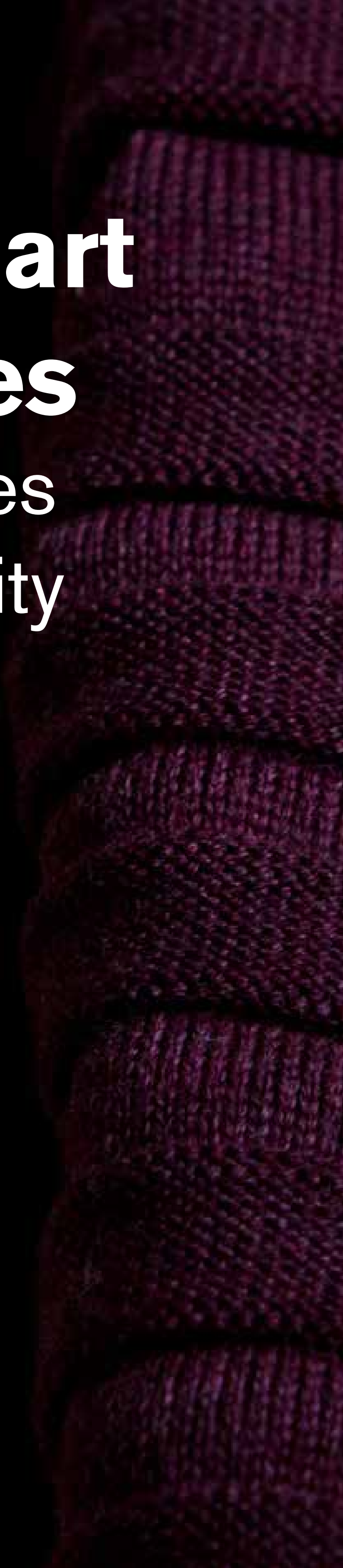
Designing embodied smart textile services : the role of prototypes for project, community and stakeholders



Designing Embodied Smart Textile Services

The role of prototypes for project, community and stakeholders

Martijn ten Bhömer

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doctoral dissertation by Martijn ten Bhömer

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PROEFSCHRIFT

ter verkrijging van de graad van doctor aan de Technische Universiteit Eindhoven, op gezag van de rector magnificus prof.dr.ir. F.P.T. Baaijens, voor een commissie aangewezen door het College voor Promoties, in het openbaar te verdedigen op donderdag 18 februari 2016 om 16:00 uur

door

Martijn ten Bhömer

geboren te Roermond

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Het onderzoek of ontwerp dat in dit proefschrift wordt beschreven is uitgevoerd in overeenstemming met de TU/e Gedragscode Wetenschapsbeoefening.

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Preface

1.1 Personal Motivation

The age of wearables has been a prophecy for decades, with visions such as the disappearing computer (Weiser & Brown, 1997) bringing technology everywhere around us. The miniaturisation of technology is reaching a point where we can finally start to evaluate the results that this vision has brought us. Increasingly, previously rigid and hard technology is being transformed and shaped to the body: for example, in wristbands, activity trackers and glasses. With these devices here, there is still one question that is mainly unanswered: how can these close-to-the-body technologies create value for us as human beings? While wearing my activity tracker during the day and clipping my sleep tracker to my pillow by night, I personally still have not found the compelling reason to keep using these systems. Waking up in the morning and checking my latest sleep statistics, I cannot help but feel like an actor in a complex information system. My activity tracker, which ended up somewhere in a drawer after a few months of use, could only seduce me to admire its fancy graphs in the first weeks, but was it truly giving me value and letting me connect to my bodily experiences? Can these mass-produced products take an intimate role in our lives, and are the design processes traditionally used for consumer products still sufficient? Shouldn't we look for alternative design processes and new business models to consider the personal impact of close-to-the-body technology?

I noticed during my experiences as Interaction Designer before this PhD project that the subtleties we designed often would not make it to the end product in the transition process from concept to market. For example, in 2010 I was working with two other designers in a start-up to create intelligent lighting for consumers. We made prototypes and had many ideas how these lights could help users in their daily lives. However, transforming these design ideas into a business plan that could show the unique value of our product to investors was a challenge because we were unable to communicate the value proposition in the right language. This will become even more urgent in the context of close-to-the-body applications. An eclectic mix of disciplines such as electronic engineers, textile engineers, fashion designers and service providers might have to work together in order to realise a new product category, beyond the wristwatch or activity tracker. It is my belief that the designer can have a large responsibility to take multiple values and perspectives into consideration to come to economically viable and socially relevant results. How can we design in this way, from a bottom-up perspective, integrating people's context and fulfilling the expectations of all the stakeholders involved?

Within the field of Industrial Design there is a growing trend where products are moving more and more into directions where services are integrated seamlessly with their physical counterparts into intelligent systems. During my education as an Industrial Designer I gained all types of knowledge and methodologies to bring the user into the design process, to evaluate the experience for the end-user.

Working as an Interaction Designer after my graduation opened up a new world, where dealing with production partners, service providers or investors was as important as designing for the end-user. I believe that in processes with multiple partners it is not the role of the designer to just be a facilitator of this process, but rather to engage in the project on an equal level with other partners with our specific skills. A complex system inherently consists of many individual perspectives, which makes it difficult to assign authorship and ownership. My research approach, embedded within the Designing Quality in Interaction research group, is inspired by phenomenology, embodied cognition and the ecological theory of perception, which all take the body-in-action as a starting point and which do not make the Cartesian mind-body division. Could the design profession be helped with an embodied approach that would bring the designer into contact with other stakeholders earlier in the project? Perhaps even using these new constraints as a source of inspiration in the making and ideating processes?

I love to work with my hands to explore the interactive possibilities of products and services: for example, by soldering electronic components, sewing textiles together, or programming microcontrollers. Being able to engage with a design problem through a material gives me the possibility to explore and enables me to reflect on the result. Particularly when issues get complex, bringing it down to the essence helps to keep things manageable. A few years before starting this PhD endeavour I joined Microsoft Research for an internship. I made quick explorative prototypes in the beginning of the process, and more elaborate and detailed ones to define the exact interaction later in the process. This helped me to realise that this approach not only gave direction to the process, but also opened up the process for other researchers to critique and evaluate over time. Applying and building our own specific design skills is crucial to be able to understand our own approaches and then argue them to others. Wouldn't it be great if a prototyping approach can help in these evaluation and decision processes, supporting all stakeholders involved in our products and services (from producers, to users to designers)?

1.2 Thesis structure

My personal motivation started with my wondering how close-to-the-body products and services can become truly meaningful to people's lives, and how these could become more closely connected to our bodily experiences than the current approaches. The main question of this thesis is therefore:

> "How to design Embodied Smart Textile Services?"

In this thesis I will argue that to come to these new types of products and services, we need to come to an understanding of how prototypes are used in the design process, collaboration and for embodied sense-making. In order to investigate these multifaceted roles of prototypes I will divide my thesis into the following chapters.

Chapter 1 will provide the theoretical framework that is used in the succeeding chapters. By discussing related work about Prototypes, Embodiment, Product-service Systems (PSS's), Soft Wearables, Participation, Collaboration and Communication, I will show the starting point that helped to frame the approach of this research.

Chapter 2 describes the three Smart Textile Product-service Systems that have been developed and function as the carrier of my PhD research: Tactile Dialogues, Vigour, and Vibe-ing. By comparing these Smart Textile PSS's with a selection of current state-of-the-art Smart Textile PSS's on the market, I will come to an overview of how personalisation of the material properties, personalisation of the look, fit and feel of the textile object, and personalisation of the interaction of the behaviour can help to transform Smart Textile PSS's into Embodied Smart Textile Product-service Systems (which I will call Embodied Smart Textile Services). In the preceding chapters I will focus on a series of analyses that will help to understand how these Embodied Smart Textile Services were designed. This results in conclusions that could support future design processes.

Chapter 3 takes a perspective of looking at the role of the prototypes in the design process: the scale of the Project. The goal is to get insight into the question:

> "How do prototypes support a bottom-up infrastructuring approach to design Embodied Smart Textile Services?"

I will be using autoethnographic accounts of how I experienced the design process, specifically for the design of Tactile Dialogues. By tracing how the Service Interfaces developed with each prototype iteration, I will conclude that the prototypes can support the bottom-up infrastructuring approach by allowing a democratic design process that is situated in context and creates quality on all levels.

Chapter 4 zooms in to the scale of the Community and focuses specifically on the collaboration between the stakeholders that took place in six design meetings. I will try to answer the question:

> "How do prototypes support sharing multidisciplinary knowledge between stakeholders in an Embodied Smart Textile Services design process?"

Here I will use protocol analysis methodologies to approach the question. This chapter presents a study in which I zoom in on six design meetings that took place between some of the stakeholders and me.

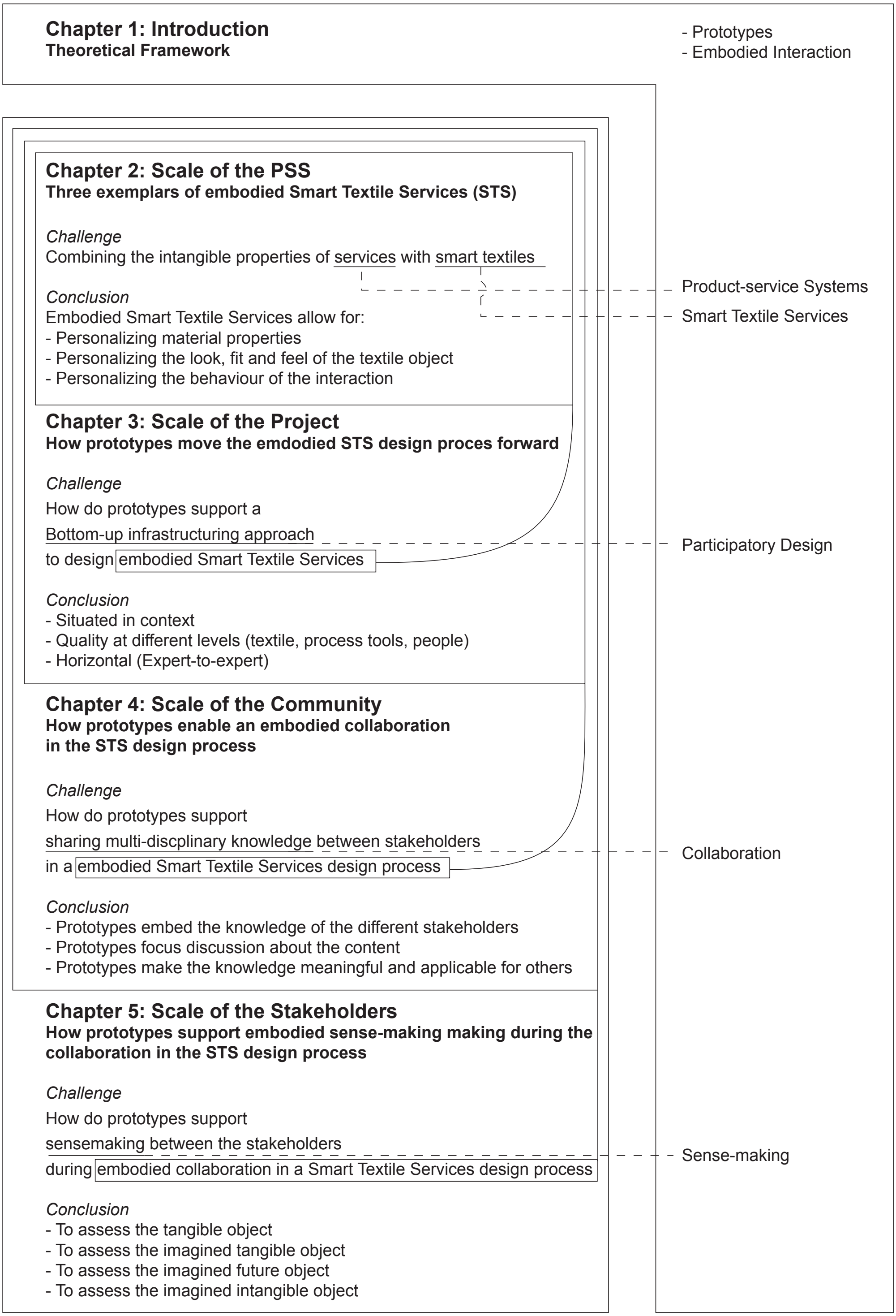


Figure 1: Chapter structure of the thesis showing the relations between the different scales.

This chapter concludes with explaining that prototypes support knowledge sharing by means of embedding the knowledge, focussing the discussion and making the knowledge applicable and meaningful to the other stakeholders.

Chapter 5 presents a detailed analysis on the scale of the Stakeholders and focusses on sense-making moments during two of the design meetings. Here I will look within the collaborations itself to investigate how prototypes supported embodied sense-making between the stakeholders, answering the question:

> "How do prototypes support embodied sense-making during the collaboration in a Smart Textile Services design process?"

By using Conversation Analysis methodologies I will zoom in on moments during the design meetings in which assessments were made as part of the sense-making process. As a result, I will come to four different type of assessments in which the prototype and the body play an important role.

Chapter 6 tries to bring all the insights from the previous chapters together to come full circle, and answers the initial research question. This chapter structure of zooming in on the different scales is visualised in Figure 1. Within the left side of the rectangles, the changing scope of the chapters and the most important conclusions are presented. On the right side, the relevant theory that frames the chapter is shown.

Chapter 3, Chapter 4 and Chapter 5 provide in-depth analyses into their specific scales in order to provide a constant presentation these are all structured in the same specific manner. The *Introduction* section introduces the research questions and provides background information from the specific research community to frame the chapter. The *Data Selection* section provides information on the dataset that is necessary to answer the research question selected. The *Data Documentation* section explains how the data was documented during the design process, and frames the context of how the data should be interpreted. The *Data Codification* section uses the specific lens based on related research from the chosen research community to codify and present the data in a specific way. The *Data Analysis* section presents the actual analysis based on the methodology linked to the research community. The *Findings* section brings forward the important outcomes from the preceding analysis, and relates them back to the initial data codification. The Conclusions section discusses the outcomes of the data analysis and relates them back to the research question set out in the beginning of the chapter.

Next to some of the photos in this thesis a QR code is displayed. These codes can be scanned with a mobile device in order to display a short video clip.

1.Introduction

I was trained as a designer in the Industrial Design Department of Eindhoven University of Technology. This education provided me with a focus on the design of intelligent products, systems and related services. Moreover, this taught me an attitude in which creating *prototypes* plays a central role in the design process. A prototyping approach supports me to integrate materials, technologies, software, and social and cultural contexts in order to come to new propositions and to confront end-users and other stakeholders with new ideas and technologies. This approach is theoretically grounded within the research and teaching of the Designing Quality in Interaction (DQI) research group within the Industrial Design Department. This led me to follow a research-through-design process, an iterative transaction between design and research (Frayling, 1993; Zimmerman et al., 2010). In this process, scientific knowledge is generated through, and fed back into consequent cycles of designing, building, and experimentally testing experiential prototypes in real-life settings (Hengeveld 2011). This process was deeply connected to an approach that starts from human skills, such as perceptual-motor, cognitive and emotional skills, leading to approaches such as *Embodied Interaction* (Dourish, 2001) to inspire the design process.

My PhD research is embedded in the Dutch Creative Industry Scientific Program (CRISP, 2015). The main focus of the programme is to create knowledge to validate and support the strategic role of creativity in innovation for society and the economy, particularly by means of designing *Product-service Systems*. The Smart Textile Services project within CRISP focuses on integrating existing knowledge from the separate domains of textiles (soft materials), technology and services. Smart textiles, which combine soft materials and electronics, may invigorate both the textile and high-tech industries by creating a new product group named *Smart Textile Services*.

In order to achieve this vision, the research programme aims to generate knowledge about how universities, service providers and industry partners can collaborate in creating these Smart Textile Product-service Systems. Research about collaboration processes from fields such as *Participatory Design* and *Participatory Innovation* helped as inspiration and a starting point to the approach within the consortium to involve all stakeholders. Studies of *collaborative design* and teamwork helped in providing the lens to understand how the knowledge sharing between these multiple disciplines worked in practice. Finally I will look at topics such as *sense-making* to understand better how meaning is created between stakeholders within these collaborative processes.

In the following sections I will discuss the topics introduced in the text above in more detail: *Prototypes* as part of my approach, and *Embodied Interaction* as theoretical inspiration for the *Product-service Systems* to develop with a focus on *Smart Textile Services*. This design process is based on *Participatory Design* processes, and the *collaborative design* that followed between the multiple disciplines, leading to *sense-making* between the stakeholders.

1.1 Prototypes

Prototypes and prototyping are widely recognised as important means by which designers explore and communicate what it will be like to interact with future products, systems and services (Buxton, 2007; Houde & Hill, 1997; Lim, Stolterman, & Tenenberg, 2008). In my work I will make a difference between prototypes and prototyping. *Prototypes* are representative and manifested forms of design ideas; *prototyping* is the activity of making and utilising prototypes in design. I am interested in this distinction because the two states often go seemingly from one to the other: when a prototype is finished, the next phase of prototyping already starts to create the next prototype. To understand better how prototypes play a role in the design of PSS's, I will discuss some of the roles of prototypes that have been identified in previous design-related studies. This overview provided me with a stepping stone of how the prototypes can play a role in the design process. In the conclusions of each chapter I reflect further on how the theories contributed to my findings.

Houde & Hill (1997) argue that selecting the focus of a prototype is the art of identifying the most important open design questions, using the prototype to ask questions such as: What role will the artefact play in a user's life? How should it look and feel? How should it be implemented? This leads to a model describing three important dimensions related to the design of an interactive artefact: role, look and feel, and implementation. Prototypes focussing on the role aim to investigate and demonstrate questions of what the design could do for a user. Prototypes focussing on the look and feel explore and demonstrate options for the concrete future experience of the design. Prototypes focussing on implementation try to answer technical questions about how a future design might actually be made to work and to demonstrate technical feasibility. This model aims to help designers to be explicit about what design questions must be answered, and is an essential aid to decide what kind of prototype needs to be built.

Lim et al. (2008) emphasise that the role of prototypes typically goes beyond tools for evaluation of design failure or success. They state that the prototypes' primary strength is their incompleteness, which makes it possible to examine an idea's quality without having completed the final design. Prototypes are a means to organically and evolutionarily learn, discover, generate, and refine designs. With their anatomy of prototypes they define two important roles that prototypes can have: prototypes as filter, and prototypes as manifestation. By using prototypes as filter, certain aspects of a design idea that a designer tries to represent can be more emphasised: for example, appearance, data usage, functionality, interactivity and spatial structure. Prototypes as manifestation are related to the variables that must be considered in exploration and refinement of the design, such as materials, resolution and scope. Their prototypes model is very relevant for us as designers as it helps us to be more cautious about which questions we are trying to address by making a prototype.

Experience prototypes aim to understand, explore or communicate what it might be like to engage with the product, space or systems we are designing (Buchenau & Suri, 2000). The goal is to enable thinking about a design problem in terms of an integrated experience, rather than one or more specific artefacts. Experience prototypes can play a role in three key ways in the design process. Firstly, by helping to develop understanding about the essential factors of an existing experience. Secondly, by exploring and evaluating ideas to provide inspiration, confirmation or rejection of these ideas. Thirdly, by communicating issues and ideas to provide common ground to establish a shared point of view. Buchenau & Suri (2000) conclude that the value of this particular approach lies more in the prototyping attitude, which asks for a blending of multiple disciplines and a low-technology mindset.

Another role of prototypes is that they support the integration of knowledge from different disciplines during the design process. In multistakeholder collaboration the design needs to make sense to the stakeholders, based on their own perspective (Bucciarelli, 1994). Star & Griesemer (1989) describe *Boundary Objects* as artefacts that are flexible enough to accommodate different interpretations by the various stakeholders involved in the process, yet robust enough to maintain a common identity across all social contexts. This is a powerful concept because it can enable stakeholders to attribute their own meaning to objects, although they have different professional languages and competencies. This can help in communication between stakeholders, to inform people across boundaries. In their seminal work, Star & Griesemer (1989) did not directly discuss how prototypes could function as a Boundary Object. However, the use of prototypes has been further studied: for example, their ability to transform knowledge in new product development (Carlile, 2002).

Conscription Devices have in common with Boundary Objects that they help in communication across boundaries of different stakeholders. However, they go one step further as they also enlist the participation during the design process, since stakeholders can take part in generating, editing and correcting (Henderson, 1991). Hölttä (2013) further shows that Conscription Devices enable linkages between the meaning of the object and the knowledge of the network around the object, and enable them to play a role in the organising of networks; they also provide assistance for reasoning, reflection, and the linking of items in new ways to facilitate new discoveries from the shared insights. Conscription Devices need to be modifiable and need to be modified as a result of the discussions surrounding it.

