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. We demonstrate five designs that combine sensing and actuation, highlighting the benefits of direct biofeedback and of keeping the personal data within the garment. The selection of projects aims to search the right balance between sensing and actuation.

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

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

Introduction
Designers have been exploring the possibilities of integrating technologies into clothing [e.g. 1, 2, 4, 5, 7, 10, 11, 12, 13, 14, 16, 18, 21, 22]. The resulting garments, here referred to as ‘fashion technology’, typically combine sensing technologies with actuators that translate the collected data into some kind of output [18]. This demo presents five fashion technology designs created by one of the authors within the past ten years. The pictorial shows how the balance between sensing and actuation impacts the ‘wearability’ [3, 6, 8, 9, 15, 19, 20, 21].

Permission to make digital or hard copies of part or all 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 third-party components of this work must be honored. For all other uses, contact the owner/author(s).

DIS ’20 Companion, July 6–10, 2020, Eindhoven, Netherlands
© 2020 Copyright is held by the owner/author(s).
ACM ISBN 978-1-4503-7987-8/20/07.
https://doi.org/10.1145/3393914.3397093
**Project 1: Biosensing Sportswear**
This project consists of a collection of women’s sportswear that uses heartrate, acceleration and respiration sensors to measure the wearer’s health, stress level and sports performance (Fig. 1). The heartrate and respiration sensors have been laminated and printed directly onto the textiles, allowing for unobtrusive, comfortable and flexible integration into the garment. The hardware (battery, communication, and acceleration sensor) is placed in a tiny removable container on between the wearer’s shoulder blades. 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 (Fig. 2).

**Project 2: Spine-Warming Dress**
The second fashion technology project 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 [17] (Fig. 3). 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. 4).

**Project 3: Smart and Supportive Garments for Caregivers**
The third fashion technology project is a collection of workwear for caregivers and nurses [17]. 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. 7). The outerwear is equipped with an anti-bacterial coating, which helps reduce the risk of bacterial contamination. Electronic ‘wearables’ in the garments can issue a warning signal when the posture trackers register overload or unbalanced postures (Lumolift) (Fig. 8).

**Project 4: Stress-reducing Shirts**
The fourth design project consists of a collection of knit alpaca yarn shirts that contain wearable technology geared towards avoiding work related stress issues [17] (Fig. 9). These biomonitoring shirts register the wearer’s heartbeat, movements and breathing and give direct feedback via a tiny vibration in the upper back. A specially developed app allows wearers to adjust the sensors’ settings, start training and check their data history (Fig. 10).

**Project 5 Gesture-sensing Presentation Shirt**
The final design project, the gesture-sensing presentation shirt, is still work in progress. We don’t present a picture in this demo paper, but hope that it helps to illuminate how sensing and actuation are related to the wearability of fashion technology. The shirt is equipped with hybrid printed micro-electronics that sense the wearer’s arm gestures via an acceleration sensor and thereby act as a 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. 5)
Conclusion
The connected pictorial concludes the following: To design fashion technology both effectively and ethically means to search for the right balance between sensing and actuation. Inward-oriented fashion technology that functions without the interferences of mobile screens and data visualizations allows the biofeedback loop to remain within the garment and with the wearer. This assures wearers of control over their personal data, as well as realizes the potential of both body and technology to ‘speak’ for themselves (Fig.6).

Demo Specifications
We prefer to present the garments on 4 female (EU size 36-38) and one male (EU size 50) mannequin. A demo on 5 clothing hangers is also possible. Accompanied with 5 cards with the above-mentioned information and one pillar for flyers and a card for written feedback.

Acknowledgements
A thanks to all the partners that collaborated during the five different projects, like Margreet de Kok, Holst Centre, Melissa Bonvie, Beam Contrechoc, Ralf Jacobs, MVO.nl and the textile consortium, and many more. And we would like to thank the DIS organizers and reviewers for doing such a complex job in this time of uncertainty.

References
[1] Joanna Berzowska. 2005. Electronic Textiles: Wearable Computers, Reactive Fashion, and Soft Computation. TEXTILE: The Journal of Cloth and Culture. 3, 1 (January 2005), 58-75. https://doi.org/10.2752/147597505778052639
[2] 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
[3] 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
[4] Venere Ferraro. 2015. Smart textiles and wearable technologies for sportswear: a design approach. Sensors and Applications (2015).
[5] Bruna Goveia da Rocha, Kristina Andersen, and Oscar Tomico Plasencia. 2019. Crafting soft wearable with and through digital technologies. Temes de Disseny, (35), 76-89.
[6] Noura Howell, Laura Devendorf, Tian, R., Vega Galvez, T., Gong, N. W., Poupyrev, I., & Ryokai, K. 2016, June. Biosignals as social cues: Ambiguity and emotional interpretation in social displays of skin conductance. In Proceedings of the 2016 ACM Conference on Designing Interactive Systems (pp. 865-870).
[7] K. Kuusk, O. Tomico, G. Langereis, and S. Wensveen, ‘Crafting Smart Textiles: a meaningful way towards societal sustainability in the fashion field?’, Nordic Textile Journal, vol. 1, no. 6–15, 2012
[8] Angella Mackey, Stephan Wensveen, Ron Wakkary, Annika Hupfeld, and Oscar Tomico. 2019, March. Wearing Digital Shimmers: A fashion-centric approach to wearable technology. In Proceedings of the 4th Biennial Research Through Design Conference (pp. 19-22).
[9] 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

[10] Kristin Neidlinger, Lianne Toussaint, Edwin Dertien, Khiét 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

[11] Marie O’Mahony and SE Braddock-Clarke. 2005. Techno textiles 2: revolutionary fabrics for fashion and design. Thames and Hudson.

[12] Irene Posch Geraldine Fitzpatrick. 2018, March. 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).

[13] Bradley Quinn. 2012. Fashion futures. Merrell London.

[14] Seymour, Sabine (2009), Fashionable Technology. The Intersection of Design, Fashion, Science, and Technology, Vienna: Springer.

[15] 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.

[16] Marina Toeters and Loe Feijs. 2014. Actuating movement in refined wearables. In Global fashion 2014, 19–21 November 2014. Retrieved January 30, 2020 from https://research.tue.nl/en/publications/actuating-movement-in-refined-wearables

[17] 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

[18] 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

[19] 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 (2017).

[20] Lianne Toussaint. 2018. Wearing technology: When fashion and technology entwine. Ph.D Dissertation. Radboud University, Nijmegen, The Netherlands.

[21] 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. 150–157.