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Published in:
Distributed, Ambient and Pervasive Interactions

DOI:
10.1007/978-3-030-50344-4_9

Published: 10/07/2020

Document Version
Peer-reviewed accepted author manuscript, also known as Final accepted manuscript or Post-print

Please cite the original version:
Townsend, R., Bang, A. L., & Mikkonen, J. (2020). Textile Designer Perspective on Haptic Interface Design: A Sensorial Platform for Conversation Between Discipline. In N. A. Streitz, & S. Konomi (Eds.), *Distributed, Ambient and Pervasive Interactions : 8th International Conference, DAPI 2020, Held as Part of the 22nd HCI International Conference, HCII 2020, Proceedings* (Vol. 12203, pp. 110-127). (Lecture Notes in Computer Science; Vol. 12203). Springer. https://doi.org/10.1007/978-3-030-50344-4_9

Textile Designer Perspective on Haptic Interface Design: A Sensorial Platform for Conversation between Discipline

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Abstract. Smart textiles have established a foothold in different academic fields, such as in chemistry, engineering, and in human-computer interaction (HCI). Within HCI, smart textiles are present in research in many ways, for example, as context, as means, or as focus. However, interdisciplinary projects tend to leave the implications of and to textile design without notice. How can a project utilise a textile designer's skills to feed back to textile design from an interdisciplinary project? In this paper, we present a case study, where a textile designer's role extends beyond the prototype production, and we analyse the project in light of textile design. Our findings show that textile design can augment data collection and analysis. We conclude with a discussion towards inclusion of textile design in HCI.

Keywords: Smart Textile Design, Haptic Interface, Interdisciplinary, Sensorial

1 Introduction

Textile design typically focuses on the sensorial nuances of material and surface patterns when designing textiles and textile-based products, in order to fulfil both aesthetic, sensorial and functional user requirements in relation to the intended use context. Fabrics that converge electronics and smart materials, namely smart textiles or e-textiles (Poupyrev et al. 2016; Stoppa & Chiolerio 2014), have facilitated fabrics with additional properties that are dynamic, responsive and adaptive, altering their perceivable properties. Consequently, smart textiles have the potential to broaden the experienced sensory spectrum compared to conventional textiles (e.g. Dumitrescu et al. 2018) for everyday living, which can contribute towards e.g. creating applications bridging real-life sensory experiences with digital properties (Abdur Rahman et al., 2010), or creating new forms of haptic-based interpersonal communication (e.g. Samani, et al. 2012). However, as a result of textiles transforming into technological material and expanding into fields outside the textile design field, textiles tend to be treated as a technical component such as a surface, or as a housing or casing in a larger wearable haptic system (Bianchi et al. 2016; Bianchi et al. 2014; Karrer et al. 2011; Parzer et al. 2017). In doing so, the subtle nuances to sensory expression and sensorial characteristics that a textile material can provide becomes lost or even disregarded in favour of new technology. In the overlapping research field of smart textiles, the disciplinary boundaries intertwine (Townsend et al. 2017), and "it is easy for one to jump from qualities of one discipline to another because two things may look similar, but the knowledge of underlying principles or ways of making that may not be as evident on the surface" (Weinthal 2016). Ideally, if the future wearable haptic 'device' is to become 'transparent' and its use as intrinsic to any regular worn garment (Bianchi et al. 2016), our hypothesis is that the understanding of these material sensorial nuances and how to apply this knowledge across disciplinary boundaries is central *for all parties*. How can a project utilise textile designers' skills to feed back to textile design from an interdisciplinary project? Thus, the design of wearable textile-based systems should include taking textile knowledge into consideration and more importantly, focus on exploiting these sensory nuances.

This paper discusses the influence of textile design and its benefits for HCI through a case study, collaborating in the development and evaluation of Shape Memory Alloy (SMA)-actuated sleeves. We use the sleeves' development and evaluation study to re-examine the design process, and discuss the outcomes through a textile design perspective in reflection with haptic interaction design. We present the overall design process in more detail, to provide insight towards a better utilisation of a textile designers skill-set in future projects. Finally, we include a post-analysis inquiry towards improving the data visualisations to better suit textile designer's utilisation in future projects.

The process presented in this paper is not intended to portray a stereotypical (smart) textile design process, as that does not exist today. Instead, the process underscores the role of the smart textile designer in a state of evolution, and the reciprocal knowledge transfer between two disciplines, textile design and design-engineering. Furthermore, our process highlights how having a textile designer as a core team member in a design team developing smart textiles creates mutual benefits that are relevant to all designers' and researchers' perspectives. This paper calls out to engage and include textile design into future research activities situated in HCI. Rather than using textiles as ready-made material that is merely used as a platform or attaching or encasing haptic technology, we encourage to explore an alternative path, in which technical and design features can co-exist to foster novel research outcomes.