Provotypes are prototypes used to provoke reactions and insights, designed to expose taken-for-granted aspects of users' values and practices (Mogensen, 1992). A recent study of prototypes in the field of Industrial Design showed that Provotypes can serve as platforms for collaborative analysis and exploration of a design space (Boer & Donovan, 2012). By embodying tensions in the area of interest the designer can use prototypes to drive dialectic processes of change.

An overview of the roles of prototypes found in other studies is shown in Table 1.1. These roles will be used in the thesis to ground my own findings with existing uses of prototypes.

Name	**Purpose**	**Role of prototype**	**Variables**	**Key Source(s)**
Prototypes as questions	Language to enable designers to make better decisions about the kind of prototypes to build	Prototypes to ask design questions	Role, look and feel and implementation	Houde & Hill (1997)
Anatomy of prototypes	Means to organically and evolutionarily learn, discover, generate, and refine designs	Prototypes to traverse a design space	Filter (appearance, data, functionality, interactivity and spatial structure), manifestation (materials, resolutions and scope)	Lim et al. (2008)
Experience Prototypes	Enables designers, users and clients to gain first-hand appreciation of existing or future conditions	Prototypes to emphasise the experiential aspects	Understanding, exploring, communicating	Buchenau & Suri (2000)
Boundary Objects	Represent, understand, and transform knowledge across functional, hierarchical, and organisational boundaries	Prototypes to support cross-disciplinary communication	Flexible enough to accommodate different meanings, robust enough to maintain common identity	Star & Griesemer (1989), Carlile (2002)
Conscription Devices	Provide the means for stakeholders to participate in constructing information	Prototypes to conscribe participation	Enlist participation, network organisation	Henderson (1991), Hölttä (2013)
Provotypes	Driving dialectic processes of change	Prototypes to provoke reactions and insights	Embody tensions	Mogensen (1992), Boer & Donovan (2012)

Table 1.1: Overview of roles of prototypes.

1.2 Embodied Interaction

Within the design and human-computer interaction community, a body of literature is emerging around embodied interaction (Dourish 2001): for example, through theoretical frameworks such as ethnomethodology, activity theory, Gibsonian (ecological) psychology, actor-network theory, and distributed cognition (Svanæs, 2013). Within my approach I will take the body-in-action as a starting point, as opposed to the Cartesian mind-body division, inspired by theories such as phenomenology and embodied cognition (Canavesio, Redlich, & Ruspoli, 2010). Before starting to investigate how the notion of embodiment plays a role in design, I will introduce these philosophical foundations.

The phenomenological approach of Maurice Merleau-Ponty (Merleau-Ponty, 2012) argues that our existence in the world and self-awareness arise from the interaction with the physical world and with other people. This *being-in-the-world* means that all our subjectivity and experiences are based on our body as a general medium for having a world. Based on Merleau-Ponty's analysis, Hubert Dreyfus divides three modes of how embodiment plays a role in our lives: innate structures, basic general skills, and cultural skills (Dreyfus, 1996). The first mode refers to the actual shape and innate capacities of the human body. People have arms, legs and a certain size. The second mode refers to our skills for coping with artefacts. As we encounter different situations to act upon, our skills get more refined and our responses become more skilful. The third mode comes from our experience and grounding with the cultural world to provide context. These are mainly interactions that have been learned, and not necessarily directly related to how our bodies are built. The world we perceive is based on the possibilities to interact with it through our bodily and learned cultural skills.
For example, as Industrial Designer when I take a piece of fabric I might say, "This textile has a certain elasticity: integrated in a garment it might limit the body movement, making it perfect for physical therapy applications". On the other hand, a knitting technician might feel the textile and say, "To produce this knit a gauge 6.2 flatbed knitting machine was used, to knit a combination of mesh jacquard, intarsia and float jacquard". This shows how our different knowledge and relation with materials affect how the world shows itself, and how it invites us to act.

What I want to emphasise with this reflection is that in my understanding embodiment goes further than just corporal and material characteristics within interaction. Our being-in-the-world cannot be separated from our bodies. We encounter, interpret, and sustain meaning through our interactions with the world and with each other. This aligns with Dourish's account of *embodied interaction*, which includes its corporal, situated and social nature (Dourish, 2001). He further claims that embodied interaction is not simply the form of interaction, but rather "an approach to the design and analysis of interaction that takes embodiment to be central to, even constitutive of, the whole phenomenon" (Dourish, 2001, p. 102). This is a crucial insight, since Dourish here argues that, for interactions to be embodied, the design process needs to be embodied in the first place.

Another element being discussed in the context of embodied interaction is the relation that we have with our tools (Dourish, 2001). Heidegger (1962) talks about embodiment in terms of present-at-hand and ready-to-hand ('vorhanden' and ‘zuhanden’). Where in the beginning we struggle with our tools, learning how to use them and ‘make them ourselves’, our tools are considered present-at-hand. At some point we learn how to use them: they become a part of our body and allow us to express ourselves fluently, resulting in a ready-to-hand way. Heidegger argues that in this ready-to-hand state tools move to the background of our lives, become part of the fabric of our lives and situated in our context. This means also that many of the materials in our environment cannot be easily disconnected from the person. A sewing machine has a totally different way of opening up possibilities for a professional seamstress, while, for example, for me it can be a tedious machine, being very much present-at-hand. For the seamstress all the social relations and all the interactions are part of the interaction with the machine; the technology behind it is transparent and it is about how the machine affords the seamstress to change the world. My research-through-design process is deeply inspired by Embodied Interaction and its underlying theories: later in this thesis I will relate the findings of my research to these aforementioned theories.

1.3 Product-service Systems

The role of products and services has changed tremendously in recent years. Philips Design (Gardien, Djajadiningrat, Hummels, & Brombacher, 2014; Rocchi & Brand, 2011) has defined four economic paradigms to explain different ways to think about value creation. In the *Industrial Economy* this is mainly achieved by the acquisition of products that fulfil functional need. In the *Experience Economy* branded products are used by consumers to express their lifestyle and associate themselves with particular social groups. The *Knowledge Economy* flourishes due to technologies such as web communities, where open innovation processes can take place that build upon user-contributed knowledge. An important thing to take away from their framework is the currently emerging *Transformation Economy* in which industry, government, academia and local user communities will need to collaborate to create local solutions that contribute to the larger whole, particularly in relation to the understanding of societal value and ethical economic value.

These four paradigms indicate a shift taking place in the way that value is created, and will require companies to keep adapting and revalidating their value propositions (Morelli, 2009). Traditionally products and services have been developed based on different methodologies and approaches. Goods-dominant Logic in New Product Development (NPD) and Service-dominant Logic in New Service Development (NSD) are two different perspectives in organisations (Vargo, Maglio, & Akaka, 2008). Both have been well documented, the former from a product design perspective (see, for example, Ulrich & Eppinger, 1995), the latter from a management perspective (for example, Scheuing & Johnson, 1989). An important element that distinguished services from products was that they were considered intangible and therefore “cannot be touched, tried on for size, or displayed on a shelf” (Shostack, 1977, p. 75). In the last two decades

Service Design has emerged as an interest within the design community. Service Designers now have an extensive set of tools and methods at their disposal based on fields such as Ethnography, Information Management science, and Interaction Design (Blomkvist, Holmlid, & Segelström, 2010; Pacenti & Sangiorgi, 2010). Morelli (2006) divides these service design tools into three categories: identifying the involved actors and stakeholders; envisioning the service; and representing the structure of the service. Most of these tools are based on the development of conceptual maps of the service: for example, mapping the service flow in a service blueprint, or the interaction between customer and service provider in a customer journey (Schneider & Stickdorn, 2010). This introduces a risk, because the designer and other stakeholders have to define the service by a top-down approach: defining the service with a select group of stakeholders before it is actually situated in the context. Therefore, one of the main challenges of designing services is to prototype and test the service before it is actually in use. Acting out scenarios and service walkthroughs are approaches that can help to communicate and test the experience of the service during its design process (Blomkvist, Åberg, & Holmlid, 2012).

Product-service Systems (PSS's) combine the design of tangible products and intangible services, so that they jointly are capable of fulfilling specific customer needs (Goedkoop, Halen, Riele, & Rommens, 1999). They are complex solutions whose design requires the consideration of multiple aspects, such as technology, development actors, users and context (Morelli, 2002). In most literature about PSS's most classifications make a distinction between three main categories (Tukker, 2004): product-oriented services (products are sold, but extra services are added); use-oriented services (product is not the centre of the business model, but in the ownership of the provider and can be shared by multiple users); and result-oriented services (client and provider agree on a result, with no predetermined product involved). These three categories of Product-service Systems have existed in the textile industry for a longer period. For example, the damask weaving company "W.J. van Hoogerwou and Zonen" (Figure 1.1 shows one of their tablecloths) was offering product-oriented services in the mid-19th century (Pel, 1997). Besides producing and selling tablecloths and napkins, the company also had a laundry service. For an additional fee the clients could bring the product back to the company where everything was professionally cleaned, ironed and packaged. Examples of result-oriented services are companies specialising in hygiene services: for example, CleanLease (CleanLease, 2016) and Synergy Health (Synergy Health, 2016). These companies offer a more hygienic environment as a service for their clients. To achieve this goal, textile products are included in the service: for example, by providing pick-up/drop-off, cleaning and maintenance for the textiles. In these examples it is visible that already in these early Product-service Systems the product was not standing by itself: services such as cleaning or even taking over the whole laundry process form a large part of the experience for the customer.

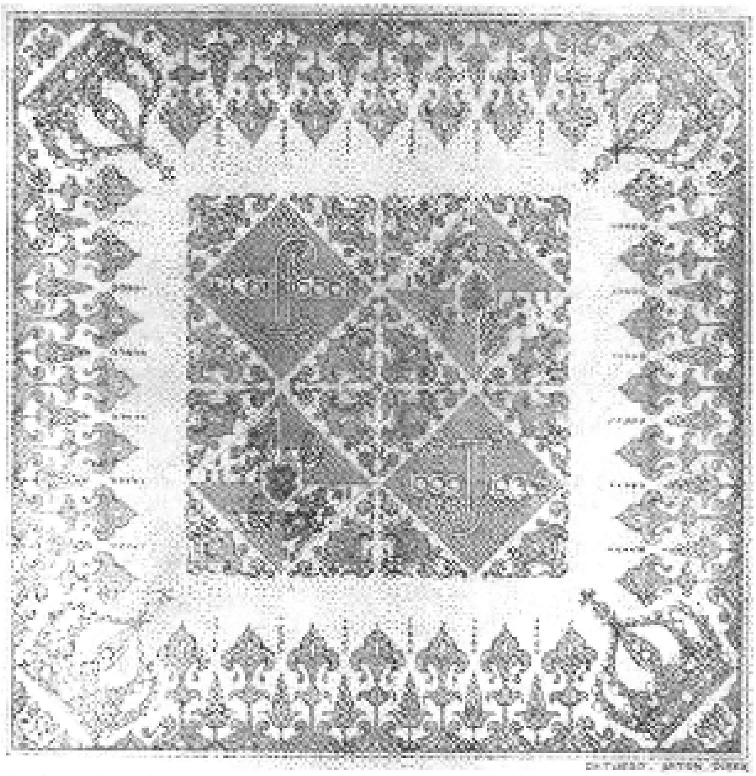


Figure 1.1: W.J. van Hoogerwou and Zonen Damask Weaving. Photo: TextielMuseum.

These PSS's show new value relations between users, producers, service providers and other stakeholders, where vertical product chains are transformed into value networks existing between several companies that collaborate for the development of specific products and services (Pawar, Beltagui, & Riedel, 2009). Challenges for these networks can be the need for unification of discrete product and service elements, and also the need for firms with competing motivations to vertically integrate or outsource activities (Williams, 2007). Another challenge within PSS's is the 'one-person – one product' approach which is slowly changing in favour of the 'multiple-nodes' approach of complex systems (Frens & Overbeeke, 2009). The ability of the components in the PSS to adapt to the interconnections with other products, other services and different users forms the total experience for the user. This relates to the concept of Smart PSS's, in which a smart product is integrated with an e-service to jointly dress the needs of the consumer (Valencia, Mugge, Schoormans, & Schiffenstein, 2015).

1.4 Smart Textile Services

Smart textiles are a type of smart material that have the ability to sense their environment or external stimuli, and can respond to these events by adapting their behaviour to it while maintaining some of the intrinsic properties of traditional textiles (Cherenack & Pieterson, 2012). Technological developments in textiles and technology make it possible to augment the existing qualities of textiles with sensing capability (for example, measuring touch, stretch, movement, light, and sound) and actuation capabilities (for example, changing heat, colour, light, and shape). The development of smart textiles has traditionally been pushed by technologically driven disciplines. In the last decade designers on the forefront of working with smart textiles have posed the question as to why we want our fabrics to be electronic (Berzowska, 2005; Quinn, 2010; Seymour, 2008). Important elements in reaction to this question are a focus on intimacy of technology on the body, using the fabric as playful disguise, for personal expression, and possibilities for experimentation (for example, Figure 1.2). Currently, Soft Design approaches are being explored for smart textiles and wearables to put forward a focus on the material explorations, the body and the context in order to understand wearables focussed on context and meaning-making (Tomico & Wilde, 2015).

Figure 1.2: One of the earlier experiments of using smart textiles for self-expression – Bubelle by Lucy McRae for Philips (2006). Photo: Philips Design.

The value of smart textiles for the end-user is also being investigated by looking at how societal and commercial adoption of smart textiles evolves (Schwarz, Van Langenhove, Guermonprez, & Deguillemont, 2010). From this analysis it is visible that the interactive nature of smart textile properties can be added to an application to further personalise it to each customer. By combining intangible properties from services (for example, the ability to measure and store data or change the functionality of a material over time) it becomes possible to tailor smart textiles to individual users. Smart Textile Services are a type of Product Service System where the value for the end-user is achieved by combining an interactive physical component (the smart textile) with intangible components, such as digital data or interpersonal relations. The combination of services and smart textiles can enable the textile and clothing industries to create value propositions with increased personal meanings and product attachment for the user (Niinimäki & Hassi, 2011). Smart Textile Services go beyond a material and often imply connections between the vertical textile chain (from production to end-user), but also collaborations with technology manufacturers and service providers. In order to achieve these collaborations, new types of design processes are necessary which will allow all the stakeholders to integrate their expertise and skills into a new Smart Textile Service proposition.

1.5 Participatory Design

Industries are constantly evolving and changing how they function, driven largely by economic considerations and the advent of Information Technology. Much of the production can be outsourced or automated, which introduces a gap between production and consumption and makes it harder than ever for consumers to relate how products are made. The textile industry is a clear example in which much of the production is outsourced to lower-cost countries such as China, India, Pakistan and Bangladesh (Kumar & Samad Arbi, 2007). *Participatory Design* tries to intervene in these processes, promoting instead that the user, social context and surrounding material culture should be central to the considerations and processes of design (Bannon & Ehn, 2012; Bødker, 1996; Kensing & Blomberg, 1998). This approach has its original roots in the 1970s during the first wave of outsourcing, where it sought to empower those affected by a design (often the weak stakeholders such as local trade unions) to have a say in the design process (Ehn, 2008). Halskov & Hansen (2015) identified five major themes within the field of Participatory Design through an analysis of one decade of publications within the community. These themes consist of: politics (people who are affected should have an opportunity to influence decisions), people (being experts in their own lives and thus playing a crucial role), context (use situation as starting point of the design process), methods (empowering users with methods to gain influence in the design process) and product (the goal of participation is to improve the overall quality of life). For me these themes lead the way to a point of departure for the participatory development of PSS's, in which embodiment is emphasised as a fundamental element of the design approach: an embodied perspective where the people who are influenced by the design take a driving role in the design process and a first-person perspective as expert, an embodied perspective in which the design process is situated in the actual in-use context.

An important development in Participatory Design processes is the move from the current *projecting* (or “design for-use, before-use”) principle to *infrastructuring* approaches that can trigger “design after design”. Ehn (2008) argues that current design processes such as user-centred design, contextual design, experience design and also Participatory Design aim to design for use cases, before actual use has taken place. Infrastructuring approaches focus on growing designing possibilities for future design, in order to come to a more inclusive approach where the boundaries between use, design, implementation, modification, maintenance, and redesign are blurred (Karasti, 2014). Infrastructuring enables open-ended, long-term and continuous design processes where diverse stakeholders can innovate together by flexibly joining resources and time (Bjögvinsson, Ehn, & Hillgren, 2012).

Another important factor in Participatory Design processes is to identify who should be considered as a legitimate participant in the design process. Is it only the users? Other people involved in the vicinity of the user who are involved in the value creation product or service? Or should the manufacturers and technicians on the factory floor also be considered? Lindtner, Greenspan, & Li (2015) question the role of the actual people involved in manufacturing processes in China. Through their study they bring forward the observation that the division between production and designing (because of manufacturing outsourcing) actually separates the designer from the embedded and embodied practice of production and the tacit knowledge that is essential to cultures of production. They advocate a Participatory Design practice not only with a deep engagement with the social context of the users, but also with the material and social conditions of contemporary productions. In general, Participatory Design emphasises that existing skills can be made a resource in the design process: making the participants’ ‘tacit knowledge’ come into play in the design process (besides their formal and explicit competences) (Ehn, 1993).

This finding resonates well with the *Participatory Innovation* approach (Buur & Matthews, 2008, 2011). Within this approach a shift is described from design to innovation, in which elements beyond the end-user are recognised, such as the market reception of a product, its contribution to a company’s turnover and its novelty (for example, in function, interaction, production process, market segment appeal, etc.). They point out that in order for a product to be innovative and successful on the market, it is necessary to address these issues. Participatory Innovation seeks to combine the strengths of Participatory Design and design anthropology, while expanding towards a market orientation. Buur & Matthews (2011) argue that a Participatory Innovation process is a “dedicated activity that takes people’s practices and needs as a starting point to generate business opportunities in the form of products and services” (p. 268). These processes serve two goals: 1. To inspire company employees to reflect on product, producer role and company identity through the knowledge about customers; and 2. To create business opportunities in the form of product/services concepts that relate to a market.

1.6 Collaboration

Product-service Systems are typically developed in heterogeneous networks of Small and Medium Enterprises (SMEs) and larger organisations (Henze, Mulder, & Stappers, 2011). The challenge of this networked way of collaborating is that companies have to adopt new innovation methods, which require people, who come not only from different disciplines, but also from different organisations and companies, to design together (Bergema, Kleinsmann, Valkenburg, & Bont, 2010). At its core of designing complex Product-service Systems, such as Smart Textile Services, fundamental challenges can be identified that deal with collaboration. Telier et al. (2011) discuss the most important contextual challenges that interdisciplinary teams will face:

- A complex environment, because many projects cross the boundaries of several organisations, stakeholders, producers and user groups
- Projects that have to meet the expectations of many organisations, stakeholders, producers and users
- Demands at all levels within production, distribution, reception and control.

In order to face these challenges related to boundaries, expectations and demands, a collaborative design effort is required. Collaborative design efforts are typically characterised by a process in which stakeholders have to create shared understanding, and eventually explore and integrate their knowledge to achieve the larger common objective (Kleinsmann & Valkenburg, 2008). The specific challenge in the context of Smart Textile Services is that the design and production processes of separate disciplines, such as textiles, technology and services, have to be combined in an integrated Product Service System. Stakeholders have difficulties in establishing effective knowledge flows, mainly because they normally lack a shared history of working together, a shared knowledge base, or methods to create, store and share information and experiences (Bertoni & Larsson, 2010). Therefore it is hard for stakeholders in networked collaboration projects to know what knowledge to share, how to share it, and whom to share with it (Bergema, Kleinsmann, Bont de, & Valkenburg, 2011).

An additional challenge for stakeholders with backgrounds is that their language is rooted in different worlds. In the specific project all the stakeholders might be able to talk Dutch with each other, perhaps with different accents or dialects. However, all disciplines also use language fixed in their own *object world*: worlds where specific scientific/instrumental paradigms fix meaning (Bucciarelli, 2002). In these worlds ordinary language is spoken in such a specialised way, as if a stakeholder is speaking a different language. For example, the textile developers use the Dutch word for “report” (rapport) to indicate the specific configuration of the needles in the circular knitting machine that was used to knit a specific pattern. Within my object world as a designer, “report” would have a different meaning, indicating mainly a textual overview of a certain process.

This short literature overview showed that the largest challenges for collaboration are related to crossing boundaries, managing expectations and meeting demand. Within these challenges, knowledge sharing and integrating knowledge are two major requirements that need to be met within a collaborative design process. In order to share knowledge it has to be mentioned that language can have different meanings depending on the object world a stakeholder comes from.

