion: An embodied approach to wearable technology. *International Journal of Fashion Studies* 3, 2 (2016), 287–303.
- [26] Anneke Smelik. 2017. *Cybercouture: The fashionable technology of Pauline van Dongen, Iris van Herpen and Bart Hess*. Smelik, Anneke (ed.), Delft Blue to Denim Blue. *Contemporary Dutch Fashion*, 252–269.
- [27] Marina Toeters and Loe Feijs. 2014. Actuating movement in refined wearables. In *Global fashion 2014*, 19–21. Retrieved January 30, 2020 from <https://research.tue.nl/en/publications/actuating-movement-in-refined-wearables>
- [28] Marina Toeters. 2016. E-fashion fusionist aiming for supportive and caring garments. In *Proceedings of the 2016 ACM International Joint Conference on Pervasive and Ubiquitous Computing: Adjunct (UbiComp '16)*. Association for Computing Machinery, New York, NY, USA, 922–926. <https://doi.org/10.1145/2968219.2979134>
- [29] Oscar Tomico and Danielle Wilde. 2016. Embodying Soft Wearables Research. In *Proceedings of the TEI '16: Tenth International Conference on Tangible, Embedded, and Embodied Interaction (TEI '16)*. Association for Computing Machinery, New York, NY, USA, 774–777. <https://doi.org/10.1145/2839462.2854115>
- [30] Oscar Tomico, Lars Hallnäs, Rung-Huei Liang, and Stephan AG Wensveen. 2017. Towards a next wave of wearable and fashionable interactions. *International Journal of Design* 11, 3.
- [31] Lianne Toussaint. 2018. *Wearing technology: When fashion and technology entwine*. Ph.D Dissertation. Radboud University, Nijmegen, The Netherlands.
- [32] Yoni Van Den Eede. 2015. *Tracing the tracker: A postphenomenological inquiry into self-tracking technologies*. *Postphenomenological Investigations: Essays on Human-Technology Relations*, 143–58.
- [33] Clint Zeagler. 2017. Where to wear it: functional, technical, and social considerations in on-body location for wearable technology 20 years of designing for wearability. In *Proceedings of the ACM International Symposium on Wearable Computers* (pp. 150–157). 150–157.
- [34] Wu, Wanqing, et al. 2015. Assessment of Biofeedback Training for Emotion Management Through Wearable Textile Physiological Monitoring System. *IEEE Sensors Journal*, vol. 15, no. 12, pp. 7087–7095.