2 Related Work

We first look at the interdisciplinary nature of smart textiles. Our literature search focused on design processes or approaches that use smart textiles either as is, or as material for creating wearables. We also looked at projects that focus or mention haptics, or use smart textiles as sensors. Even though our case-study is not utilising a sensor, we raise these examples to signify the utilisation of smart textiles in the HCI-research.

2.1 Smart Textiles

Smart textiles as a focus of research has grown rapidly in the last decade (Shi et al., 2019). While the approaches towards smart textile research have been described to be relevant to several fields (Castano & Flatau, 2016), the multi-and interdisciplinary nature is evident in the majority of the publications. *"Smart textiles are unique in that they require the combined experience from very different disciplines."* (Cherenack & van Pieterson, 2012). A call for action towards the interdisciplinary development of smart textiles has been mentioned either directly e.g. *"To address this lack of dialogue, there is a need for mechanisms that bring the different industries closer."* (Baurley, 2004), or indirectly *"Besides, with the help of processing units and big data, the textile-based motion sensing systems could even give some analysis and feedbacks about the motions, which benefits the clinical diagnosis and treatment of neurological disorders, such as Parkinson's disease, muscle rigidity and stroke."* (Shi et al., 2019).

There seems to be a division between the textile-design focused smart textile research, such as e.g. (Dumitrescu et al., 2014; Li et al., 2014; Persson, 2013) and the HCI-focused research such as e.g. (Parzer et al., 2017; Yoon et al., 2014). Curiously, there have been signs of omissions towards textile design in projects that focus on engineered textile-integration, such as e.g. (Mehmann et al., 2015; Varga & Tröster, 2014). This can also be seen in the extensive surveys on smart textiles (Shi et al., 2019; Weng et al., 2016). The review-papers on smart textiles (Castano & Flatau, 2016; Cherenack & van Pieterson, 2012; Shi et al., 2019; Weng et al., 2016) generally tend to avoid publications that originate from textile-design, unless they are a part of a 'scientific' field, such as e.g. in (Shi et al., 2019), references 176g (Karttunen et al., 2017) and 258a (Mikkonen & Pouta, 2015).

2.2 The Role of Textile Design in the Smart Textile Design Process

Recent years have shown an increased capacity building in the design community specifically addressing the field of smart textile design (e.g. (Kettley et al., 2015), (Pailes-Friedman, 2016) and (Guler et al., 2016)). As a consequence, also interdisciplinary projects, where the textile designer's role has been more emphasised with respect to HCI have been conducted. These projects focus on making textile design accessible (Devendorf & Di Lauro, 2019; Poupyrev et al., 2016; Kim et al., 2019), or describe specific projects that create wearables (Brueckner & Freire, 2018; Fransén Waldhör et al., 2017; Heller et al., 2014; Skach et al., 2018), or describe design processes or methods primarily with an artistic textile design lens (Joseph et al., 2017; Nilsson, 2015; Persson, 2013; Winters 2016). Of these, (Heller et al., 2014) make a distinction between the examples from 'DIY crafting community' and 'scientifically validated' outcomes - only methodically produced numerical values validate the research outcome as science.

Due to the nature of technical HCI-research on interactions or limiting the use to specific situations, smart textiles-as-sensors tend to be presented as an interface with the electronics as a separate platform, isolating the textile as the primary research element: (Gioberto et al., 2014; Hamdan et al., 2016; Leong et al., 2016; Parzer et al., 2018, 2017; Singh et al., 2015; Yoon et al., 2014). Due to this separation, the textile tends to be distanced from the electronics, and as expected, primarily focusing on the capacity of the smart textile as a sensor. This approach implies the smart textile sensor to be a component that could be integrated as part of a system, while the textile design ends at a prototype. Thus, there's no indication of there being any reflection to the actual smart textile process, nor how these are communicated towards textile design.

Regardless of the use, smart textiles within HCI have haptic qualities, as they are being interacted with in some way (Baurley, 2004; Bianchi et al., 2016, 2014; Brueckner & Freire, 2018; Fransén Waldhör et al., 2017; Greinke et al., 2016; Hildebrandt et al., 2015; Holleis et al., 2008; Joseph et al., 2017; Leong et al., 2016; Schelle et al., 2015; Skach et al., 2018). They can be a natural or an artificial part of a wearable system (Fransén Waldhör et al., 2017; Greinke et al., 2016). However, we point out two papers having the typical test-approach where a separate test-apparatus is constructed to focus on the properties of the textile: this approach is nonsensical for the textile designer. The textile is distanced from the typical textile context by introducing elements that are conventionally not present with textiles, in this case the bulky mechanism for moving the haptic textile (Bianchi et al., 2016, 2014). How can this information be useful for the smart textile design process? If the textile qualities are evaluated in a way that is distant to the textiles as worn items, how can they inform the textile design process on textile qualities?