1.7 Sense-making

The literature about collaboration and embodiment shows that language can have a different meaning for all stakeholders. This raises the question how within a collaboration the stakeholders can come to decisions about which direction to take in the design process. This process has much to do with sense-making: the creation or appreciation of meaning. I will approach sense-making from an embodied perspective, following the notion that sense-making is not exclusively defined by individual cognitive mechanisms. De Jaegher & Di Paolo (2007) argue that participatory sense-making is a shared process grounded in ongoing embodied and situated interactions in a shared action space. This follows the concept of Situated Cognition theory, which describes how people embedded in a sociocultural situation continuously coordinate their own actions in relation to those of others (Suchman, 2007).

Hummels & Dijk (2015) bring forward an approach to apply phenomenology-inspired embodied theory into practice by providing seven design principles: social situatedness (placing the interactions in the context which is valuable for the stakeholders); scaffolds (tools and props in the environment used to enable creative thought and solve problems); traces (physical traces of the interaction guide the way people interact with one another); interactive imagery (triggering imagination to stimulate ambiguity and openness); dialogical system (acting face-to-face, coordinating with each other, and co-adapting to each other); first-person perspective (creating engagement, empathy and engagement through a first-person perspective); and catalysing engagement (triggering bodily engagement through catalysers). These principles are based on eliciting sensorimotor couplings in order to support social coordination between participants.

Within my process I will operationalise the process of embodied sense-making through theories of co-reflection. Co-reflection is a collaborative critical thinking process which aims to trigger sharing knowledge, intersubjective understanding and relationship building between people (Yukawa, 2006). In related studies this method has been applied to reflect on different ideas during meetings with multiple stakeholders to change the frame of reference for both stakeholders and design researchers (Tomico & Garcia, 2011). Co-reflection consists of an exploration, an ideation, and a confrontation phase (Tomico, Frens, & Overbeeke, 2009).

1.8 Summary

Within this chapter I have discussed the theoretical foundations to frame my thesis. I started with introducing different roles that prototypes can play in the design process, for example to explore the design space, cross boundaries or drive processes of change. After that I continued with introducing an embodied approach towards Industrial Design which is based on corporal, situated and social elements. I continued with describing how the distinction between products and services is fading into Product-service Systems, where products and services jointly fulfil the customers' needs. A specific type of Product Service System is found in Smart Textile Services where the value for the end-user is achieved by combining an interactive physical component (the smart textile) with intangible components, such as digital data or interpersonal relations. More examples of Smart Textile Services and the notion of Embodied Smart Textile Services will be introduced in the Scale of the PSS (Chapter 2).

In order to develop these Smart Textile Services many different skills and perspectives of stakeholders need to be integrated. I introduced five themes of Participatory Design (politics, people, context, methods and product) in order to give direction to an embodied process. I will go into more depth on how the Participatory Design approach played a role in the Scale of the Project (Chapter 3).

Theory about design collaboration gives more depth into why multidisciplinary collaboration breaks down, and how sharing knowledge is critical to mitigate these difficulties. I will take a detailed look at the collaboration process during design meetings in the Scale of the Community (Chapter 4).

Finally, I introduce sense-making techniques, particularly in relation to embodied sense-making, to clarify my approach as to how knowledge could be shared and how different stakeholders create meaning in collaboration. Co-reflection is introduced as a method to share knowledge and intersubjective understanding. I will discuss how sense-making played a role during the interpersonal interactions within design meetings in the Scale of the Stakeholders (Chapter 5).

2.Scale of the PSS: Three embodied smart textile services

(Tactile Dialogues, Vigour, Vibe-ing)

This chapter is based on the following publications:

ten Bhömer, M., Tomico, O., a, & Wensveen, S. A. G. (2015). Designing ultra-personalized embodied smart textile services for wellbeing. In L. Van Langenhove (Ed.), *Advances in smart medical textiles: Treatments and health monitoring* (pp. 155-175). Cambridge, UK: Woodhead Publishing.

Schelle, K. J., Gomez Naranjo, C., ten Bhömer, M., Tomico, O., & Wensveen, S. A. G. (2015). Tactile dialogues: Personalization of vibrotactile behavior to trigger interpersonal communication. In *Proceedings of the 9th International Conference on Tangible, Embedded, and Embodied Interaction* (pp. 637-642). New York, NY: ACM Press.

ten Bhömer, M. ten, Jeon, E., & Kuusk, K. (2013). Vibe-ing: Designing a smart textile care tool for the treatment of osteoporosis. In *Proceedings of the 8th International Conference on Design and Semantics of Form and Movement* (pp. 192-195).

ten Bhömer, M. ten, Tomico, O., & Hummels, C. (2013). Vigour: Smart textile services to support rehabilitation. In *Proceedings of the Nordic Design Research Conference* (pp. 505-506).

2.1 Challenge

Smart textiles benefit from the intrinsic properties of textiles, such as the flexibility to conform to the body, comfort to touch, softness, wearability, and familiarity (Black, 2007). This offers tremendous opportunities for applications on and close to the body, for example in well-being and healthcare contexts such as rehabilitation. As discussed in the previous chapter, embodied interaction can relate to a corporal, situated and social nature. Within the disciplines of textiles and healthcare there is a natural tendency to start from an embodied approach. The textile industry revolves around materiality: practitioners working in the textile industry are, for example, trained to evaluate the "fabric hand". This includes tactile elements such as stiffness, roughness and thickness (Winakor, Kim, & Wolins, 1980). Healthcare practitioners strongly emphasise the bodily abilities of their clients (physical rehabilitation, movement). However, when services are being connected there is a tendency to disconnect the body and materiality from the service design process. The influence of embodiment, emotions and the phenomenological significance of ways of expression about the service are an aspect not widely recognised: service research has always focussed on an information process approach (Küpers, 2013). Consider, for example, sensor devices that track physiological data: very often there is no direct reciprocal interaction with the body, with neither the context nor the social environment.

Smart textiles are becoming more integrated with service ecosystems and will extend the tangible properties of textiles with the intangible properties from services. Smart Textile Services are a type of Product Service System where the value for the end-user is achieved by combining an interactive physical component (the smart textile) with intangible components, such as digital data or interpersonal relations. This interaction between the service itself and the end-user (provider and client) is often characterised as an exchange mediated by a material artefact, and is also known as the Service Interface (Secomandi & Snelders, 2011).

In this chapter I will present an overview of commercially available Smart Textile Services for well-being, and reflect on the embodied properties. After this reflection I will present three Smart Textile Services that have been developed during my PhD project. I will describe the underlying ideas, discuss the value for the stakeholders, and reflect on how embodiment plays a role within these Smart Textile Services. This notion of Embodiment in Smart Textile Services is further specified with three notions of ultra-personalisation: personalisation of the textile material properties; personalisation of the look, fit and feel of the textile object; and personalisation through programming the interaction.

2.2 Existing Smart Textile Services

To better understand the relation between the smart textile components and the added services, an overview of Smart Textile Services currently on the market is shown in Table 2.1. The overview was created by first selecting applications in the areas of lifestyle and medical (in order to find the applications related to well-being) from the Vandrico Wearable Tech Market database (Vandrico

Name	**Smart Textile**	**Service**
Adidas miCoach: micoach.adidas.com 	Portfolio of various physical products, such as the X_cell (module that attaches to shirt and tracks heart rate, acceleration, and body movement), Fit Smart wristband (heart rate tracking), and Smart Ball (integrated sensors that measure speed, spin, trajectory, and strike point).	The hardware modules all connect to an online software platform; this platform offers coaching feedback, pre-planned workouts, and goal setting. The data is stored in the miCoach platform and can be shared and accessed by third-party applications.
OMsignal: www.omsignal.com 	The OMsignal smart shirt reads biological and physiological information such as breathing (respiratory rate and volume), activity intensity, and ECG. The OMsignal platform delivers a wide variety of physiological data directly to a user's smartphone or tablet via an application.	OMsignal is building a platform in which a collection of biometric smart clothing plays an important role. Initially the OMsignal platform will be used to inform the wearer about his or her emotional well-being. Later, this platform will be opened up to third-party developers and users.
Owlet Smart Sock: www.owletcare.com 	A sensor-lined sock for babies monitors vital signs such as skin temperature, heart rate, blood oxygen levels, sleep quality, and movement. The data is transmitted to a monitoring base station, and can be further sent to the Owlet cloud service, smartphone app or other internet-based devices.	As a monitoring tool, rather than a medical or diagnostic device, the Smart Sock aims to help parents be more aware of potential health-related danger signs. The base station is in contact with cloud services from Owlet, which can further alert other contacts if the baby's vitals signs are outside the norm.
Sensoria: www.sensoriainc.com 	Body-sensing wearable devices with integrated e-textile sensors such as a Fitness T-shirt, Fitness bra (with integrated heart monitor), and Fitness socks. The proprietary software is aimed at fitness and health applications.	Sensoria provides services to collect and visualise the data generated by their products. The goal is to help patients and caregivers by providing systems and services that enable monitoring of patients remotely, reducing costs and readmissions, and providing better quality care to patients.

T.Jacket: www.mytjacket.com 	A jacket simulates the feeling of a hug using air pressure to provide comfort, calm, and control to both people with sensory processing challenges and their caregivers (parents, teachers, therapists, etc.). Built-in sensors measure and automatically record user activity levels (seated, walking, jumping, running).	The product's cloud service allows the data gathered by the jacket to be visualised over time; also custom notification alerts based on the information are generated for the involved contacts. It is possible to control the air pressure directly from the smartphone app or to choose a pressure from the automated pressure programmes.
ZOLL LifeVest: lifevest.zoll.com 	This wearable defibrillator continuously monitors the patient's heart using dry, non-adhesive sensing electrodes to detect life-threatening abnormal heart rhythms. If a life-threatening heart rhythm is detected, the device releases gel over the electrodes and delivers a treatment shock to restore normal heart rhythm.	The company provides services with the project, such as an online patient management system where clinicians can monitor patient data from the LifeVest. This gives them the possibility to assess arrhythmic risk and make appropriate plans. The data visualisation and notifications can be tailored to the patient. Further services include partnerships with most health plans in the United States.

Table 2.1: Overview of propositions that can be considered Smart Textile Services from the Vandrico Wearable Tech Market database (Vandrico Solutions Inc, 2015).

Solutions Inc, 2015). This selection was then further specified by filtering the criteria to contain both a smart textile and a service component. The resulting examples are then discussed from an embodied perspective to provide insights into the value that an embodied approach can bring.
Looking at the overview through the lens of Embodied Interaction, we can conclude that a large part of the services is based on proprioceptive data measured by the smart textile component: for example, all the applications (except for ZOLL LifeVest) measure movement activity. Some applications also measure complex physiological data. The OMsignal shirt can extract breathing rate information and ECG measurements, and the Owlet Smart Sock measures skin temperature and oxygen level. From all the examples it is clear that there are new services emerging because of the rich amounts of sensor data that can be collected from our body and our environment.

Besides T.Jacket and ZOLL LifeVest, many of the applications use visual representations to process and represent this complex data (smartphone or tablet applications, websites) and therefore rely mainly on cognitive process. All the Smart Textile Service examples include platforms in which data is stored and visualised for the user. This data is in some cases, such as OMsignal and Owlet Smart Sock, communicated back to the user through a smartphone application.

These cognitive processes do not directly relate to the inherent goal of these close-to-the-body applications. Some of the examples extend the data and link back to the body of the wearer. The ZOLL LifeVest uses shock treatment to react to a life-threatening heart rhythm and the T.Jacket uses air pressure to simulate the feeling of a hug. Linking our body with the digital world (and thereby with the services that are possible) through perceptual-motor skills can help to maintain a direct link with our body. With this focus on the body we can achieve a certain sensitivity in interaction; however, the material qualities of the tangible parts of the service need to be considered. To give an example: do we really need a massage manual to be able to perform a pressure-point massage? Wouldn't it be much better if the instructions for performing this massage could be presented through the garment itself?

Besides the corporal aspects, situatedness and social nature are important elements of Embodied Interaction. In the examples of existing Smart Textile Services, other than the T.Jacket, Owlet Smart Sock, and ZOLL LifeVest, the context of application is less considered. The business models of smart textiles are often still based on traditional business models, in which mass production is preferred over small-scale personalised business proposals. Owing to value chain thinking, production and servicing are often outsourced to facilities elsewhere in the world. With context in mind, local groups of stakeholders can collaborate and tailor their products and services specifically to a certain market. By doing this, not only can margins increase as profit moves to the services behind the product, but also it will become possible to customise the service to the skills and identity of the particular user and stakeholders. For example, in the case of the ZOLL LifeVest, the visualisation style can be tailored to the specific patient. The air pressure programmes of the T.Jacket can be personalised through an accompanying mobile phone application, to provide the most comfort and reduce stress for people with sensory modulation difficulties. Allowing one to personalise the air pressure programmes opens the door for a new kind of service. Wouldn't it be better if these air pressure programmes could be co-developed between practitioners, families, and users as part of the caregiving process?

To realise Embodied Smart Textile Services it is necessary to implement a tight coupling between digital data and the human body, and put focus on the context of the application. The past three years we have been working on cases to demonstrate an Embodied Smart Textile Services design approach. Examples of smart textiles for close-to-the-body applications include directions such as using textile material and interactive vibratory triggers to aid in communication during dementia care (Tactile Dialogues), measuring movement and providing auditory feedback during rehabilitation (Vigour), and vibratory massage of pressure points to improve self-healing of patients (Vibe-ing). I will describe for each project a description of the Smart Textile Service and the Service Interfaces that are part of the service. Furthermore, I will go back to the topic of embodiment by discussing how the role of the body and the context in each of the applications are addressed.

2.3 Tactile Dialogues: keeping dementia patients in touch with their families

Background

Dementia is a common name to describe the different conditions that affect the well-being of the human brain and intervene in a patient's ability to read, talk, write and move. Dementia is usually associated with old age, as it currently affects one in three people above the age of 65. This disease that affects the ability to be independent is not a natural part of growing old; it is a side effect of other diseases of the brain, the most common being Alzheimer's which represents 60-80% of cases worldwide. The most recurrent symptoms of dementia include memory loss, mood changes, and problems in communication and reasoning (Prince, Prina, & Guerchet, 2013).

Dementia is usually evaluated and treated in four stages, which increase with time. The CDR (Clinical Dementia Rating) is a structured interview protocol that identifies the stages as follows: Very mild (0.5), mild (1.0), moderate (2.0) and severe (3.0) (Kramer & Gibson, 1991; Morris, 1993). The first two stages relate to recent memory loss and forgetfulness, and loss of concentration. The moderate stage is characterised by the impossibility to fulfil daily activities such as dressing or eating, memory lapses, person recognition and disinhibition. The severe stage presents a significant barrier for communication as it relates to fragmented speech and incapability to make decisions. Dementia is currently the main cause for elderly entry to residential care, creating more demand for quality facilities (Prince et al., 2013). These factors are not only a weight in the investment on healthcare, but also reflect on the conditions of care to dementia patients. In order to allow an active and more independent old age, personalised care is necessary but often neglected (Prince et al., 2013). Family members can play an important role in this. However, when the phase of dementia becomes more severe, visits become more rare, leaving more pressure on professional caregivers. In order to develop more personalised solutions, connections between different stakeholders such as service providers, caregivers, physiotherapists and family members are required. The next section will introduce an Embodied Smart Textile Service that was designed for people with severe dementia and their family members.

PSS Description

Tactile Dialogues is a Smart Textile Service which consists of a textile object in the form of a pillow with integrated vibration elements that react to touch (Schelle, Gomez Naranjo, ten Bhömer, Tomico, & Wensveen, 2015). The goal of the textile object is to enable a dialogue by triggering physical communication patterns between a person with severe dementia and a family member, spouse, or other caregiver, by a joint interaction with the product, as demonstrated in Figure 2.1. The pillow provides various vibrotactile stimulus patterns and haptic sensations that, when combined, encourage the patient to move and develop conversations

Figure 2.1: Picture of Tactile Dialogues PSS used while visiting a family member with dementia.

Scan the QR code to see a video about Tactile Dialogues, scan the picture with Layar to see a video of the interaction

Models in the picture: Rinie Verhaegh (Kantfabriek), Marina Toeters (by-wire.net). Photo by Wetzer and Berends.

in an alternative yet bodily way. The object can be used in spaces where two people are sitting: for example, at a table, couch, or over the armrests of a wheelchair. The object consists of a textile with integrated vibration elements. When these elements are touched (by rubbing, stroking, or pushing) a soft vibration can be felt from multiple locations on the object. This stimulates small movements and social connection between the people using the pillow: it allows for a dialogue based on physical interaction to begin. The vibrations in the pillow can be programmed to create specific vibratory behaviours. For example, when both sides are touched simultaneously, the vibration will increase. The standard vibrotactile behaviour is the mirroring behaviour: touch on one end of the pillow is mirrored with vibrations on the other end. The service provider offers a coaching process in which the family member and the person with dementia are instructed together in using Tactile Dialogues and also co-create the vibration patterns together. In collaboration with a motivational therapist, the vibrotactile behaviour of the pillow can be adapted to the person. An example of a tailored vibration is a game in which the people have to move their hands to find where the vibration is coming from.

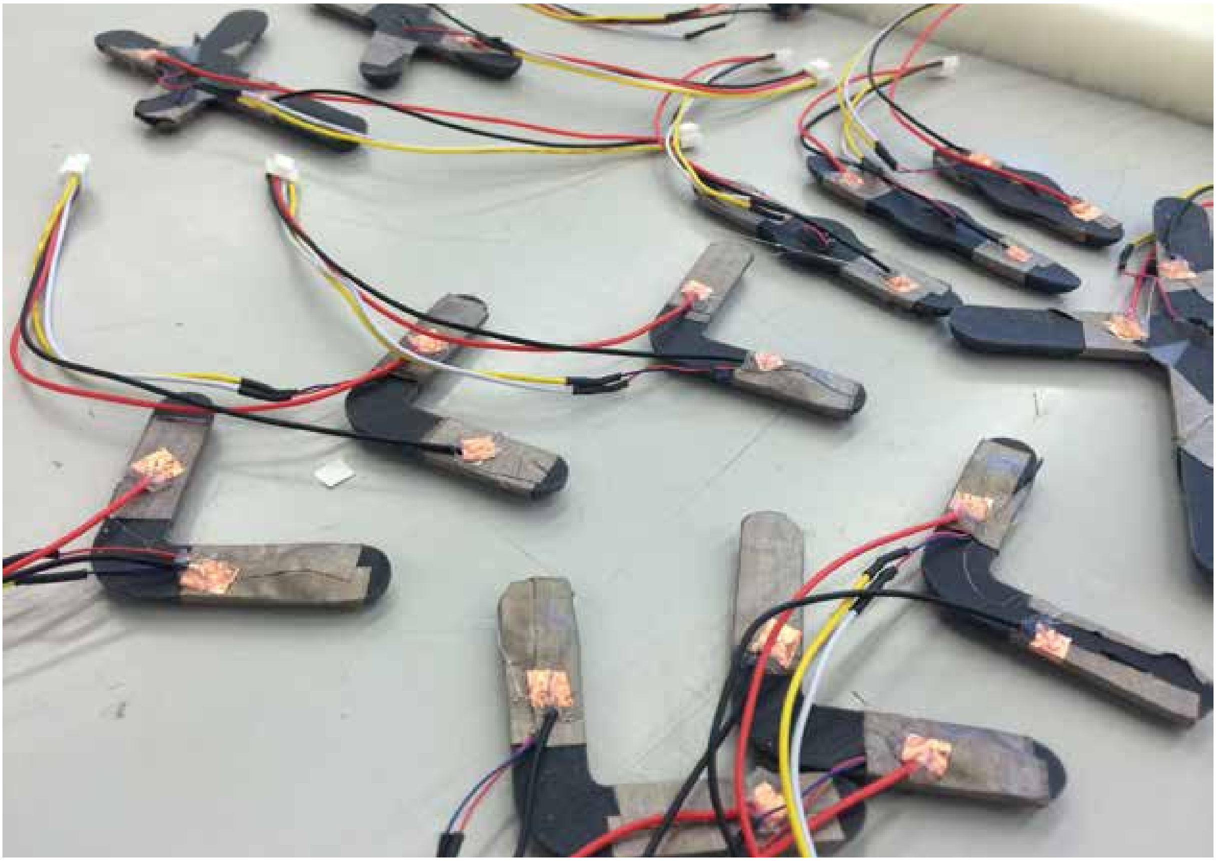
PSS Prototype

The Tactile Dialogues pillow was developed in such a way that it looks inviting for the client, but is still perceived as respectful towards the communication partner. This to prevent the negative stigma of other multisensory products which often look a little childlike. It is meant to fit within modern eldercare organisations, but could also be placed in a living room. The functional properties gave direction to the aesthetic choices during the design process. For example, we chose for a pillow based on the knowledge that people with dementia react better to the outside world when there is extra weight on their bodies. The choices for the tactile properties of the fabric resulted after conducting tests from which we concluded that different surfaces trigger different hand movements. For example, a thick layered fabric would trigger plucking movements, and ridges in the fabric would trigger rubbing with the hands. The colours of the fabric were chosen in such a way that there were two contrasting colours in the graphic pattern. For example, in the green pillow the secondary colour was a bright red which was used to create the outline of all the graphics (Figure 2.3 shows the fabric); these contrasting colours would still be perceivable for some people. The vibrations in the pillow were designed in such a way that they felt as pleasurable as possible by embedding them in specially designed, flexible 3D-printed casings (the casings are presented in Figure 2.4). These casings are integrated in the fabric, which also results in different tactile experiences when touching the fabric. The vibrations can be programmed to react to the touches on the fabric in various ways. Figure 2.5 shows a vibratory behaviour that increases in intensity when the family member increases her force on the pillow. In this example, the touches from one side of the pillow are replicated on the other side of the pillow.

This Smart Textile Service was developed by TU/e (Martijn ten Bhömer, Oscar Tomico), De Wever, byBorre, Optima Knit and Metatronics.

Figure 2.2: Circular knitting machine that was used to knit the fabric.

Figure 2.3: Fabric with contrasting colours, structure and graphic pattern.



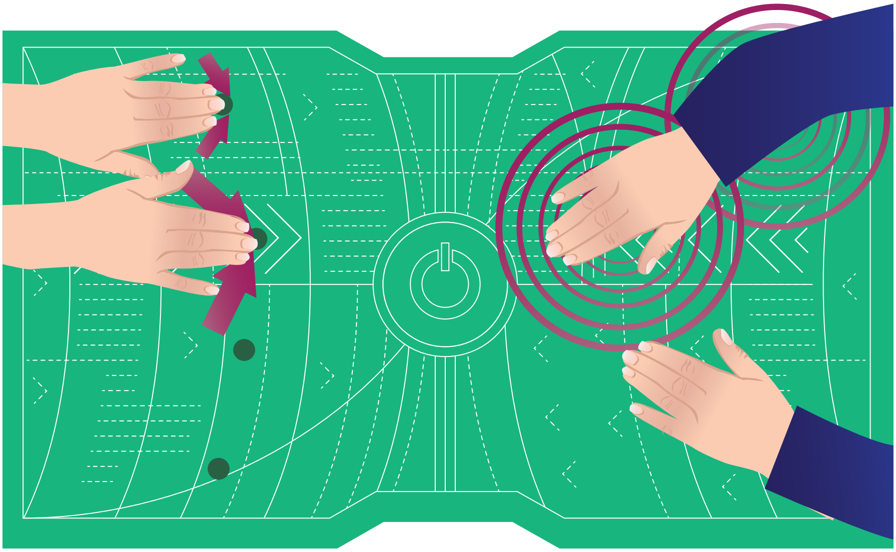


Figure 2.4: Flexible 3D-printed casings containing the vibration actuators and the sensors.

Figure 2.5: One of the interactive vibratory behaviours (Illustration by Carolina Gomez Naranjo).

Service Interfaces
As presented in Table 2.2, the clients and providers involved in the service are the Tactile Dialogues company, the eldercare company (manager, caregiver, and motivational therapist), the family members, and the person with dementia. Tactile Dialogues is part of a Product Service System which is offered to an eldercare organisation in a total package. The following pictures show a visual overview of the Service Interfaces the QR codes in the pictures can be scanned to see short videos.

All photos and videos of Service Interfaces (except Service Interface 2) by Bart van Overbeeke.

Service Interface 1: Tactile Dialogues is demonstrated by a representative of the company, after which the care provider can decide to acquire it and sign the service contract. The colour and shape of the Tactile Dialogues pillow can be adapted to the interior of the organisation.

Front end			Service Interfaces	Back end		
User profile	**What the user can do**	**Interaction supported**		**Interaction provided**	**What the provider offers**	**Provider profile**
Eldercare manager (decision-maker)	Experience service value to make better decision	Try, ask questions, personalise and buy	(1) Representative visits care home	Set up demonstrator and convince customer	Dementia knowledge and technical support	Tactile Dialogues company
Tactile Dialogues company	Transfer user-based parameters to production	Deliver customised production specification	(2) Tactile Dialogues pillow is produced	Coordinate process with production partners	Customised assembly of textiles and electronics	Production partners
Caregiver or motivational therapist	Understand benefits, guide configuration	Test pillow configuration for specific organisation	(3) Tactile Dialogues pillow delivery	Deliver pillow, configuration and training	Technical knowledge and training for staff	Tactile Dialogues company
Multiple families of people with dementia	Decision whether to use pillow during visits	Try, ask questions about own situation	(4) Tactile Dialogues information meeting	Explain about pillow, example usage	Information about product and service	Eldercare provider
Family of person with dementia	Understand benefits of pillow and personalise	Experience pillow and dialogue with staff	(5) Introduction during coaching session	Demonstrate pillow and personalise vibration	Knowledge about family member to personalise	Caregiver or motivational therapist
Person with dementia	Responding to interaction with the family	Look at pillow, feel, stroke, hug, throw, etc.	(6) Interaction session during family visits	Possibility to use pillow during visit	Trigger physical and emotional response	Family of person with dementia
Person with dementia and family	Finding different ways to use pillow	Use pillow during visit, ask for feedback	(7) Interaction session guided by therapist	Observe interaction and dialogue with family	Provide pillow and assistance during visit	Caregiver or motivational therapist
	Evaluate session and understand dementia	View video of session and ask questions	(8) Evaluating with motivational therapist	Analyse video and instruct family	Evaluate client and involve family	
Elder care manager	Receiving a working pillow	Explain problems with pillow to maintenance	(9) Maintaining and recycling Tactile Dialogues	Remove and replace broken parts	Small maintenance on location	Tactile Dialogues company
	Give dirty pillowcases away	Pick up dirty pillowcases from (care) home	(10) Washing Tactile Dialogues	Wash pillow when dirty or repair when broken	Pillow is picked up and delivered back	

Table 2.2: The Service Interfaces of Tactile Dialogues that show the interaction moments between user and service.

Service Interface 2: The Tactile Dialogues company collects the orders and creates all the instructions for the other stakeholders who produce the textile, electronics and software. These elements are assembled and integrated by the Tactile Dialogues company.
Service Interface 3: When the Tactile Dialogues arrives in the care home, a representative of the Tactile Dialogues company offers training for the caretakers and motivational therapists involved in the dementia programmes. During these trainings it is explained how the pillow fits in with the current services of the

organisation and ecosystems such as information infrastructures for patient files. Furthermore, it is explained how the family can be coached in using the pillow.

Service Interface 4: The eldercare organisation offers the Tactile Dialogues pillow to the family of their clients. During an introduction meeting, the family members can try the pillow and ask questions.

Service Interface 5: After the family members decide to start using the pillow, the vibration patterns can be further personalised to the stage of dementia and particular habits of the client. During this meeting the motivational therapist will

also give advice and tips about how to use the pillow during visitations.
Service Interface 6: This personalised vibration pattern is activated during the visits of the family member and the person with dementia to support their interaction; this step can be repeated during every visit.
Service Interface 7: At regular intervals there will be coaching sessions where the motivational therapist is present to observe during the family visits. Simultaneously, video recordings are made which the family can look back at at a later moment.

Service Interface 8: In a new service provided by the eldercare organisation, the motivational therapist rewatches the crucial moment of the interaction together with the family. They discuss opportunities to change the interaction, and which signals to notice (for example, small changes in facial expression or body posture). At the same time, these meetings are also a moment when knowledge about dementia is exchanged between motivational therapist and family member. The sensor data is analysed in order to monitor the long-term trend of the interaction: for example, to see whether the person with dementia becomes less active over time.

Service Interface 9: In case the Tactile Dialogues pillow is damaged, a representative of the company will visit the care organisation and examine whether the repairs can be done on location.
Service Interface 10: The dirty pillowcases can be regularly removed and exchanged for clean ones by the Tactile Dialogues company.

Value for the Stakeholders
For the person with dementia, Tactile Dialogues offers an activity that can be adapted to the capabilities that the person still has, which aims to increase the quality of life. For the family members of the person with dementia, the Product Service System enables them to have a different type of dialogue with their loved ones, and involve caregivers, with as a larger goal enjoying each other's company longer. The aesthetics make the pillow a product that treats both the client and the family members respectfully. For motivational therapists the Tactile Dialogues helps to involve the family members of the client more in the care process. Dementia is a topic which is often hard to discuss: the pillow and the services around make it possible to open up and give direction to the conversations. For the daily care staff and nurses, the pillow can help to keep the clients more calm and relieve the pressure of their daily work. Tactile Dialogues provides a moment of distraction with the pillow, or can increase the willingness of the family members to visit and be with their loved one. From the perspective of the physiotherapy staff, the pillow helps keep people with dementia active. Small hand and arm movements can help with the general health of people who are normally more passive. For the management of eldercare organisations, Tactile Dialogues provides the opportunity to show that they are working with innovative projects, which helps the organisation to differentiate themselves from others.

This Smart Textile Service enables local textile producers to apply their in-depth textile knowledge with a new digital platform. Eventually new business models can emerge in which the service elements can generate new financial opportunities.

Personal Reflection on Embodiment
During the demonstration visit (Service Interface 1) the body is used as a way for the decision-maker to experience from a first-person perspective the effect of the vibrotactile stimuli and customise the fabric structure. Similarly, the family member has a chance to experience interaction with the pillow in an introduction session (Service Interface 4). During this session the family member and expert from the service provider can choose the textile and appearance of the pillow to match the needs of the person with dementia and the family member, since the reactions to the tactile stimuli that the pillow provides might be completely different. When the pillow is used during the visit (Service Interface 6), the exploration through the interaction with the pillow opens up opportunities for social interaction between the person with dementia and caregiver. Furthermore, the vibrotactile stimuli patterns and haptic sensations have a direct relation to the movements of the body. This principle makes it possible for people even with limited cognitive capabilities to still have an activity together with a loved one. The motivational therapist has an important role to evaluate these corporal qualities during the evaluation meeting (Service Interface 8). The data which is generated from the pillow can further be used to adapt the vibrotactile behaviour, and also evaluate the other service elements in which the client is enrolled.

2.4 Vigour: a knitted cardigan that keeps people active

Background
Ageing of the population is one of the challenges that our society in Europe is facing. One of the strategies to transform this into a more positive outlook is described as active ageing, which aims to increase “opportunities for health, participation and security to enhance the quality of life of aging people” (World Health Organization, 2002). Within the field of geriatric rehabilitation it is known that physical training can help people in older age groups with Alzheimer’s disease to show less physical limitations and better motor skills (Neeper, Góauctemez-Pinilla, Choi, & Cotman, 1995). Besides these measurable improvements, regular exercises also contribute to the subjective health experience, and strength is maintained and balance improved: for example, the ability to walk or the ability to get into or out of a chair. Physical rehabilitation and exercises are included in the services offered by most eldercare organisations.

Physical therapy can be a debilitating experience for the body and psyche. There is the discomfort from the exercises, as well as anxiety about whether you are doing them correctly. The monitoring devices worn are bulky and stigmatising, telegraphing that there is something not quite right with the person wearing them.

Figure 2.6: Vigour PSS in use: a family member is helping a patient with rehabilitation exercises.
Scan the QR code to see a video about Vigour, scan the picture with Layar to see a video of the interaction.
Models in the picture: Oscar Tomico (TU/e), Corrie Aarts (De Wever). Photo by Wetzer and Berends.

Plus, if you are an elderly person or suffering from cognitive conditions such as dementia, the process can seem like a slippery memory: What was I supposed to do? How was I supposed to do it? And what was it supposed to feel like? One solution is Vigour, a knitted wool cardigan that uses aural feedback to motivate patients to move.

PSS Description

Vigour is a Product Service System that enables geriatric patients, physiotherapists and family to gain more insight into the exercises and progress of a rehabilitation process. It is a knitted, long-sleeved cardigan with integrated stretch sensors made of conductive yarn and an accompanying iPad application which monitors the movements of the upper body and can give sound feedback (ten Bhömer, Tomico, & Hummels, 2013). The garment can be worn all day and thereby gather a large amount of data. Next to this the garment can be worn when executing rehabilitation exercises and give feedback to the wearer by making sounds on an iPad application, as shown in Figure 2.10. For example: the further a particular sensor is stretched, the higher the pitch of the piano or the increase in volume of the voice in a song. Vigour's accompanying iPad app uses this data to give direct feedback to both the sweater's wearer and the physiotherapist, helping them both visualise progress. It also allows them to customise each sensor's sound and sensitivity, providing another way to track effort in each targeted area. The project has a high social value, since it advances ways of communication between geriatric (Alzheimer's) patients and their therapists, and encourages interaction and movement.

PSS Prototype

Vigour is designed in the form of a garment that can be worn as a normal cardigan. The reason for this is that the garment is more likely to be accepted by the target group (older adults and seniors). Family and caregivers do not like the stigma of a patient that a garment with a strong medical look puts on the wearer. It is important that the person wants to wear it, first of all because it is comfortable and also fits their identity and is beautiful, and additionally has the other features you expect from a smart garment (Figure 2.7). The sensor areas themselves are directly knitted into the fabric during the knitting process (Figure 2.9). To connect the sensor areas to the electronic components, a manual process is required in which the connections are made by bonding an adhesive between the sensor and the conductive yarn. There are in total four sensors integrated into the textile of the garment: two in the lower back area, to measure back movement (bend of the back), and two stretch sensors under the arms to measure arm movement (Figure 2.8 shows the back of the cardigan). The movements that can be measured are quite rough, and are used mainly to indicate that there is a movement, and how fast this movement is. On the back of the wearer, at the height of the neck, there is a separate 3D-printed casing that contains a battery and the Bluetooth transmitter. Every sensor area is combined with a custom PCB that can measure the signal of the stretch sensor and

Figure 2.7: The cardigan is first of all a beautiful, comfortable cardigan. Photo by Joe Hammond.

Figure 2.8: The sensors are located in the arms and lower back. Photo by Joe Hammond.

Figure 2.9: The sensors are knitted in the fabric, the casings contain the electronics.

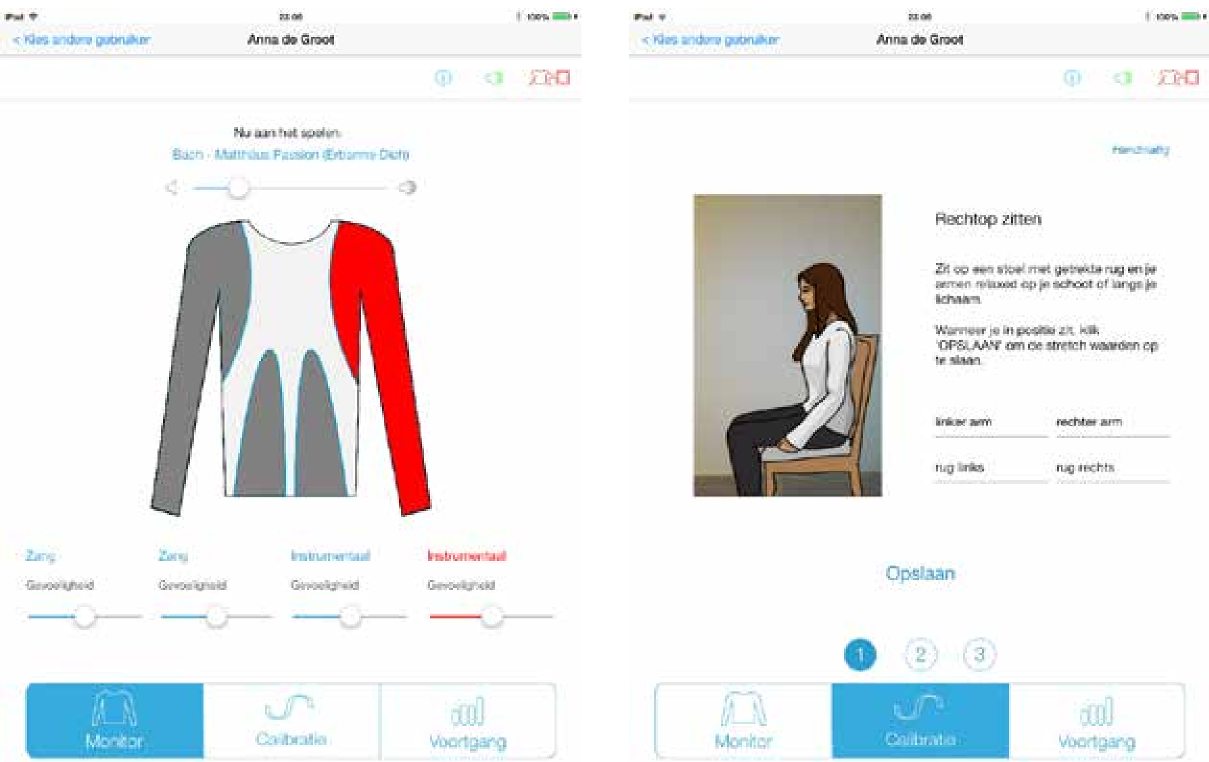


Figure 2.10: Application to project the sound and calibrate the sensors before use. Screenshots by Lisa Vork.

transmits this signal to the Bluetooth transmitter. All the electronics are encased in custom 3D-printed casings and have connectors to remove them before washing. The fabric for the cardigan was made on a knit-and-wear knitting machine. The garment was assembled on regular industrial sewing and overlocking machines. The Vigour App is mainly used for providing the audio feedback (Figure 2.10 shows two screenshots of the application).

The collaborators who helped in realising this Smart Textile Service were: TU/e (Martijn ten Bhömer, Oscar Tomico), Pauline van Dongen, De Wever, Metatronics, Unit040, Savo BV, TextielMuseum TextielLab.

Service Interfaces
The overview of the Service Interfaces of Vigour (Table 2.3) shows exchanges between the clients and the providers involved in the service; these stakeholders are the Vigour company, the insurance company, stakeholders involved in the caregiving process (physician and physiotherapist), the family members, and the geriatric patient.

Service Interface 1: During a general check-up Vigour is recommended by a physician to the geriatric patient to help preventively with maintaining the health of the patient. The physician creates a treatment plan with the approval of the patient and initiates the process.
Service Interface 2: The other parties involved, such as family and insurance company, are informed by the physician. The treatment plan is approved by the insurance company, and the financial details are discussed between family and insurer.
Service Interface 3: The patient can customise the size, colour, and sensor locations of the cardigan alone or together with family and the help of a physiotherapist.
Service Interface 4: The personalised cardigan is knitted and the technology is integrated by the Vigour company and its partners. When the tailored cardigan is finalised it is delivered to the home of the patient.
Service Interface 5: During a first introductory session together with the physiotherapist, the cardigan is tried on and a training programme is made which includes several exercises that the patient can do. During this session the initial sound feedback is configured to the preferences of the patient.
Service Interface 6: This training programme is executed when the patient is performing the exercises individually (or with help from a family member) at home. The wearer can use it to track their movements, or do exercises with auditory feedback.
Service Interface 7: The exercises and sounds that link to the movements are personalised and adapted together with the physiotherapist. This is done at regular intervals, in order for the physiotherapist to monitor the progress.
Service Interface 8: The progress of the rehabilitation process can be followed using the application. The patient can communicate the progress to family and healthcare parties (if they want to).

Front end			Service Interfaces	Back end		
User profile	What the user can do	Interaction supported		Interaction provided	What the provider offers	Provider profile
Geriatric patient	Undergo the check-up	Describe physical problems	(1) Patient visiting physician	Check physical well-being of patient	New treatment plan for cure and prevention	Physician
Family of geriatric patient	Agree on treatment plan, take next steps	Family receives information	(2) Physician informing other parties	Examine treatment report	Financial support for patient	Insurance company
Geriatric patient (could be together with family)	Wear the cardigan, test the fit to the body	Customise size/fit, colour, male/female	(3) Customising the Vigour cardigan	Load parameters of patient into platform	Web platform to configure cardigan	Physio-therapist
	Decision whether to use pillow during visits	Receiving cardigan at home	(4) Delivering Vigour cardigan	Cardigan is knitted based on parameters	Production on demand	Vigour company and production partners
	Test personalised experience and comfort	Ask questions and perform exercises	(5) Testing Vigour cardigan	Introduce cardigan and training programme	Check sensors and personalise sounds	Physio-therapist
	Motivation and awareness of body by sound feedback	Manipulate sound by body movement	(6) Performing exercises with Vigour cardigan	Tailored training programme for patient	Involve patient in treatment and self-control	
	More motivation because of adaptation	Indicate progress training	(7) Adapting training and sound feedback	Adapt training and select sound together	More effective rehabilitation	
	Get insight into the exercise progress	View visualisation of treatment	(8) Using application to follow treatment	Feedback and advice based on analysis	Analyse the visualisation over time	
Physical therapist	Broken cardigan is given away	Pick up from physical therapy location	(9) Maintaining Vigour cardigan	Repair cardigan when broken	Cardigan is picked up	Vigour company
	Cardigan is given away	Dispose of cardigan	(10) Recycling Vigour cardigan on disposal	Pick up cardigan after life cycle	Cardigan is picked up	

Table 2.3: The Service Interfaces of Vigour that show the interaction moments between user and service.