3 Case Study 'SMA-Sleeve'

This case study involves the development of the actuator knit revolving around three knitted sleeves, with SMA inlaid into the structure. The sleeves were designed with different surface shape-change properties, stimulating the skin with heat and tactile effects. The textile-structural development was employed with textile design methodology, and the overall process was guided by the goal of user-testing towards a garment situated in HCI. The process ended in post-analysis inquiry, making new textile design-relevant analytics.

3.1 The Development of the Actuator Knit

Knit Location on the Body. When designing new textiles, it is customary to create fabric samples, which undergo several iterative cycles of evaluation before producing larger pieces. We started by creating a section of a garment in order to verify a knit structure that would work with a pattern of SMA. To select the body location and the section of a garment for evaluating the actuator knit, we found several studies supporting the placement of the knit onto the forearm. The forearm has been used as an interactive surface (Harrison et al., 2012; Ogata et al., 2013), that not only has good overall detection rates for both static and mobile conditions (Wilson et al., 2011), but thermal perception (Song et al., 2015) can be attenuated when thermal stimulation is accompanied by dynamic tactile stimulation (Green, 2009). Similarly, the forearm has also been seen as a preferable location for skin- input (Weigel et al., 2014), and demonstrated as having significant touch acceptance (Abdur Rahman et al., 2010), while having a personal character (Suvilehto et al., 2015). A sleeve, on the other hand, offers an interesting section of a garment, as canvas for fashion (Bloomfield, 2014; Heimann, 2012; *Shout Out To Statement Sleeves | Lola May Blog*) and for inserting added interactivity and functionality, *i.e.* a metaphorical storage for digital content (Olberding et al., 2013), and for sensing and receiving different types of sensory stimuli (Baurley, 2005; Randell et al., 2005).

The Development of the Textile Structure and the Inlaid Shape Memory Alloy. The textile design process grew from the conceptual idea of 'revealing-concealing', to explore the interplay between material, fabric interstices and holes, directing the design towards a lace-like structure.

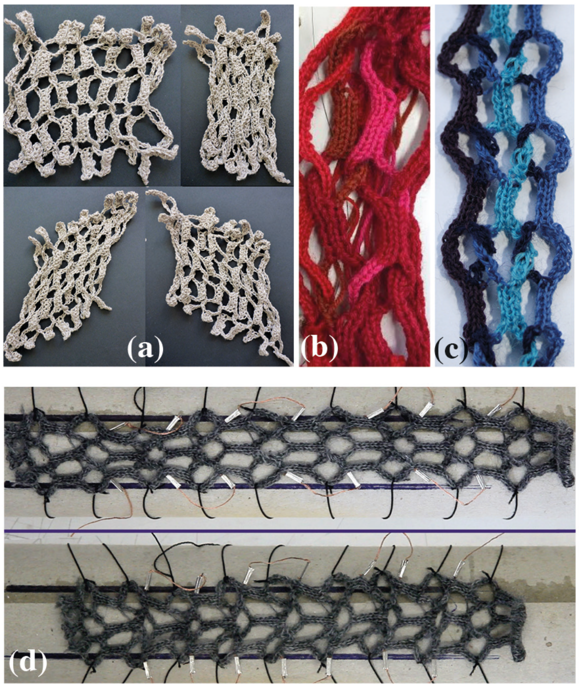

Fig. 1. Stages of the knit's structure development shown through representative samples: (a) dimensional movements of a hand-crocheted sketch without actuation, (b) the sample transformed into knit form with a hand-operated knitting machine, (c) the knit structure developed further with an industrial knitting machine, (d) evaluation of a SMA-knit sample's movement.

The development of the knit followed an iterative process from ‘sketching’ hand-crocheted explorations for an interconnected chain-like structure. The textile’s dimensional movement without added actuation (Figure 1.a.) was first ascertained through human-material interaction, then explored with inlaid SMA wire, and documented with a video camera. A hand-operated knitting machine, Silver Reed SK 860, was used for establishing a knit structure with similar movement to the sketch, shown in Figure 1.b., before exploration for fabrication using Stoll CMS 340 TC industrial knitting machine (Figure 1.c). During this stage, 15 different knit structures were developed and evaluated, to obtain a single knit pattern - a basis for evaluating the placement and reactions of different SMA inlays. An example of the SMA-induced movement is shown in Figure 1.d.

The power to the sleeves was controlled with a IRLML2502 n-channel MOSFETs connected to an Arduino Mega and powered by a laboratory power supply. The Arduino was programmed with fixed on-off times and delays in an automated sequence, initiated through a serial interface. The sequence for powering U- and I-sleeves was 7 secs on, 10 secs off (repeated twice), which enabled complete shape change and adequate time for the SMA to recover from heat.