Service Interface 9: Vigour can be washed at home after the electronics are removed from the integrated pockets; however, repairs will be serviced by the Vigour company through the service contract in case.
Service Interface 10: Finally, Vigour will be picked up by an employee of the company after the product finishes its life cycle.

Value for the Stakeholders
For the senior (the wearer) the service allows for giving aural feedback to augment basic fitness exercises. We deliberately do not give feedback on exact metrics because this would not help with the goal of staying active. The application shows general movement information, and trends in the data to motivate or give basic insights. The family member can use the sound feedback and the application to support the senior with performing the exercises. In general this leads to more involvement and insights into the treatment. For the physiotherapists the Smart Textile Service enables them to adapt the exercises and treatment plan better to the actual data patterns which are generated through the garment. The eldercare organisations are benefited by the Vigour Smart Textile Service because it enables their clients to become more independent. By following their own treatment, and basically becoming more proactive in the care process they can focus on delivering higher quality in other services. The health insurer uses the data generated by the garment in order to acquire more insights into activity and exercise patterns of their clients, allowing them to be more involved: for example, by proposing different healthcare services.

Personal Reflection on Embodiment
Since Vigour is a wearable product, the body plays an important role during the whole service journey. During the standard check-up the physician will mainly focus on the physical well-being of the patient (Service Interface 1). The body is measured to adapt the garment measurements, and also the sensor locations have to be carefully matched to the individual characteristics (Service Interface 3). When Vigour is delivered and tested for the first time the patient is focussed on the bodily experience to judge the comfort and effect of coupling the sound feedback to their body movement (Service Interfaces 5 and 6). Finally, during the actual use of Vigour (Service Interfaces 7 and 8) the link between the bodily movements and the digital data is made. Movements such as lifting the arms and bending the back are translated into sounds such as piano chords or musical instruments, which fade in and out. Vigour is ultra-personalised by adapting its physical appearance to the body and preferences of the patient who will be wearing the cardigan (Service Interfaces 2 and 3). This means that the back end of the service is aimed at producing individual customised pieces, rather than mass-produced high volumes. The patient and physiotherapist have tools available (by using the iPad application) to adapt the sensor sensitivity and sound feedback according to the actual exercise and physical and cognitive capabilities of the patient (Service Interfaces 6 and 7). Through this end-user programming procedure the garment can be adapted further to the specific wearer.

2.5 Vibe-ing: a self-care tool for personal well-being

Background

A feeling of comfort is not necessarily synonymous with absence of pain, but can be better described as a subjective phenomenon which is part of human basic needs (Vink, 2004). A positive understanding of comfort can be found in feelings such as a sense of enjoyment, healing, security, support, and assistance (Jeon, 2009). People are likely to maintain their comfort zone precisely because it evokes a pleasant feeling. Conversely, to be uncomfortable is regarded as a highly undesirable state and something that should be minimised. In addition, to be uncomfortable in a social situation, such as wearing an unsuitable garment in a public space, may be different to the discomfort experienced from pain in the body. In other words, comfort is closely related to the sensual relationship of the body with its physical surroundings or physical interaction with objects, whether intimate or not. Comfort is also more than a specific physical state; it is coupled with psychological and sociocultural responses that create its own image and usage. Whilst comfort is a highly complex affective state, its definition, particularly in clothing, is a very important subject for emotional, physiological and psychological sciences in association with well-being (Jeon, 2010).

Vibration has numerous positive therapeutic applications, such as the improvement of bone density and muscle strength (Verschueren et al., 2003), the attenuation of delayed-onset muscle soreness (Lau & Nosaka, 2011), an increase of the speed of the blood flow through the body (Klima, Weigand, & DeLisa, 1991), and relieving and reducing pain by stimulating acupressure points on the body (Lundeberg, Nordemar, & Ottoson, 1984; Pomeranz & Berman, 2003). The relation between triggering pressure points by pressure and relieving pain is not entirely accepted by Western medical sciences. However, it is certain that there are subjective benefits for people who believe the technique will benefit them. Boyd (2011) present an overview of pressure points for people to practise at home. For example, activating the pressure points between the two most prominent bones at the top of the spine can have an influence on coughs, fever, flu, headaches, hives and rash, immune system, neck and nosebleed; similarly in the back waist area that relates to general and upper backache, haemorrhoids, hiccough, hypertension, nausea, sciatica, stomach pain, vomiting and retching.

PSS Description

Vibe-ing is a self-care tool for well-being in the form of a garment which invites the body to feel, move, and heal through vibration therapy (ten Bhömer, Jeon, & Kuusk, 2013). Through stimulating selected acupressure points on the body, the garment allows for subtle exploration and connection with oneself. The knitting and felting technique to produce the garment resulted in a soft and bulky surface. This surface invites the wearer to stroke and touch the fabric and the body, which could have positive effects on the subjective well-being of the wearer by providing comfort. The natural properties of the merino wool are related to the

Figure 2.11: Vibe-ing is a self-care tool in the form of a garment

Scan the QR code to see a video about Vibe-ing, scan the picture with Layar to see a video of the interaction.

Model in the picture: Jos van der Weele (TU/e), Photo by Wetzer & Berends textile comfort of the garment: they can regulate body temperature, have antibacterial properties, and feel soft. The garment contains touch-sensitive areas that stimulate selected pressure points on the body with vibration. Vibration on the body was chosen because of its positive therapeutic properties. By combining vibration actuators with touch-sensitive areas in the textile pockets, the design enables programming of the exact areas and type of stimulation on the body depending on the specific person's need for rehabilitation and healing. The therapist or doctor can co-create vibration patterns together with the patient: for example, a vibration pattern on the shoulder to treat neck pain, based on a ripple pattern (similar to a wave in the water or sound travelling through air). A vibration starts in the pocket touched by the person wearing the garment, and the vibration slowly transfers to the surrounding pockets, until it fades away after a certain period. Data which is generated by the garment is stored and can be used to adapt the vibration patterns during the treatment.

PSS Prototype
Vibe-ing has been produced using a fully fashioned knitting machine (shown in Figure 2.12). This technique allowed us to create digitally designed, pre-shaped pieces for the garment. The textile contains pockets in which circuit boards with sensors (touch sensors) and actuators (vibration motors) can be placed (Figure 2.13 shows the printed circuit boards that went into the pockets). Throughout the textile, power and communication lines are integrated that connect the pockets with each other. For the textile design we used two layered knitting and felting techniques to produce a textile with a voluminous shape, soft and bulky surface. In the garment design we placed the pockets to align with critical pressure points on the body (Figure 2.14 shows how the pockets align with the pressure points). Within the pockets we embedded specially developed casings which transferred the vibration to the skin (a collection of casings is shown in Figure 2.14). By rotating the garment (back to front, top to bottom) we can further stimulate pressure points on the front of the body, such as the hip area. Simultaneously, flexibility in wearing the garment in different ways enables different treatments with the same garment, limiting the amount of textile, electronics and energy.

This Smart Textile Service was developed by TU/e (Kristi Kuusk, Martijn ten Bhömer, Oscar Tomico and Jesse Asjes), TextielMuseum TextielLab Tilburg, and Metatronics.

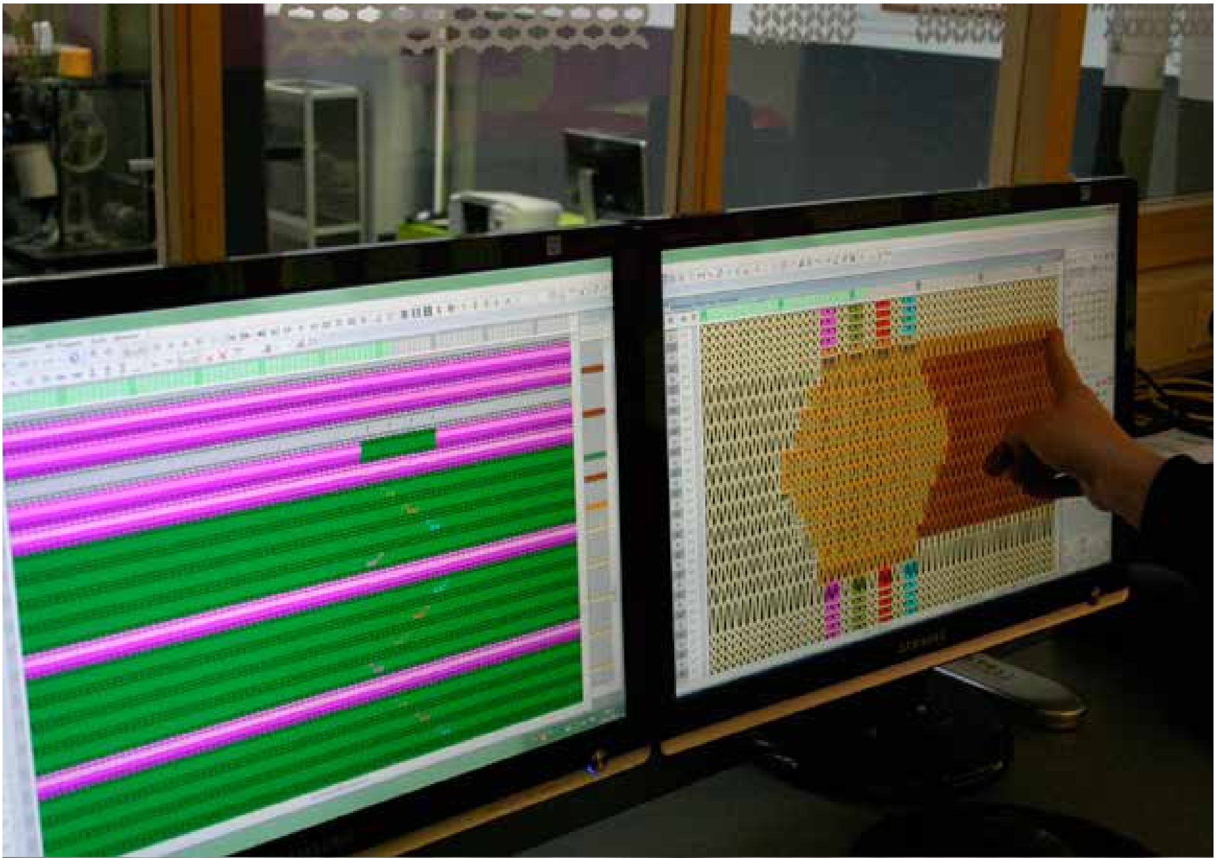


Figure 2.12: Part of the knitting programme for the fabric of Vibe-ing.

Figure 2.13: The fabric with conductive yarns to connect the printed circuit boards.

Figure 2.14: The pockets and casings match the pressure points on the body.

Figure 2.15: 3D-printed casings with soft parts and rigid pointy parts.

Service Interfaces

The customer journey of the Vibe-ing self-care service (Table 2.4) presents the exchanges between the patient and the various stakeholders involved, such as family doctor, medical sportswear shop, and the Vibe-ing company.

Service Interface 1: Annual health check-ups are offered as an additional service by hospitals. Together with the family doctor, a patient can decide to apply for an annual health check-up.
Service Interface 2: The patient is introduced to the self-care tool by the physician who proposes a change in lifestyle to improve the general health condition.
Service Interface 3: The patient visits the medical sportswear shop, where a physiotherapist measures the body and chooses the pressure points that can be treated based on the report from the physician.
Service Interface 4: In the same medical sportswear shop a specialist applies test vibration points on these pressure points to personalise the location and intensity of the vibration by creating vibration patterns.
Service Interface 5: After a certain amount of time the personalised Vibe-ing garment is produced and delivered back to the medical sportswear shop, where the patient picks the Vibe-ing up and, after an initial test procedure, starts to use the garment at home.
Service Interface 6: The patient can use Vibe-ing as a self-care tool at home alone or together with a partner or family member. The vibration leads the patient to explore the pressure points and find comfort in wearing the garment and in the interaction. The experiences can be logged in a booklet.
Service Interface 7: Once the patient starts using the garment the Vibe-ing platform is made accessible, where experiences and questions can be shared with other Vibe-ing users and experts can be consulted.
Service Interface 8: After a longer period of time using the garment, an appointment is made with a physiotherapist to analyse the progress based on the data from the garment, discuss the logbook, and prescribe potential adjustments of the self-care treatment.
Service Interface 9: After the vibration elements are removed, Vibe-ing can be washed at home, but for repairing damage an external service is still necessary.
Service Interface 10: A pick-up is also included in the service for when the garment reaches the end of its life cycle.

Value for the Stakeholders

Vibe-ing aims to contribute to the wearer's feeling of comfort and pain relief. The material of the garment and the interaction possibilities are the main enablers. Professional caregivers can benefit from the service because of the impact it can have on the preventive caregiving process. The patients are developing a more conscious relationship with their own body, which can reduce the effects of stress and pain. Furthermore, the connected garment allows the professionals to have more insights into the daily health patterns. The medical sportswear shop

Front end			Service Interfaces	Back end		
User profile	**What the user can do**	**Interaction supported**		**Interaction provided**	**What the provider offers**	**Provider profile**
Senior patient	Receive information, purchase service	Ask questions about service	(1) Buying annual medical check-up	Answer questions about care service	Personalised healthcare support	Family doctor
	Change lifestyle for recovering health	Discuss current health problems	(2) Visit hospital for medical check-up	Medical examination	Prescribe the self-care treatment	Physician in hospital
	Indicate preferences during measuring	Finding specific body pressure points	(3) Visiting medical sportswear shop	Analyse body shape and movement	Personalised treatment	Physio-therapist
	Test performance of electronics on body	Determine adequate vibrations for the body	(4) Testing pressure points and vibration	Analyse effect of vibrations on body	Placement of sensors and vibration motors	Medical sportswear shop
	Test garment performance and comfort	Receive the manual to use garment	(5) Receiving personalised Vibe-ing	Garment is handed over to user	Customised vibration patterns	
	Comfort and conscious about body	Self-care treatment at home during daily life	(6) Usage of the Vibe-ing self-care product	Instruction how to find pressure points	Log to report progress	Physio-therapist
	Connecting with people through the product	Find other people and discuss experiences	(7) Connecting with other people in community	Access to platform with other users and experts	Platform and experts to answer questions	Vibe-ing company
	Therapeutic non-invasive self-treatment	Discuss progress and analyse treatment	(8) After-usage service for Vibe-ing	Prescribes adjustment of self-care treatment	Health service monitoring	Physio-therapist
	Broken garment is given away	Give garment away	(9) Maintenance of Vibe-ing	Repair garment when broken	Garment is picked up	Vibe-ing company
	Broken garment is given away	Dispose of garment	(10) Recycling Vibe-ing on disposal	Pick up garment after life cycle	Garment is picked up	

Table 2.4: The Service Interfaces of Vibe-ing that show the interaction moments between user and service.

contributes by measuring and tailoring the garment to the individual. This type of service is a new category for these shops. Contrary to a purely medical tool, patients who use Vibe-ing are more self-motivated and willing to try other products and services that can contribute to their well-being.

Reflection on Embodiment
Vibe-ing allows practitioners to offer a therapeutic non-invasive treatment method to support both the physical and the psychological well-being of the patient (Service Interface 2). By introducing to the patient what pressure points are, and how to locate them on his or her own body, it becomes possible to discover which vibration locations and vibration intensities are most efficient (Service Interface 3). The garment can be personalised to the patient by using fully fashioned flatbed knitting techniques. This enables the garment to be produced in smaller quantities and customised to the user's needs, body shape, and aesthetic preferences (Service Interface 4). The garment is further personalised to the patient through the modular electronics system, which enables patients and caretakers to programme the exact areas and the type of stimulation on the body depending on their need for rehabilitation and healing (Service Interface 5). Whenever the patient is in need of comfort on his or her body, the garment can be touched or massaged by the patient or a family member (Service Interface 6). The Vibe-ing platform offers the possibility of sharing body-specific knowledge that the various users have built up through the usage of the garment (Service Interface 7). The service includes a body check-up after a certain amount of time, in which a physiotherapist evaluates the health of the person to recommend further treatment or adaptations to the garment. The vibration programmes can be updated to match new treatment settings (Service Interface 8).

2.6 Conclusions

At the beginning of this chapter I started out with the challenge that current services are still often driven from an information processing approach. However, textiles and healthcare disciplines are based on embodied approaches that take the corporal, social and situated characteristics into account: for example, the fabric hand for people coming from the textile world, and the focus on the bodily abilities and social well-being of the patients of medical practitioners. Based on the overview of current Smart Textile Service on the market, it became clear that many of the existing services are based on proprioceptive data measured by the smart textile component: this data is often represented using mainly visual representations. Many opportunities are emerging because of the large amounts of sensor data that can be collected from our body and environment; however, there is still not much integration between service, body, context and social environment. I concluded that, in order to realise Embodied Smart Textile Services, it is necessary to implement a tight coupling between digital data and the human body and to put focus on the context and social environment of the application.

Body-centred technologies can provide more meaningful and trustable feedback and thus allow us to perform more effectively and enhance our quality of life (Nunez-Pacheco & Loke, 2014). There have been ideas for investigating how these principles can be applied in services from the perspective of providing better bodily experiences (Sundström et al., 2011). In these embodied services an important issue is how digital information is linked to our perceptual-motor skills. To acquire bodily data there are a range of possibilities: for example, the use of physiological sensors to measure information such as heart rate, skin temperature, and muscle tension. On the other hand, proprioceptive sensors can measure dynamic movement such as orientation, position, and speed of joints or the whole body. In addition to the acquisition of bodily data, embodied services will be able to feed data back to the bodily sensorimotor system to trigger action: information for action. One characteristic of embodied services is the strong link with the context in which they are positioned. It is the context that will give meaning to the embodied action performed by the user. In embodied services, the Service Interfaces can be customised through digital applications and the innovative use of data, and personalised by means of tailored textiles. This customisation can enable the user to create personal meanings and form attachments to products (Niinimäki & Hassi, 2011).

The three Embodied Smart Textile Services presented in this chapter (Tactile Dialogues, Vigour and Vibe-ing) all use personalisation in order to achieve the link with the human body, context and social environment. For example, the material properties of Tactile Dialogues can be personalised to the environment of the specific organisation and context of the eldercare organisation and the interaction capabilities of the person interacting with the pillow. The Vigour cardigan needs to be personalised to the body shape of the person wearing it in order for the sensor areas to match the right body locations, and measure the right exercises for the specific treatment. The interactive behaviour of Vibe-ing can be personalised by changing the digital data input so that the vibration patterns match the needs of the wearer. The personalisation of the Service Interfaces was driven by thee main elements: personalisation through the material properties, the look, fit and feel of the textile object, and the use of digital data in the interaction.

Personalising the textile material properties

In the Tactile Dialogues Smart Textile Service the fabric that is used to create the pillow is knitted specifically to trigger certain hand movements from the person with dementia. For example, arrow structures trigger the user to move his or her hand forward, and stuffed rectangles act to trigger the person to use the fingertips to explore the fabric. Areas that are more filled have different tactile properties, allowing the person to pinch, stroke, and rub. In addition to the direct relation between the personalisation of the fabric and bodily behaviour, the programming of the textile material has a relation to how the interactivity is later programmed. For example, the arrows knitted in the fabric material also allow the vibration motors in these arrows to make a haptic pattern in the forward direction by alternating from one vibration to another. This haptic sensation can be used to personalise the interaction with the user, and in the end contribute to the development of an embodied language which works on the basis of perceptual-motor skills, rather than cognitive skills. This personalisation through the material properties can also be seen in Vigour, in which the material properties of the textile define how the fabric can be stretched. In Vibe-ing, felting the merino wool transforms the textile into a denser and more pleasurable fabric to touch.

Personalising the look, fit and feel of the textile object

In the case of Vigour, it is necessary to implement the movement sensors in the garment on exact locations on the body to be able to measure the movements of the rehabilitation exercises. By measuring the body shape of the person, the sensors can be better customised to the person, and also the overall fit of the garment can be tailored specifically to the person. Personalising the garment also has advantages for the aesthetics of the garment; it enables the user to feel more connected to the design and express their own identity through the garment, for example, by selecting colour and materials. These factors contribute to the comfort of the wearer, physical comfort as well as emotional comfort, which are factors that can lead to an increase in the subjective well-being of the person. Furthermore, this level of personalisation could also result in reducing textile waste compared to traditional mass production of textile garments. The textile needs to be produced only when it is necessary for certain applications. This personalisation in the design of the garment and object can also be seen in Tactile Dialogues and Vibe-ing, for which digital fabrication methods in circular knitting and flatbed knitting are used to adapt the design to the person using it.