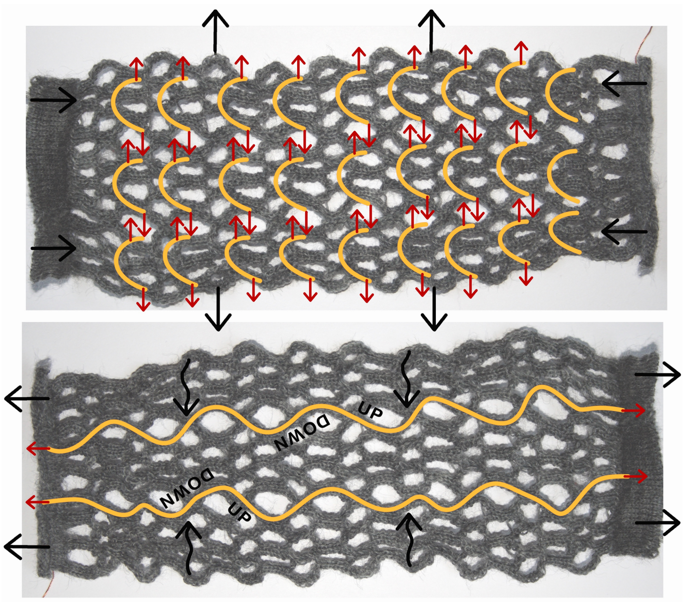

Fig. 2. The placement of SMA wire in U-sleeve (top) and I-sleeve (bottom) are overlayed in yellow, while their respective movements are represented with arrows. The red arrows indicate the movement of the SMA wire, whereas the black arrows depict the sleeve’s movement.

The Final sleeves (U and I), with actuator placement overlayed in yellow, are shown in Figure 2. U-sleeve had three separate columns of u-shaped SMA wires embedded across the rows of loops. A total of 34 metallic wire end caps were embedded into the knit structure to connect the conductive yarn to the SMA wire and to secure the SMA wire to the woollen yarn during actuation. This added rigidness to the knit structure, decreasing the sleeve's softness. In I-sleeve, SMA was threaded into a knitted tube forming an s-shaped zigzag connection that held the three individual knit pieces together, making the sleeve partly rigid and partly pliable. The SMA wires were attached to the conductive- and wool yarn with two wire end caps on the top, and two on the bottom end of the sleeve. While the overall feel of the I-sleeve was softer than U-sleeve, there was also a more distinct contrasting feel between hardness and softness across the knit surface. As T-sleeve remained without SMA, the sleeve was the softest and most pliable of all three sleeves.

The movement of U-sleeve caused by actuation simultaneously contracts in the vertical axis (along the arm) while expanding in the horizontal axis, whereas I-sleeve expands in the vertical axis while contracting in the horizontal axis. However, due to the longer and larger freedom of movement of the SMA within the I-sleeve, and the alternating shapes of the two SMA wires, the I-sleeve moves in an uneven manner across the surface. The length of SMA wires is directly proportional to the heat produced. Heat generated by U-sleeve is greater than by the I-sleeve, at similar SMA control temperatures. The power required by the U-sleeve is roughly four times greater, 25W, the I-sleeve actuated with 6W. The thermal pattern follows the placement of the SMA.

3.2 Evaluation of Sleeves' Sensory Effects and Tactile Appeal for Feedback

Evaluation/testing procedure. We invited 3+12 participants with design background, for a pre-structured evaluation of the three sleeves. The first three participants were excluded from the results. Their feedback was used to validate the test. The rest were included in the final counterbalanced evaluation. The participants wore each of the three sleeves in succession, and a set of 13 questions were asked for each sleeve on a 5-point Likert scale (1 is strongly disagree and 5 is strongly agree, 3 is neutral). As the focus in this paper is on how the analysis influenced the whole process from a textile design perspective, detailed results are beyond the scope of this case study. Therefore, only questions Q1-Q5 are addressed in this paper, and are seen in Table 1.

The individual data based on the behavioural observation and the discussions were also analysed using affinity diagramming (Kawakita, 1991; Lucero, 2015). While this offered some insights, the analysis did not directly add understanding to the numerical data, and in that respect, it was unclear how the feedback could be taken to the next round of development. As a result, this prompted a different way with which to look at the numerical data: by the textile designer developing visually descriptive and relatable patterns to understand the data in a novel way.

3.3 Re-analysing the Evaluation

Developing Analysis for Textile Design. In an effort to make sense of the data in relation to the textile design part, to draw a connection between the numeral data and the sleeves' materiality and sensoriality, a second set of analysis was developed. Focus was initially placed on the individual sleeve and the distribution of responses collectively for each question. The first of the textile-designer's visualisations are shown in Figure 3., illustrated side-by-side with the bar charts.

Table 1. Questions asked to the participants during testing/evaluation.

Question number	Question
Q1 / Q5	The sleeve appealed to my tactile senses (before/after)
Q2	I liked the heat effects in the sleeve
Q3	I liked the tactile effects in the sleeve
Q4	I liked the overall effects in the sleeve

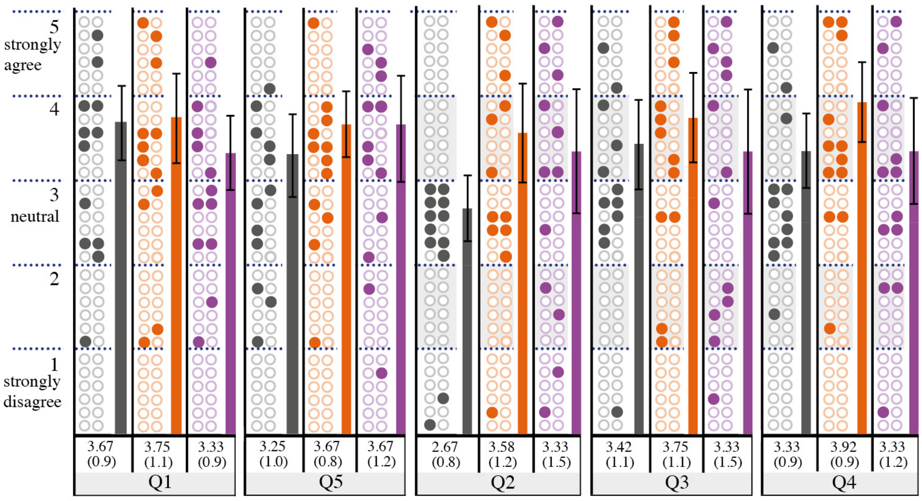

Fig. 3. All participants are represented with an empty circle and placed within the grid of each value (1-5) always in the same order. The participant's numerical response of each question is marked with a coloured circle.

Although this analysis provided further insight to the overall distribution of responses to each question concerning the individual sleeve, the data was still very static. While it showed clustering of the individual result, it did not show the individual change or combined influence. This prompted the textile designer to draw distribution bars, which show the results as a group, but with individual values. These are shown in Figure 4.a. This distribution can be considered to depict the sensory profile of a sleeve's individual sensory effect, or tactile appeal.

Next, the textile designer developed a "dynamic-droplets", shown in Figure 4.b. (bottom) The side-by-side responses of each sleeve are grouped and accordingly colour coded. This portrays the response-relations between the actuation-based sensory effects of each sleeve, while indicating potential differences in the participant answers. The graph in Figure 4.b. (top), displays how the perception of the sleeve changed per individual. Thus, the longer the difference between Q1 and Q5, longer the circle-connecting line. Overlapping circles indicate no change in response, *i.e.* represents the same value given to different questions. Additionally, each unchanged value has a pink background colour, further emphasising the pattern-nature of the results.