Personalising the interaction with the digital data

In the Vibe-ing garment example, the vibratory actuators can be programmed to create a dynamic sequence reacting to body movement. The personalisation on this level enables the Embodied Smart Textile Services to link to the senses of the person during actual use. In the example of Vibe-ing, the personalisation of this interaction can be further customised by the user or together with a family member or expert. Through the interaction the data coming back from the service can be more directly related back to the bodily senses of the user. The vibration patterns in Vibe-ing can develop over time, as the expert changes the treatment or as new treatment possibilities are offered from a community of other people who wear a similar garment. In the example of the Tactile Dialogues service, it is possible to programme different mappings depending on the reactions of the patient, such as the mirroring behaviour or the vibration game. With Vigour, the user and therapist can choose between a direct mapping of sound (stretch to tone) or a more ambient volume feedback.

3.Scale of the project: How prototypes move the PSS that does not exist yet

3.1 Introduction

One of the challenges of designing Embodied Smart Textile Services is the difficulty to grasp what exactly is the object of design that is being designed. For example, once the Tactile Dialogues pillow was completed it was easy to see that one of the elements of the PSS was a pillow with certain material and interactive qualities. In contrast, it was harder to understand that the family members could personalise the behaviour of the pillow together with a motivational therapist to the abilities of the person with dementia. The PSS is often a combination of tangible and intangible aspects, knowledge distributed among stakeholders from often separate disciplines, and many different agendas originating from different contexts. Most likely the different actors involved in the design process even have different interpretations of what the object of design is. Therefore, rather than trying to pin down what the object of design exactly is for everyone, it is more interesting to ask the question how it can still move forward, even when it is such an ambiguous phenomenon. Moving forward implies more than just keeping the process running: it hints at a process where in each iteration more detailed questions are being asked, and in which over time the true value of what is being developed is discovered. This implies also a growing community around the object of design, because as the questions get more detailed new skills and expertise are necessary to be involved.In this chapter I will try to answer the following question:

> "How do prototypes support the bottom-up infrastructuring approach process that enables the design of the Service Interfaces to move forward?"

Research Approach
I will try to answer the question as set out based on autoethnographic accounts (Chang, 2008) from myself. I choose this approach because I want to show the richness that is captured through a first-person perspective on how the PSS was developed, with all the bias it entails. The main value of my being a designer as well as researcher is that I can trace back the origin of the design choices through materials such as notes, pictures, videos of design meetings, and my own memories.

More specifically, my focus is on investigating how the PSS grew and evolved: for example, by showing the evolution of the detailing of the PSS over time, tracing how new stakeholders brought in new expertise, comparing the goals we had between prototypes and the PSS and the interrelations between the stakeholders and prototypes. Autoethnographic account methodology supports such research objectives since its goal is also to interpret the author's own behaviour, as well as the thoughts and experience in relation to others in society (Chang, 2008), in this case my own accounts in relation to the stakeholders who were involved in the development of the PSS.

For the purpose of this study I will use the concept of the Service Interfaces to describe the object of design (the PSS). I will take an embodied perspective by following Secomandi's (2013) conclusion that it is in the interaction with the Service Interface (related to the body, and situated in a social context) that the service gives meaning to the users of the service. Designers can influence how the users and other stakeholders relate to the service by carefully designing the Service Interface. As a consequence I will focus particularly on the relation between the embodied prototypes (including the relation to the body, how it is situated in context, and the social elements) and the Service Interfaces.

Design Approach

Within Participatory Design an important trend is the move from projecting (or "design for-use, before-use") principle to infrastructuring approaches that can trigger "design after design" (Ehn, 2008). Projecting approaches focus on traditional problem-solving methods and normally start with defining a certain problem to tackle. An infrastructuring approach blurs the boundaries between use, design, implementation, modification, maintenance, and redesign (Karasti, 2014). As is the case in most design projects, instead of deciding upfront what the problem to solve is, the object of design grows because of the specific contexts, expertise and skills of the stakeholders who are identified and included in the process. For the Smart Textile Services project a specific infrastructuring approach was used: the *Growth Plan* (Ross & Tomico, 2009; Wensveen, Tomico, ten Bhömer, & Kuusk, 2014). Rather than a fixed methodology, the Growth Plan offered a reference that helped in creating the platform that would make the project move, and with managing expectations of the stakeholders. The CRISP Smart Textile Services project set out to explore how the three phases of Growth (Incubation, Nursery and Adoption) would come about in the process.

> "Incubation focussed on creativity, innovation and exploration. Important in this phase was that each stakeholder can input their current knowledge and innovation potential, which can then be combined and explored and combined into PSS's. The knowledge, approach and facilities within the test-bed support the creation of inspiring prototypes made of textiles and electronics. Typically, these prototypes are one-offs, or one m2 and 'tested' with one person. At the end of this phase the stakeholders jointly create the proper methods and tools to determine success criteria for the concepts. Successful concepts go to the second phase, the Nursery phase. Here concept testing, the implications of scaling up and the business opportunities are explored together with the partners. Most of these activities will take place within the test-bed. The prototypes in this phase need to be scaled up to tens, 10 m2 and tested with 10 participants. In the transition to the next phase prototypes of the concepts leave the inspirational test-bed, and continue to be evaluated in the eco-system, where industrial partners pick up and adopt the concept to continue within the phase of Adoption where value- and in-situ testing, manufacturing and the business implications are being explored."

Excerpt 3.1: Original description of the Growth Plan approach in the project proposal (Wensveen & Overbeeke, 2010).

An important consequence of the Growth Plan approach was the primacy of design right from the beginning of the project. For me this was a logical starting point, since the expertise that I brought to the table was my design skills and attitude. This also involved a prototyping approach where making and the dialogue with materials (textile, technology and service) became part of the equation. Based on this bottom-up approach, the PSS started growing and evolved as expertise and knowledge from stakeholders became necessary. The Growth Plan had further impact on the collaboration with stakeholders. In the Wearable Senses Lab (Tomico et al., 2014) I was most comfortable as a designer, having the tools and expertise at hand to hatch the initial prototypes.

Based on the embodied design approach, it only made sense that the stakeholders should also be situated from within their own context, and had their tools and expertise close. This also ensured that during the design process the context of the PSS was already embodied in the process. For example, a meeting with physiotherapists would be right next to the gym where Service Interface 7 of the Vigour Embodied Smart Textile Service would take place. This resulted in an approach where in situ reflection and collaboration during design meetings became important ways of working. Most of the design meetings involved a specific goal and only involved the people from one organisation: for example, a meeting with the physiotherapists and me to discuss the locations of the sensors to measure exercises. During the meetings the stakeholders were encouraged to bring their materials, tools and experiences to the table. For me this often meant bringing the prototype I had been working on from the Wearable Senses Lab to the stakeholders' location. Over time, the prototypes became more refined and the stakeholders started to contribute directly to the prototype: for example, with materials (a knitting producer developing a new fabric), with technologies (the electronics company developing a specific circuit) or conducting tests with the prototype (the eldercare organisation testing the Service Interface). The prototype became a capsule of past design choices and an embodiment of the developed PSS. This design approach is illustrated in Figure 3.1.

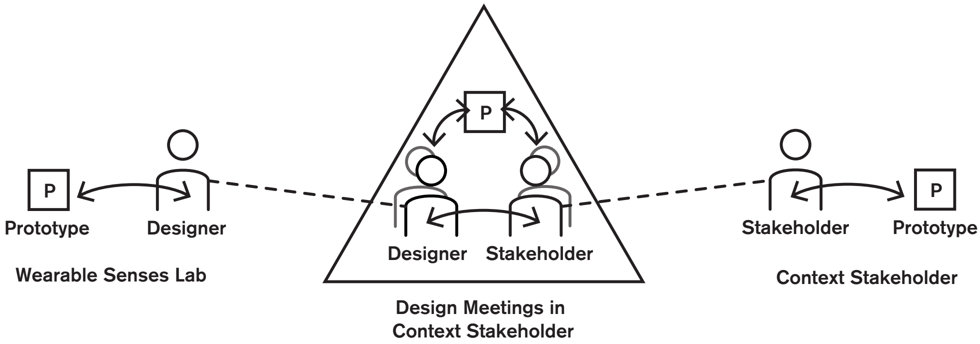


Figure 3.1: Model of the design approach in the process. The designer works with the embodied prototype in the Wearable Senses Lab. The designer and embodied prototype move to the context of the stakeholder, where a design meeting (triangle) takes place. In these meetings the embodied prototype, designer(s) and stakeholder(s) are present; the embodied prototype is part of the designer and the stakeholder, and takes a central role during the meetings. Just as the designer works with the embodied prototype in the Wearable Senses Lab, the stakeholders also interact with the embodied prototype before or after the design meetings in their own context, for example by producing materials, conducting tests or engineering technology.

Structure of the chapter

With this chapter I aim to investigate how the prototypes moved the development of the Service Interfaces over time. In the *Data Selection* section I will describe how I filtered the relevant data from all the activities within the longitudinal project. I will show a visualisation of this dataset to show the richness of all the prototypes, stakeholders, meetings and tests that played a role in the development of the three PSS's. In the *Data Documentation* section I will further zoom in on the description of the important prototypes that played a role in the development of Tactile Dialogues PSS. The aim here is to introduce an objective factual overview of each prototype. The *Data Codification* section introduces my autoethnographic insights and reflections per prototype. These reflections are structured based on whether changes in relation to the Service Interfaces occurred. In the *Data Analysis* section I use these reflections to induce clusters which give a higher level overview of how each Service Interface developed over time. In the *Findings* section, I will use the clusters to come to a set of three main insights of how the prototypes drove the process that enabled the PSS to emerge. Finally, in the *Conclusions* sections I will discuss the consequences of how these findings might impact design practitioners.

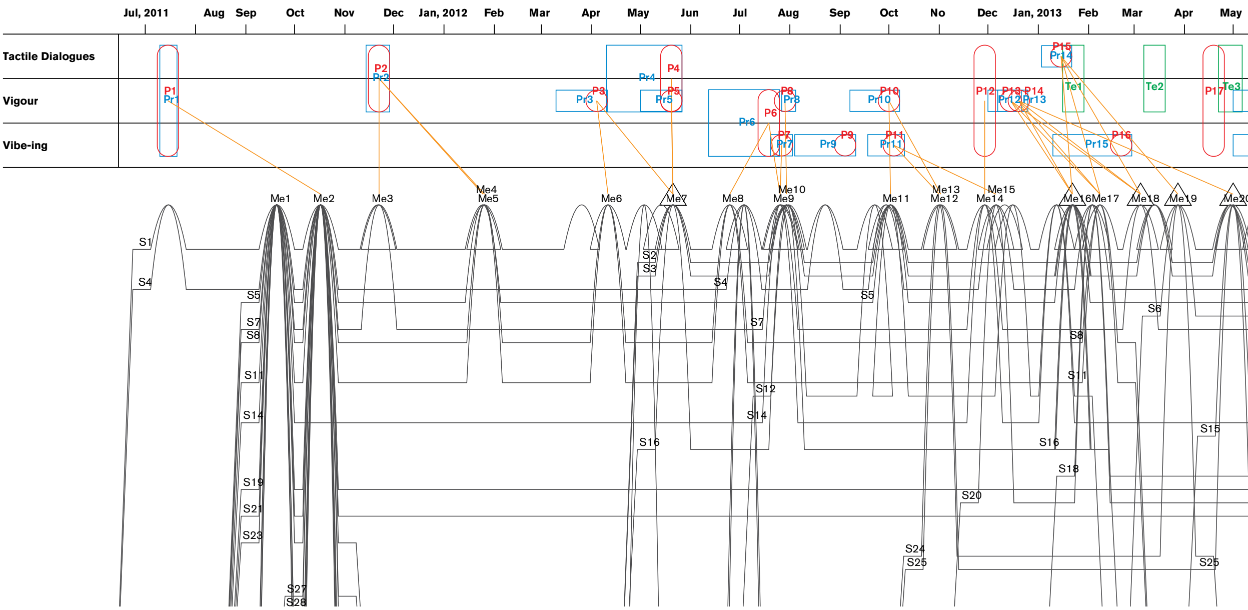


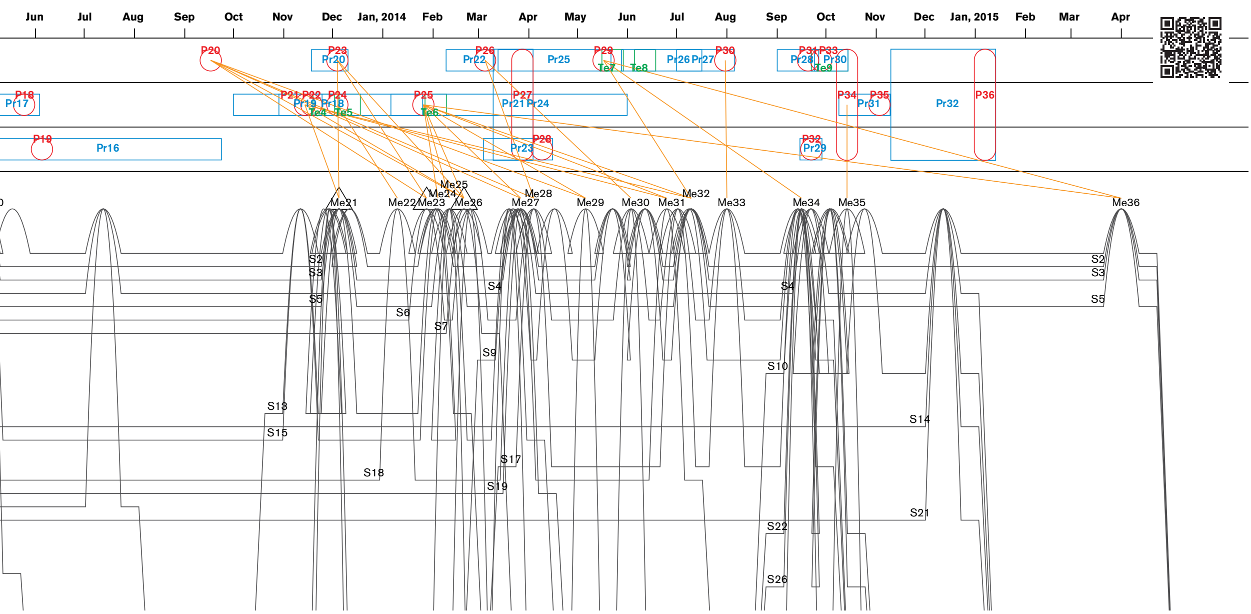
Figure 3.2: Scaled-down visualisation of the Design Process. Showing Prototypes (P), Meetings (Me), Prototyping (Pr) events, Testing (Te) events and Stakeholders (S). The full overview together with the tables that describe the data can be found in Appendix A.

3.2 Data Selection

The main goal of this chapter is to investigate the emergence of the Service Interfaces in relation to the chain of prototypes used in the process. To help finding patterns within the past four years of the development activities a visualisation was created that shows the relations between the artefacts (prototypes), the people involved (partners), and the events that occurred (development activities). Aided by this visualisation, I will shortly introduce the characteristics of each Growth Plan phase.

Process Visualisation

The Design Process Overview (Appendix A) shows the timeline that represents the development of the three developed Embodied Smart Textile Services (Tactile Dialogues, Vigour and Vibe-ing). Figure 3.2 shows a scaled-down version of the complete overview. The timeline shows the use of prototypes from the start of the project (July 2011) until the last event documented for this PhD thesis (April 2015). The overview is built up from three timelines: the top one represents the events that occurred when developing the Tactile Dialogues Smart Textile Service, the middle line represents the events of Vigour, and the bottom line represent the events that occurred for Vibe-ing. The red circles on the lines represent the moments that the Prototypes (P) were first used during the development. The blue rectangular boxes that precede the prototypes indicate the *Prototyping* (Pr) process to create the prototype. The green rectangular-shaped boxes represent the *Testing* (Te) events that were conducted with the prototypes.



Under the timeline the design *Meetings* (Me) are visualised. Some meetings have a triangle around them: this indicates an important meeting. The selection of these important meetings and the analysis of them will be further discussed in the next chapter (Collaboration). The lines connecting the Prototypes with Meetings indicate the relations, meaning that the Prototype was present during the Meeting. Under the Meetings the lines representing the *Stakeholders* (S) are visualised. Every line represents a Stakeholder, the moment the line originates in the bottom of the figure indicates the moment when the person became involved, the line moves away back to the bottom after the last moment the person was involved. Through these larger lines it is possible to get a general idea about when people became involved, for how long, and when they left the process again. The dents of the line towards the timelines show the involvement of the Stakeholder in the process. This can be during a Meeting event, Prototyping event, or Testing event. The goal of this visualisation is twofold. Firstly, I present it to show the richness and complexity of the development process to the reader. Secondly, it helped me as a research tool to make a relevant selection of the personal autoethnographic reflections that were necessary for this chapter.

To come to the process of visualisation as shown in Figure 3.2, a set of selection criteria were needed to filter the most relevant elements. With the first selection criteria I checked whether I was present in the meeting and had logged the activity (for example, in a notebook or in my calendar). In total I was involved in 542 activities that were related to the development of the three Embodied Smart Textile Services. These activities included workshops, prototyping sessions, tests, presentations, teaching activities, meetings with partners or networking events. To further narrow down this selection, two other criteria were introduced: firstly, within the activity a prototype was present; and secondly, the activity was between me and at least one other stakeholder. Based on these criteria, a shortlist of 77 activities was created consisting of 36 meetings with partners, 32 prototyping events, and nine testing events with end-users. Related to these activities, 36 prototypes and 48 stakeholders were involved. All the tables that show these items are also shown in Appendix A. It should be noted that, as a result of this filtering, some events that might be important for managerial purposes are not included in the dataset: for example, a larger meeting with one of the textile production partners in which we discussed the number of hours that would be spent on the project. During this event there was no prototype discussed and no important design decisions were made; however, it was important for being able to continue with the project. Not taking these types of meetings into account can be justified since this chapter focusses on the design process related to the Service Interfaces of the Smart Textile Services.

Phases

Before discussing how the prototypes supported the bottom-up infrastructuring approach (operationalised through the Growth Plan) I will first discuss the three phases of the Growth Plan in more detail. The descriptions of the key characteristics of the phases (Ross & Tomico, 2009; S. Wensveen et al., 2014) are illustrated with examples of the design processes of the three Embodied Smart Textile Services.

Incubation: In this first phase, personal creativity, material innovation and conceptual curiosity are central. The approach is characterised by 'learning through doing', and the focus is on the diversity of the design space of integrating textiles and computing and developing quick iterations of prototypes. The Wearable Senses Lab supports this process with facilities through tools that support both personal hand crafting and rapid prototyping. While the hand crafting supports material engagement through a slow process, the rapid prototyping allows for fast iterations of technical feasibility. Typically, the resulting prototypes range from the productive to the pointless. The design result of this phase consists of early prototypes, typically one-offs, or one stretching meter, and are evaluated through informal design critiques. In this phase it was mainly about learning and understanding the different areas necessary for the development of Smart Textile Services. Exceptions were the two kick-off meetings of the project (Me1 and Me2), which aimed to share the expertise of all the stakeholders in the project (Figure 3.3). The meetings with other stakeholders were mainly used to find direction, and to confront each other with different ideas (for example, in the meeting with the physiotherapists, Me7, shown in Figure 3.4).

Figure 3.3: The first workshop organised with all the stakeholders who were part of the consortium.

The prototypes in this phase aimed to explore the design space of combining textile and technology. The service context was broad and covered topics such as sport and rehabilitation. The prototypes were mainly examples for myself, to get to know what the materials mean, to know the variables such as fabric, touch and structure, to understand the techniques, and to know the limits of each technique (for example, sewing the Music Fabric, P2, in Figure 3.5). Existing technology was used for easy prototyping. During Incubation, most of the prototypes (P1 to P15, with exception of P6 and P12) were created inside the Wearable Senses Lab with the help of internal stakeholders such as S4, S12, S13 (Figure 3.6 shows the workshop setting of the Wearable Senses Lab). At the end of the phase, important decisions were made, such as the focus on knitting as a textile-processing technique, creating a customised electronics platform that aimed to combine sensing and actuation, and narrowing down the aim of the Smart Textile Services to support people with dementia in eldercare rehabilitation. At the end of the phase we tested (during T1, T2 and T3) Tender (P11, shown in Figure 3.7), Vigour v1 (P14, shown in Figure 3.8) and Blanket (P15) in their context with the help of stakeholders from the eldercare organisation.

Nursery: A ‘Nursery’ is an environment that allows testing with participants, and is equipped with a range of measuring devices and facilities for empirical

Figure 3.4: Design meeting Me7 with the physiotherapists, prototype Knee Band on the table (P5).

Figure 3.5: Constructing Music Fabric (P2) using techniques such as thermal bonding, embroidery, applying snaps, stitch-locking and sewing.

Figure 3.6: Wearable Senses Lab setting. Photo by Oscar Tomico.

Figure 3.7: Tender, an interactive, touch–sensitive, illuminated garment (P11).