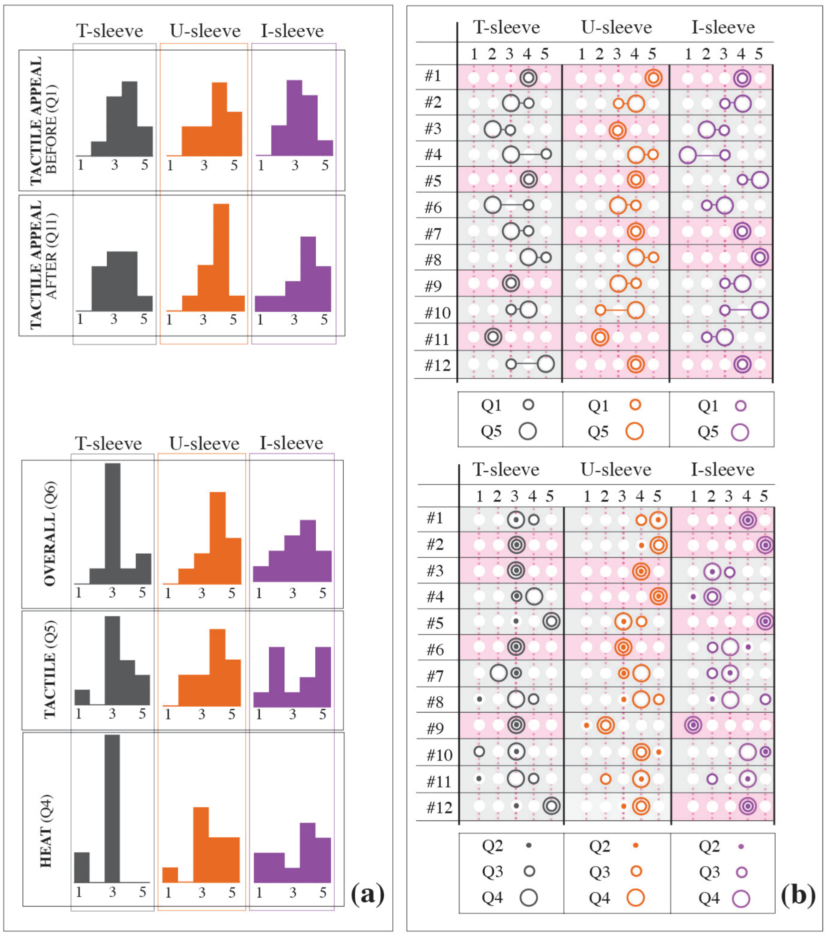

Fig. 4. The responses drawn into distributions bars (a), depicting the sensory profile of a sleeve's individual sensory effect (below) and tactile appeal before and after actuation (top). In the first form of the "dynamic droplets" (b), the representation overlays the responses on liking the respective sensory effects of each individual (bottom). In the second form (top), the smaller circles depict the participants' individual replies to Q1, thus indicating whether the sleeve appealed to the tactile senses of the participant. The larger circles, on the other hand, refer to the tactile appeal of the sleeves after experiencing the textile's dynamic behaviour and sensory effects from the actuation.

The Influence of New Analysis to the Results. The new patterns were useful, revealing new perspective to the textile designer. This new way of analysing the data enabled that the sleeves' influences could be seen through the visualisations shown in Figure 4. All visualisations concerning the response to the dynamic sensory effects are summarised using the results for I-sleeve in Figure 5., showing the same data through different representations. In the case when the calculated means and standard deviations were identical, the new analysis for textile design revealed more nuances to the data. As an example, with I-sleeve, the statistical values suggested the participants response to heat and tactile effects identically, and with only a subtle difference in liking the overall effects compared to the liking as an individual sensory effect. Figure 5. revealed a clear difference in the liking of each sensory effect. Only 5/12 demonstrated liking all three sensory effects equally. In fact, the responses concerning the tactile effects had the strongest divided opinion.

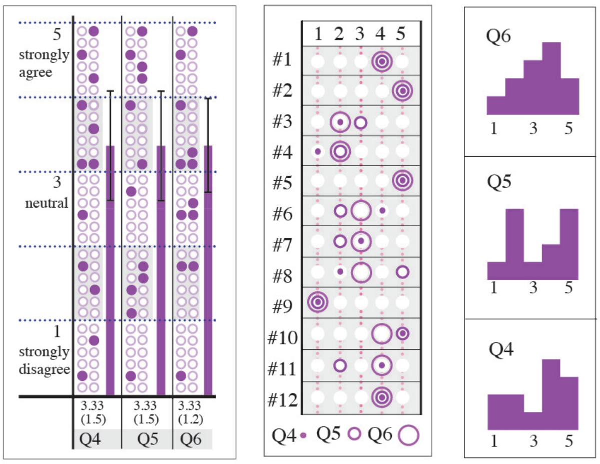

Fig. 5. Three different representations of the same data based on the participants' responses for I-sleeve.

When comparing the sleeves' initial appeal to the tactile senses after the actuation experience, T-sleeve's tactile appeal declined the most, seen both in the dynamic-droplet-representation, as well as in the distribution diagram depicting the sensory profile of a sleeve's individual sensory effect. This could hint that the lack of dynamic behaviour in regards to the two sensory modalities in T-sleeve allowed the focus to be placed more readily/easily on the actual feel of the knit in its conventional state. The visual analysis on tactile appeal of all three sleeves before actuation, revealed U-sleeve having the highest tactile appeal, which was in line with the initial analysis. Unexpectedly, the droplet-form was required for the textile designer to establish and comprehend U-sleeve's appeal. After all, it has 34 wire end caps and more SMA wire, making it the least soft and the most rigid sleeve! Equally surprising was T-sleeve not having the most tactile appeal, as it was the softest and most pliable of sleeves.

4 Discussion: The Sensorial Platform for Conversation Between Disciplines

The discussion revolves around three aspects that emerged from the interdisciplinary actions taking place in the case study. Firstly, we discuss the textile design process for an evaluative HCI process. Secondly, we discuss data visualisation creating a sensorial platform, and thirdly, insights from the visualisation.

4.1 Constructive Textile Design Process towards an Evaluative HCI Process

The textile designer's role was central in the early development stages of the actuator knit, and even before this, as a creative catalyst. When examining the process of developing the actuator-knit sleeve from a macro-level perspective, the first stages of the design process were similar to a knitted sleeve without actuation. As the initial experiments with SMA embedded material sketches were suggestive to the possibilities of adding movement and shape change, rather than an analytical study of its movements, actuation and its related material did not have an effect on transforming ideas into knit form. Instead, the conceptual starting point had a significant influence on supporting the choice to use a knitted structure, especially when using stitch transfer for creating lace-like patterns. Also, the knit's agile set up, and the future prospect of achievable industrial manufacture, guided the direction of the sleeve's development in terms of fabrication method.

As in any textile that is designed with specific functionality or performance, the textile's utility- and durability-related material characteristics are important considerations that need to meet the user requirements of its intended use context. From a textile design perspective, in this case the textiles technical HCI-performance referred to the functionality of the SMA-knit's structural movement and its related sensory expression, as well as its safety to the user. These performance characteristics were equally important design considerations, and provided a basis for the material selection of the knit, guiding the textile's final surface and structure development process. The decision for the final structure of the design was based on three simultaneous criteria: 1) to enable subtle tactile stimulation; thus, the structure should provide a mildly uneven skin-contact surface, 2) the structure should be open allowing excessive heat dissipation to prevent burns, and 3) allow for both vertical and horizontal movement of the structure. While the choice of using wool yarn supported these three criteria, a counterbalancing influence to the fibres physical properties was, in this case, the knit structure; an open fabric structure exhibits lower thermal insulation as a result of high convective losses, as well as a lower amount of air entrapped in the structure (Kothari, 2006). Also, wool's natural crimp contributes to the resilience and elasticity of the fibre (Hatch, 1993), an important consideration when designing a textile structure needing to withstand mechanical stress during the knitting process, whereas an open structure also allows for movement in all directions.

However, while the actuator-knit's design process was in the hands of the textile designer, the HCI orientation of the design brief, which emphasised the development of the sleeve's active haptic qualities, caused the main focus to be placed on the actuation and less on the textile itself. Therefore, when the design process entered the stage of fine-tuning the final structural pattern of the industrially knitted sleeve to enable evaluating the movement of all SMA-configurations, some of the taken design decisions regarding material required compromising in areas that are typically at the core of textile design practice. The design decisions had become driven by technical HCI- performance.

Despite the importance of performance considerations, the choice of material and knit structure, especially when designing a worn garment, also requires considering aesthetic and sensorial material characteristics to provide a pleasing sensorial experience as a whole to its user. The neglect of the textile's appearance and feel in the design brief, most notably reflected on the choice of grey wool yarn, was in fact a compromise between performance and sensorial material characteristics. This compromise caused considerable distress to the textile designer. In a response to finding a middle ground between the HCI-orientated design brief and textile-thinking, and 'compensating' for the limited utilisation of specific material sensoriality, the textile designer shifted perspective from the macro-level of the design process to micro-level. This perspective shift to the micro-level of the design process enabled applying 'attention to detail'. In practice, this meant mitigating the effects of the macro-level compromises and making the SMA-inlay functional. As a result, focus was placed on single stitches at the edges of the knits' structural pattern, turning inwards to enable embedding SMA to the knit structure more discreetly.

Because SMA was not knitted into the structure, wire caps were used to ensure electromechanical connectivity, going against the textile aesthetics and sensorial design. As the knit structure was not a ready-made, the textile design-process was balancing between the creative textile design thinking in the micro-level and confronting technical limitations on the macro-level. Overall, the material itself was highly sensorial, and the data resulting from the first round of analysis was not. The post-analysis led us towards the sensorial platform, which we discuss in the next paragraph.

4.2 Data Visualisation Creating a Sensorial Platform

While the post-analysis inquiry increased the understanding of the collected data for the textile designer, from the new analysis also emerged the need to invent ways for making sense of the data, which allows to discuss the process of designing and evaluating the knit actuator-sleeves from both HCI and textile design perspective. Responding to this need led to uncovering the post-analysis inquiry's more profound value: Using the dots and circles to discuss new insight from the post-analysis inquiry creates a foundation through which communication can take place across the disciplinary fields of the case study. This pivotal point transcended data visualisation and transformed the dots and circles into a sensorial platform for conversation between technical HCI & textile design.

One of the challenges that we faced during the initial data analysis, was that the analysis from the Likert scales and the affinity diagram did not include the participants' experiences of materiality and sensoriality of the sleeves. Since textiles are suggested to represent a second skin (Weinthal, 2016) and accordingly, can be considered as being inherently personal, the numeral data was insufficient for the further development of the sleeves. Furthermore, the numerical data was especially challenging for the textile designer, who relies directly on the human senses as a tool to design with and through material. The process of re-examining the sleeves' evaluation through visual patterns, provided what we call a sensorial platform and research space for conversation between disciplines. What this meant in practice was that the textile design-led post-analysis inquiry enabled to draw the numerical data closer to the participant's experience of the materiality and sensoriality, Thus, the sensorial platform provided means for fostering interdisciplinary knowledge.