Figure 3.8: Vigour v1, motivating patients to do geriatric rehabilitation exercises through sound (P14).

research. Such a space also allows fine-tuning of a system to the specifics of its context. In this phase, commitment, co-crafting and confrontation are central. The approach is characterised by 'scaling up and stepping out' to build credibility with and within a larger creative community. The tools in this phase are both in, and outside, the Wearable Senses Lab and support scaling up, participatory innovation, and in situ evaluation. The prototypes in this phase are developed to be scaled up from the one-off to multiple copies or stretching meters and tested with multiple participants. A larger creative community is built by giving it access to the new materials, concepts and prototypes that were initially developed in the previous phase. Issues of sustainability, whether environmental, social or economic, come to the foreground in this phase. In the Nursery phase I started together with other stakeholders to embed the PSS's further in the context. The prototypes needed to be more robust to be able to test the PSS for a longer time. To realise this, more stakeholders became involved in the process: for example, a fashion designer (S15) for the development of Vigour PSS (Figure 3.9 shows the fashion designer explaining the design), a textile designer (S6) for the development of Tactile Dialogues PSS (Figure 3.10 shows the roll of fabric that was knitted in order to develop Tactile Dialogues v2, P29), and a researcher specialised in embodied interaction for Vibe-ing (S20). Other production stakeholders became involved in the process, for example for the development of the knitted textiles (S18, S24 and S25). Figure 3.11 shows the textile developer (S18) working on the fabric for Vibe-ing (P19). The technology stakeholders scaled up the CRISP modules platform (P17), and a first batch of 500 modules was produced by S7, S43 and S47 (Figure 3.12 shows some of the motor type CRISP modules ready to be integrated in the Vibe-ing fabric). My role shifted more to driving the projects forward, meeting the stakeholders regularly, working closely together and integrating the separate parts into coherent prototypes. This phase was characterised by many iterations of testing (T4 until T8), prototype

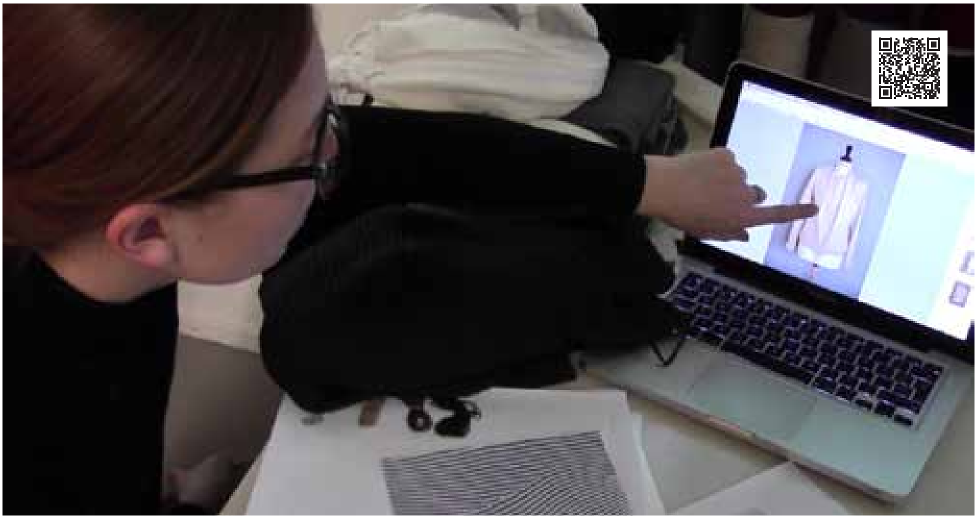


Figure 3.9: Fashion designer (S15) explaining the design of Vigour v2 (P25).

Figure 3.10: Fabric for Tactile Dialogues v2 (P29), developed by textile designer (S6).

Figure 3.11: Textile developer (S18) knitting the textile for Vibe-ing (P19).

Figure 3.12: Some of the CRISP modules v2 (P17) with vibration motors added for integration in Vibe-ing.

development and meetings in order to develop the PSS's further. P16 to P29 are examples of the various iterations within the three PSS's. Examples of developed prototypes in this phase are Vibe-ing (P19), Vigour v2 (P25), Vigour iPad Application (P21) and Tactile Dialogues v2 (P29).

Adoption: In this phase exhibition, exposure and entrepreneurship are central. The approach is characterised by 'show off and tell' and 'creating value'. The tools in this phase support documentation and dissemination for various audiences, ranging from the general public to academia, funders, investors and companies. The goal is to show the innovative potential of the combination of textile, interaction technology and service design. The communities involved are also adopting the

Figure 3.13: The new version of the CRISP modules, based on a flexible PCB connecting the modules, right: screenshot of the community forum where the software was open sourced.

Figure 3.14: Exhibition of all results from the CRISP project in TextielMuseum Tilburg.

concepts and start caring for them outside the Nursery environment. Demonstrating the prototypes through exhibitions, videos and stories in local, national and international media is also building up societal awareness and public sensibility of what smart textiles services could mean. This is going to be a long process, as often the concepts and their market are quite novel and underdeveloped. In the transition from the Nursery phase to Adoption, the stakeholders involved started to take over responsibilities in the development of the Smart Textile Services. Tactile Dialogues v2 (P29) was used by the eldercare organisation for a longitudinal study with their clients (T9) (see Schelle, Gomez Naranjo, ten Bhömer, Tomico, & Wensveen, 2015). They involved a different department for testing the prototypes, which required new employees on different levels in the organisation to be convinced. The CRISP modules iterated into a new version of the modules which has been distributed to 2000 visitors of a technology fair in The Netherlands, shown in Figure 3.13 (P35). This step was mainly driven by the technology stakeholders (S43 and S47). Prototypes of the Vigour Smart Textile Services are taken into the permanent collection of the Technology Museum in Vienna, and into thematic exhibitions in the TextielMuseum in Tilburg (the exhibition in Tilburg is shown in Figure 3.14). The textile designer (S6) and I continued to collaborate on projects and developed prototypes such as P26 and P31 (Figure 3.15 shows results of this collaboration). These have been presented during various design events, and elicited many responses from press and other societal channels. My role changed with most of these evolutions as I was not in the driver's seat anymore, but rather involved as stakeholder with specific smart textile design expertise. Examples of developed prototypes in this phase are BB.Suit (P26), BB.Suit Clean Air (P31) and Well-be (P32).

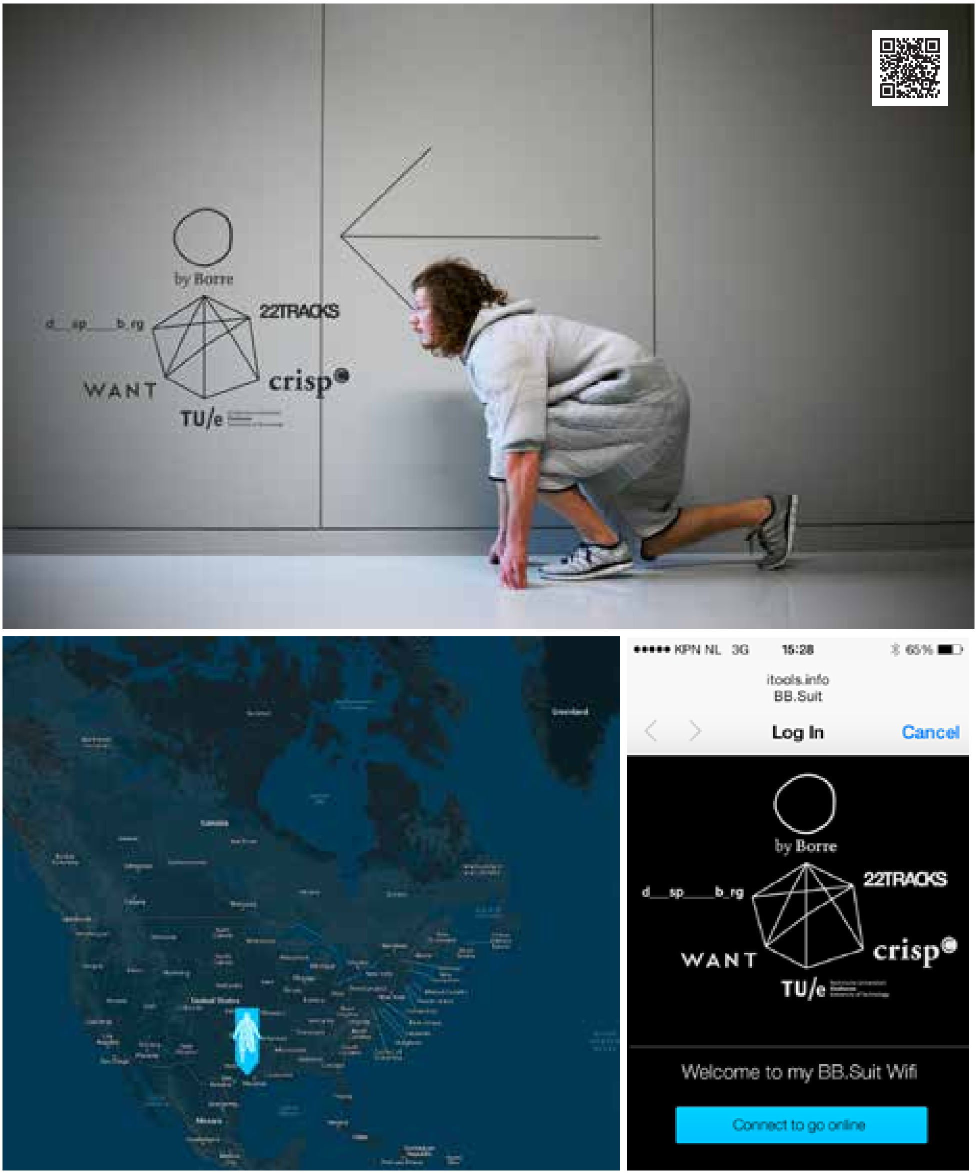


Figure 3.15: Various elements from the BB.Suit project (P26):

Top: the BB.Suit and all the partners.

Left bottom: the location of the BB.Suit could be tracked on a website.

Right bottom: the BB.Suit emitted a wifi hotspot, and the corresponding pop-up showed project information.

3.3 Data Documentation

Having a bird's-eye view of the data through the visualisation presented in the previous section, I will use this chapter to go into more detail. The goal of this chapter is to investigate how prototypes support the bottom-up infrastructuring approach process that enabled the design of the Service Interfaces to move forward. In order to answer this research question I will focus on the Tactile Dialogues Embodied Smart Textile Service. Tactile Dialogues followed a similar development pattern as Vigour and Vibe-ing. The difference is that the process went one step further in the Adoption phase, because the project was used as a research carrier to test the effects of personalised vibratory behaviour.

In this chapter I will present an overview of the eight prototypes that played a role in the development of Tactile Dialogues PSS. I acknowledge the possibility of cross-pollination between the prototypes of the different Embodied Smart Textile Services, because they were developed in parallel. However, an analysis of these parallel processes is outside the scope of this study. For each prototype I will give a description, discuss the prototyping process, the tests which were conducted, the meetings in which the prototypes played a role, and the people who were involved, and the goals I had with the prototype.

P1: FeltBall

Description	FeltBall is an exploration where a textile technique (felting) is combined with integrated hard technology (LED, battery, movement sensor). The integrated lights would react to movements of the FeltBall: for example, turning it upside down, shaking it, throwing it.
Goals of the prototype	The goal of FeltBall was to experiment with a collaborative approach between two people coming from two different disciplines: Kristi (S4) with her background in fashion design, and me (S1) with my background in Industrial Design. By making a prototype, without a clear plan upfront, we tried to share our skills and see where it would take us.
Prototyping	A craft approach inspired by the combination of our skills. I learned how to felt wool fibres and crochet a tube, in exchange for my explanation about sensors and programming (Pr1).
People	Design Researcher (S4) and Design Researcher (S1, myself).
Meetings	The prototype was shown during the "Golden Egg Workshop" (Me2), with a goal to show a possible direction to work on with other stakeholders.
Testing	Informal design critique within the team.
Insights	An insight from this prototype which inspired myself was the playfulness and flexibility of textile as a material. The soft properties immediately invited squeezing, throwing or stroking: interactions that other materials would not allow. This was also an important reason to introduce playfulness and interaction as themes within rehabilitation. Simultaneously, through this prototype I became aware of the possibilities to actuate the textile with data from external sources, in this case the light reacted to movement data.
Personal reflection	The approach was very new for me: I did not have previous experience with crafting textiles. Additionally I did not feel very confident about starting a project based on a prototyping approach, without having a clear design concept beforehand.

Table 3.2: Properties of the FeltBall Prototype.

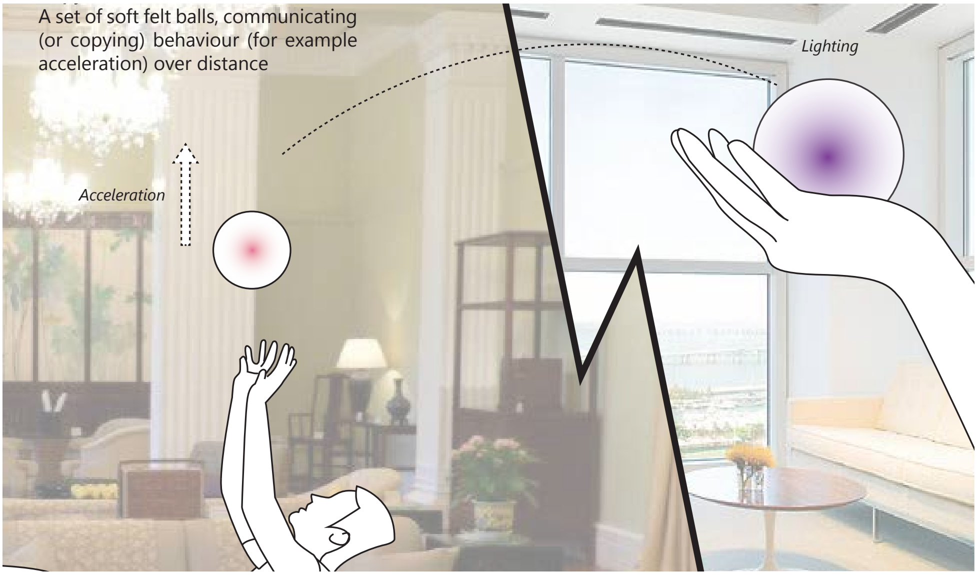


Figure 3.16: Impressions of the FeltBall prototypes.

Figure 3.17: Impressions of the Music Fabric prototype and making process.

P2: Music Fabric

Description	Music Fabric is a piece of fabric with pressure sensors that control a mobile phone application playing music samples. By putting pressure on the different areas of the fabric, certain instruments could increase in volume. For example, touching the top part would let the rhythm increase in volume.
Goals of the prototype	Music Fabric was developed as an example of how sound and smart textiles can be combined to trigger physical movement of people interacting with the textile. At the same time the goal of creating the prototype was for me to become acquainted with textile techniques such as laminating and building pressure-sensitive surfaces.
Prototyping	Experimenting in the Wearable Senses Lab with different textile techniques such as laminating and embroidery, combination with technologies such as piezoresistive materials and wireless connections. Furthermore, the prototype included an application on a smartphone that mixed the different soundtracks based on the pressure (Pr2).
People	Design Researcher (S1, myself).
Meetings	Meeting with engineer (S7) about the pressure-sensitive capabilities of the fabric that they can use in curved surfaces (Me3). Discussion about the business opportunities of Smart Textile Services (Me5) with business developers (S8 and S11).
Testing	Personal reflection, testing the prototype myself. Informal design critique with several stakeholders (S7, S8 and S11).
Insights	The prototype triggered discussions about the next step to take with both the engineer and the business developers. From the engineer I learned that soft sensors also have value for non-wearable applications: for example, to measure touch or deformation of objects with curves. From the eldercare organisation I learned that it is important to get the material properties right: comfort is very important in their context. From a service point of view, this prototype showed the possibilities of adapting the digital layer (the sound that was played) after the prototype was developed and inspired ideas about personalising the sounds to different users.
Personal reflection	An important lesson for me was about learning the value of sharing a prototype which is not finished. As a designer I was used to mostly sharing prototypes that have a certain level of finishing. However, in the case of meeting the engineer this prototype triggered a lot of unexpected responses. Based on the feedback from the eldercare organisation, I learned that it is very important to be confronted with the real context as early as possible in the process, to be able to build directly on early feedback.

Table 3.3: Properties of the Music Fabric Prototype.

P4: Touch Sleeve

Description	Knitted textile with lines of conductive yarns in the shape of a sleeve, when worn around the arm touches on the arm will react in changes in a visualisation that is displayed on a screen.
Goals of the prototype	Touch Sleeve was the first experiment in developing a fabric of my own design. We focussed on knitting, because of the stretchability and comfort of wearing it on the body. The goal of the prototype was to show an approach to rehabilitation where physical touch was an important element and could be used to stimulate patients during group activities.
Prototyping	Using a flatbed industrial knitting machine to create fabric with conductive yarn, sewn into the shape of a sleeve to make it wearable. Development of an electrical circuit to measure touch and wireless communication to send to display device (Pr4).
People	Knitwear Student (S44) and Design Researcher (S1, myself).
Meetings	Demonstrated during meeting with physiotherapists from eldercare organisation (Me7).
Testing	Informal design critique with several stakeholders (S2, S3 and S16).
Insights	Discussions triggered by this prototype during Me7 were a direct link to design of the next prototype, Blanket (P15). Especially the ideas of light and colour reacting to touch triggered by the tactility of textiles, were elements that could be very interesting for developing a product for people with dementia.
Personal reflection	During the prototyping process of the fabric I learned an important lesson about collaboration. When making the previous prototypes (FeltBall and Music Fabric) I tried to understand the other discipline, and really make their disciplines my own. During this process I realised that a technique such as knitting would take years to reach a level that would allow me to use it in a creative process. In this case I trusted the skills and knowledge of the knitting expert (S44), and did not try to get to the same level.

Table 3.4: Properties of the Touch Sleeve Prototype.

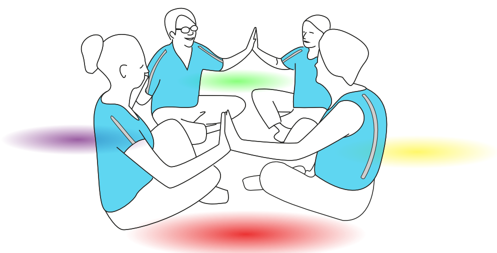


Figure 3.18: Left, an impression of how the touch-sensitive material could elicit colours during an activity, right: the material that was created with the conductive yarn knitted into the fabric.

P12: CRISP Modules v1

Description	Set of modular electronics with own processing chips, making it possible to use them for locally integrating functionality such as light, sound, movement and heat in smart textile prototypes. Can be programmed using existing Arduino hardware, leveraging it as a prototyping tool for students and designers.
Goals of the prototype	The modules were initially developed to integrate functionalities on the location of the body where you need it. Furthermore, the goal was to bring sensing and actuation closer together by combining the two in one module.
Prototyping	After initial prototypes created in the Wearable Senses Lab, the engineering company developed and produced a set of the modules to be used in future prototypes.
People	Engineer (S7), Design Researcher (S1, myself).
Meetings	Discussing and evaluating the CRISP modules (Me14).
Testing	Informal design critique: discussing and evaluating the modules during Me14 with stakeholders S4 and S7.
Insights	Based on the first iteration of the modules, we realised that there were still a lot of points that could be improved: for example, a programming library that made it easier to set up the communication between the modules. There were also challenges that would require substantial re-engineering. For example, we realised the connectors were not very practical to use in combination with textiles. Furthermore, we learned that the combination of sensor and actuator was a very strong principle because feedback loops could be created. For example, on a module with an LED there should also be a light sensor. On a module with a vibration motor, there should also be an accelerometer. The idea of programming this feedback loop through the use of external data from service providers inspired us to adapt the behaviour of a product to the bodily capabilities of the user.
Personal reflection	The modules were based on the design of an earlier electronics board (P9) that I developed for the Tender prototype (P11). Initially it was hard to give this part of the process away, because part of me would love to keep developing the electronics further. Another challenge that surfaced was the collaborative process between the engineers and me. On the one hand, I had a clear idea of the electronics that needed to be developed, but on the other hand, I wanted to keep the collaboration as open as possible so that the engineers could bring in their own expertise and interests. Unexpected solutions, such as the design of a shield that could be used to programme the modules, were very valuable and required a more open approach.

Table 3.5: Properties of the CRISP Modules v1 Prototype.