4.3 Visualisation Insights Towards a Set of Guidelines for Textile Design in HCI

In the first form (Figure 4.b. bottom), the representation overlays the result-relations between key questions on tactile and thermal feel, as an actuation effect, or an effect created by an external object. It suggests how questions focusing on these aspects are related to each other, and indicating differences in participant answers. As a provocation for further conversation between disciplinary perspectives, the result-relations of all three sleeves implicates to how the liking of 'artificial' sensory effects as an integrated part of the knit possibly differs to the more typical effects, when the sensory stimulation comes from an 'outside' source and is not a permanent part of the knit.

The second form (Figure 4.b. top) displays how the overall perception of the sleeve changed per individual: represented by a small circle as before, a large circle as after, and the difference through a connected line. The line, or its absence, was seen to entail the participants' experiences of materiality and sensoriality based on the actuation of the sleeves. We suggest that it allows reflecting on the given responses of the sensory effects of active haptics, in relation to possible changes in tactile appeal; thus, placing material and actuation as equal 'partners' in the future design process.

The larger circles of T-sleeve, in Figure 4.b.(top), were discussed as referring to the sleeve's tactile appeal after the knit was touched across its surface with an external object. The feedback from this question was seen connected strongly to material and indicating to the sleeve's *mediated* tactile appeal, having a point of reference to a material experience similar when worn as a regular garment.

From a material perspective, the smaller circles offered valuable insight, functioning as a point of entrance to a conversation to bring the possible tactile differences between the sleeves in their inherent or in their original state to the foreground. The importance of taking into consideration the knit's inherent tactile appeal from the collected feedback is especially relevant in wearable context, since the knit needs to fulfil the sensorial requirements of the user whether activated or not.

Besides the material sensorial characteristics, the small circles also could be seen representing a textile designer's competency to offer aesthetic, sensorial and emotional pleasure through a textile-based product to its users. This competency, (or repertoire) is built on the understanding of the interrelated, complex and hierarchical system of fibre-, yarn-, and fabric construction and finishing process, which is derived from knowledge that is both 'tacit' (e.g. Igoe, 2010), 'experiential and implicit' (Bang, 2009).

From the outset, a technical HCI perspective made no distinction between the three sleeves in terms of material. The smaller circles of I- and U-sleeve were seen to function as a point of reference to the possible changes shown in the larger circle, which was caused by the effect of the machine-device-system. In fact, it is the embodiment of the smaller circles that the textile designer's skills and knowledge on material sensoriality and sensibility has stronghold; a strength, which is demonstrated in the development process of the actuator knit, described in Chapter 3. From an interdisciplinary perspective, and as a meeting point between technical and designerly skills, the smaller circles, regarding Q1, represent a design space in which negotiations can take place: to negotiate between the sensorial material characteristics of the conventional textile material and the additional material relating to the actuator in relation to its technical functionality.

In this section, we used the visual representation of the data in Figure 4.b. to discuss ways in which textile design can act as a value in HCI, and work across disciplines. We learned that this way of analysing the data was meaningful for the entire team since it provided all participating disciplines with a common ground. This we refer to as the 'Sensorial Platform' - and we apply it for further understanding and development of the SMA actuated sleeve. We see this as a starting point for a set of guidelines enabling textile designers and traditional HCI-professionals to benefit from a mutual relationship.

5 Conclusion

This case study was not intended as an argument for or against the design potential of SMA with wearables. Instead, this case study is intended to act as a perspective in a conversation between disciplines that use textiles for various purposes, and to entail a story of the potential sensory-aesthetic and functional diversity that can be exploited when designing a material. Although tangible and sensorial, discussing design decisions and their implications were challenging with the samples at hand. The results could not be found in them. The numerical data, on the other hand, lacked the materials sensorial aspects. The sensorial platform brought these limitations together.

Thus, this paper calls out to engage and include textile design into future research activities situated in HCI. Rather than using textiles as ready-made or a flat material that is merely used as a platform for attaching or encasing haptic technology, we encourage to explore an alternative path, in which technical and design features can co-exist as equal partners. We do this by suggesting an alternative way to analyse the data-set collected by a Likert scale. This approach led to adequate interpretations of the material, and it enabled the researchers (from different disciplines) to apply the professional skill-sets they bring in, in order to get as much knowledge as possible from the experiment.

This case study was not intended to portray a stereotypical (smart) textile design process, as that does not exist today. In this light, the role of the smart textile designer is in a state of evolution. Our case study revolved around three sleeves, and the detailed process needed for creating them. Textile characteristics affecting the feel, is an overall reflection on an interrelated and hierarchical textile system (fibre, yarn, fabric, finishing), also encompassing user related factors. Due to the diverse use of textiles, the design and production of textiles accordingly varies and is subject to adaptability, depending on its intended outcomes. This requires specific knowledge to exploit.

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