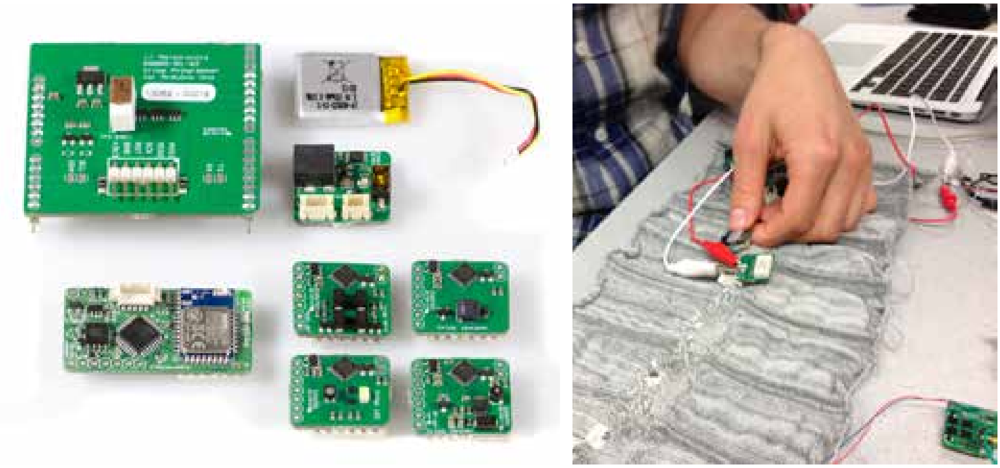


Figure 3.19: The complete set of CRISP modules Printed Circuit Boards (PCB), with the programming module, battery, power PCB, Bluetooth PCB, motor PCB, sound PCB, light PCB and heating PCB. right: using the CRISP modules during the prototyping of Vibe-ing (P19).

Figure 3.20: Blanket (P15) prototype. The bulky pockets (touched by the hand) contain the different actuators, such as vibration, light and sound. The seam on top of the pocket is sewn with conductive yarn, and is able to measure touch through capacitance.

P15: Blanket

Description	Blanket is a textile object that reacts to touch with different stimuli, such as light, sound and vibration. Integrated were six capacitive touch sensors, six vibration motors, two LEDs and one speaker. When one side of Blanket was touched, Blanket would react with vibration in the side where it was touched, and in the other side where the other person has their hands. When touching for a duration of three seconds, the intensity of the vibration increased, the lights started blinking and the speaker started to make a small sound.
Goals of the prototype	Blanket was an exploration of how different stimuli, triggered by touching the fabric, would activate people with dementia. Actuators such as light, sound and vibration were therefore integrated in the fabric. An interactive element was added based on the principles of reciprocity, coordination and resonant interaction (Giusti & Marti, 2011). This would translate the touch of the hand on one side of Blanket to a reaction on exactly the other side of the fabric. The idea behind this was that family members could trigger light, sound or vibration, and with this get a new type of activity with the person with dementia.
Prototyping	Experiments with new techniques that would enable the larger components to be hidden in the textile. For example, tunnels were created to guide the conductive yarns, and on specific points in the tunnels padding was placed to embed the sensors and actuators. The fabric itself was an existing knitted piece of textile with contrasting colours (grey and white) and with decorative elements that could be used to create the tunnels. By using a mix of the first STS modules produced by Metatronics (P12), and our own first version STS modules (P9), a network was created with six touch sensors and nine actuators. Using two communication lines and two power lines, all the modules could be individually controlled by a master module to define the interaction behaviour (Pr14).
People	Textile Student (S12), Design Researcher (S1, myself).
Meetings	Blanket has been used in discussions with stakeholders from the eldercare organisation (Me16) to evaluate the business proposition (Me17), with the engineer to evaluate the use of the modules (Me18), and with the textile designer and production partners to discuss a new prototype (Me19).
Testing	Tests with five pairs of people with dementia and caregiver to find out whether people with severe dementia could be stimulated by visual, auditive or tactile stimuli. And to investigate whether Blanket makes it easier to communicate with the person with dementia (T1, T2 and T3).
Insights	Conclusions of the test were that the training for the caregiver was of vital importance and that the stimuli needed to be improved to be better adjusted to the person with dementia. During the meetings with the eldercare organisation we realised that the stimuli were too subtle for many of the people with dementia. Especially light and sound were in this integration almost not perceived. Also the size and weight of the Blanket were not ideal. To use it in social situations a larger object would be easier to put on the legs, and an increase in weight would benefit the person with dementia because of the constant pressure.
Personal reflection	I started to feel confident about the project starting from this iteration. Context, technology and textile came together. The prototype became robust enough to be experienceable, even without me necessarily there. In other projects this could have been a moment to transfer the project to other people: for example, to test it further for academic purposes. However, in this case we relied on the expectation set out by the Growth Plan approach. As a community we were not satisfied yet with this state of the prototype. We realised that the strength of this Embodied Smart Textile Service was in the details, and for that we needed to have more control over the material and production processes.

Table 3.6: Properties of the Blanket Prototype.

Figure 3.21: (left) the construction of Blanket showing the vibration motors; (right) one of the light actuators.

Figure 3.22: Blanket tested with a physiotherapist during one of the tests (T3).

P23: Tactile Dialogues v1

Description	Pillow created from circular knitted fabric with conductive yarns, to sense capacitive touch and conduct power. The vibrator motors are integrated in small, 3D-printed casings in the fabric, the modules are placed under the top layer and connected in a network.
Goals of the prototype	The development of Tactile Dialogues v1 was mainly triggered by the curiosity to scale up the production of the fabric by collaborating with the textile producer (S24). Furthermore, the goal was to explore how different conductive yarns with two different functionalities (conducting power and measuring touch) could be integrated into the fabric directly during the production process.
Prototyping	Experiments with the textile producer to create a fabric where the different conductive yarns were integrated into the fabric. Because of limitations of the machines, the design was limited to a grid of squares, large enough to hold the vibration motor with casing. Different versions of the casings were made with different properties, such as stiffness and structure. Through these explorations we experimented with different sensations of the vibration. The fabric was combined with an existing fabric created by the textile designer, and sewn in the shape of a large pillow (Pr20).
People	Textile designer (S6), Textile Producer (S24), Textile Student (S29), Industrial Design Student (S48), Design Researcher (S1, myself).
Meetings	Tactile Dialogues v1 has played a role during discussions with various stakeholders to evaluate the prototype, stakeholders from the eldercare organisation (Me21), a meeting with the textile designer (Me23), and a meeting with the engineer (Me26).
Testing	Discussing and evaluating the modules during Me21, Me23 and Me26.
Insights	We realised that the communication between the modules was not as easy as initially thought. We had problems because the conductive yarns influenced the signal quality, and decided to go back to normal stiffer electrical wires for the communication. At the same time the physiotherapists and manager from the eldercare organisation were very critical about the fabric and shape of the prototype. The interactivity could not be demonstrated clearly, and the object lacked a clear language that defined the interaction.
Personal reflection	This prototype was developed in a two-step process. Firstly, I discussed and devised together with the knitting producer a pattern for his machines. By exchanging information we came to a programme for the machine; however, it was mainly focussing on the technical requirements. Here I felt I lacked the in-depth knowledge that could help me to work more creatively with the constraints. In the end we realised a test fabric that achieved most requirements, but it was lacking material and aesthetic qualities necessary for the context. In parallel to this process I started talking with a textile designer (S6) to collaborate on a next iteration of the design of Blanket. This was a large step, since it was the first time I acknowledged that more specific design knowledge was necessary to create the prototype. The designer's knowledge about textile design helped us to bring the technical test to a more aesthetic result.

Table 3.7: Properties of the Tactile Dialogues v1 Prototype.

Figure 3.23: Tactile Dialogues v1 (P23) during an interaction session. The squares within the fabric contain the 3D-printed casings and the vibration motors. In the squared fabric itself, the touch sensors are also knitted into the fabric.

Figure 3.24: Left, several test pieces of fabric that have been knitted in the process to come to the final fabric. Right, exploration of several casings to contain the vibration motors within the fabric. The different surfaces on top aimed to explore different tactile sensations.

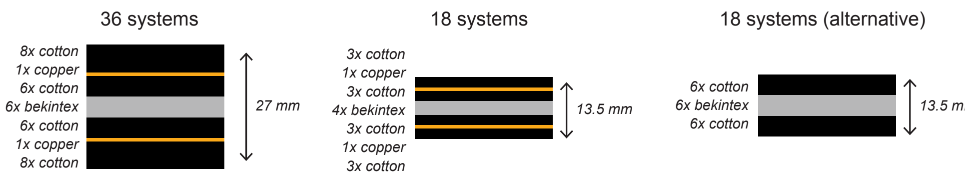


Figure 3.25: In order to communicate with the knitting developer, we worked with different representations of the fabric to knit: for example, these three options for different combinations of conductive yarns for machines with different needle configurations.

P29: Tactile Dialogues v2

Description	Tactile Dialogues is a textile pillow that can react to touch with vibrotactile stimuli and haptic sensations. The fabric of the pillow contains several different areas with touch surfaces. For example, a thick layered fabric would trigger plucking movements, and ridges in the fabric would trigger rubbing with the hands. The vibration elements are integrated in 3D-printed casings with different shapes, to elicit different touch sensations: for example, a circular-shaped casing that could be squeezed, and an arrow-shaped casing that pointed in a certain direction.
Goals of the prototype	Tactile Dialogues is designed to stimulate movement and interpersonal contact for patients in the late stages of dementia, their family members and their caregivers. The goal of this prototype was to create an aesthetic combination of the electronics and tactile structure of the textile.
Prototyping	A pattern was created with the goal to trigger a range of different hand movements. This pattern was knitted with a more advanced circular knitting machine that was able to create the complex pattern. Instead of integrating the conductive materials during the knitting process, we decided to integrate these as a step after the textile production. In the outer layer of the fabric, conductive fibres were felted together, making them work as pressure sensors. Special casings with different shapes were created to contain the vibration motors and pressure sensors, and these were integrated in the outer layer as well. In the inside of the pillow a layer was created which contained the modules and power (Pr27).
People	Textile designer (S6), Graphic Designer (S30), Industrial Design Student (S9), Design Researcher (S1, myself).
Meetings	The working version of Tactile Dialogues has been mainly used in meetings with the eldercare stakeholders (Me32, Me34 and Me36).
Testing	To develop this prototype, several tests (T7, T8) were necessary to test the different integration possibilities of the vibration motors. In between the tests the prototype was further refined and stabilised.
Insights	During the different tests we found that the adaption of the vibration is important for people with dementia. We saw some people immediately became less tense when using the pillow, and just enjoyed the vibration, while other people became activated and followed the vibration as a game. Another insight was that the prototype was not stable enough for real-life situations. Because the prototype looked like a finished, textile pillow, people used it that way: for example, pushing it and bending it. We realised that this will always be the case with such products, and that it is important to bring it into the design process rather than work against it.
Personal reflection	To develop this prototype, the textile designer (S6) and graphic designer (S30) had to take control about the direction of the aesthetic look and feel of the pillow. An example is the graphic representation of a button that the designer introduced in the middle of the object. For him, the button signified strongly to the world that this was an interactive smart object. For me, creating a representation of a button went against an embodied approach where I wanted to create a richer interaction than just pushing buttons. In the end we decided to use the design, since this is part of bringing in different perspectives. It taught me that in collaborative processes balancing control and possible approaches is part of the process.

Table 3.7: Properties of the Tactile Dialogues v2 Prototype.

Figure 3.26: The Tactile Dialogues v2 (P29) fabric.

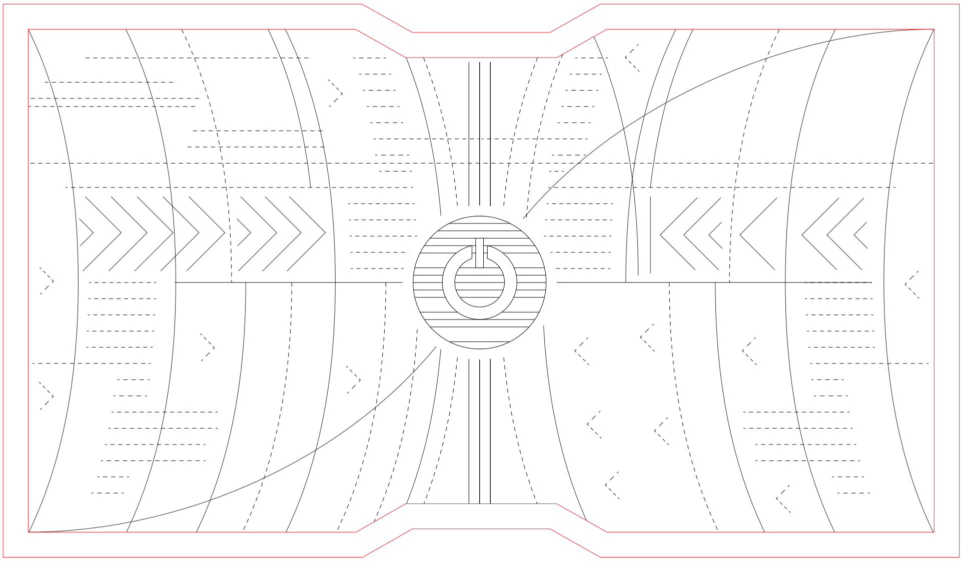


Figure 3.27: The graphic pattern (designed by graphic designer S30) which formed the basis for the knitting programme to develop the fabric. llustration by Daan Spangenberg.

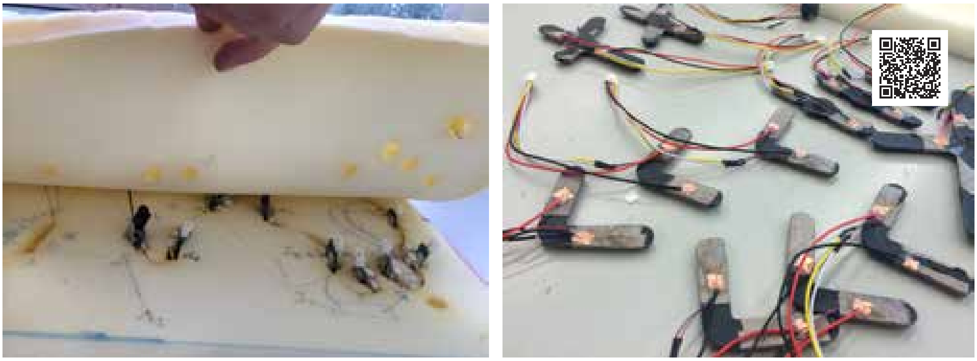


Figure 3.28: Left, the inner layer of the pillow in which the electronics were placed and connected. Right, the flexible casings for inside the fabric with different shapes. The metallic elements are the electrodes that touch the conductive fibres inside the fabric in order to measure pressure.

P33: Tactile Dialogues v2 Behaviour

Description	The interactive possibilities of Tactile Dialogues allow designing personalisation of the vibrotactile behaviour. This is an aspect worth exploring as it can enable the product to be tailored to a particular individual's use, characteristics or preferences. The standard vibrotactile behaviour was the mirroring behaviour: touch on one end of the pillow is mirrored with vibrations on the other end. We could adapt the programme to design different behaviours for each person.
Goals of the prototype	The aim of this prototype was to find out whether personalisation of the vibrotactile stimuli is appreciated over a mirroring vibrotactile behaviour.
Prototyping	In order to change the interactive behaviour easily, a software protocol was developed which would leverage certain interaction mechanisms: for example, patterns to realise a change in intensity or frequency of the interaction, and methods to differentiate between soft pressure and hard pressure. These behaviours could then be loaded onto the pillow through a USB cable connected to a computer, after which the pillow independently runs the programme (Pr30).
People	Industrial Design Student (S10), Interaction Design Researchers (S22 and S26), Design Researcher (S1, myself).
Meetings	The working version of Tactile Dialogues has been mainly used in meeting with the eldercare stakeholders (Me32, Me34 and Me36).
Testing	These new interactive possibilities of the pillow have been tested during 15 separate visits of family members or caregivers with patients (T9). The aim of these tests was to find out whether personalisation of the vibrotactile stimuli is appreciated over a mirroring vibrotactile behaviour. A full description of the tests can be found in the publication by Schelle et al. (2015).
Insights	A result is the proposal of a three-scale measurement to help family members and caregivers examine the responses of the patient: muscular relaxation, physical movement, and interpersonal contact. Through the semi-structured interviews it was identified that family members and caregivers do appreciate the opportunity to personalise the vibrotactile behaviour, and that the pillow mainly functions as a way to establish communication with the patient.

Personal reflection	Being able to conduct the tests with the interactive personalised vibratory behaviours were the moment that things came together for me. The tests showed the promise of the Embodied Smart Textile Service and there was a beautiful prototype which did very well in communicating the story to the outside world. For me this was the moment that I felt ready to give the PSS out of the protected environment in order to transition to a commercialised PSS. However, I recognise that for this transition different stakeholders will be necessary that were not involved beforehand, such as for example business minded partners.

Table 3.8: Properties of the Tactile Dialogues v2 Behaviour Prototype.

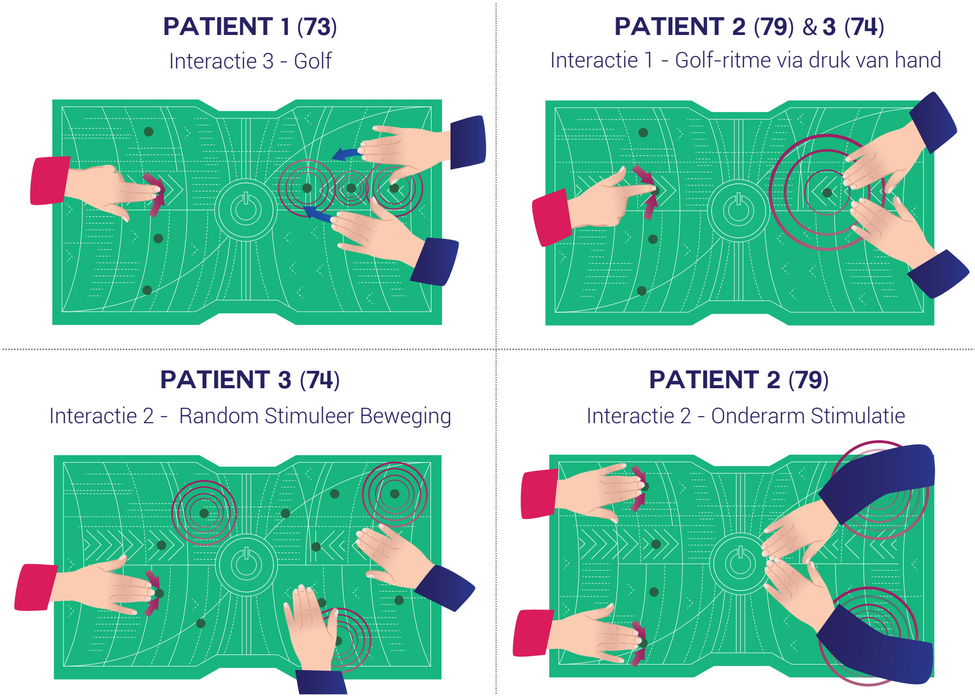


Figure 3.29: Several interactive vibratory behaviours that were developed during the tests, personalised to the specific people who were interacting with Tactile Dialogues. (Illustrations by Carolina Gomez Naranjo).

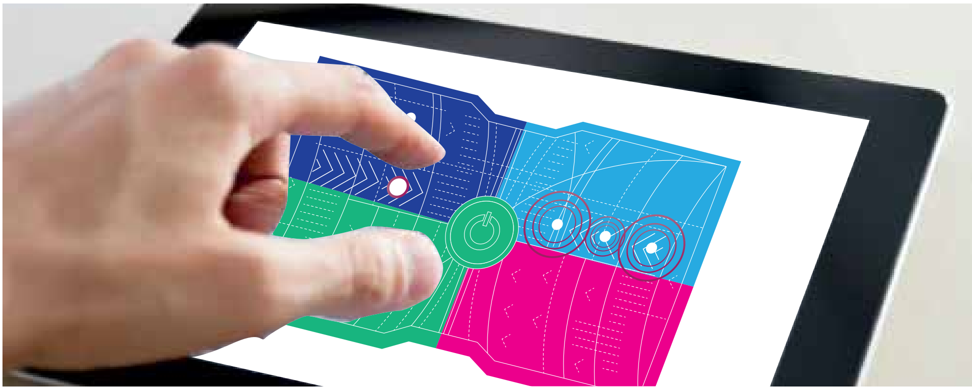


Figure 3.30: Mock-up (by S22) of how programming the vibratory behaviour could work on a tablet. (Photo by Carolina Gomez Naranjo).

3.4 Data Codification

Based on the autoethnographic accounts methodology, I will codify the dataset by providing my personal reflections on the development of the Service Interfaces from Tactile Dialogues Embodied Smart Textile Service during the design process. These reflections will mainly focus on how each prototype contributed to the Service Interface as it would come to be in the final Embodied Smart Textile Service. For these reflections I use the latest overview of Service Interfaces, as discussed in the previous chapter. Figure 3.31 shows a summary of the Service Interfaces with the pictures; the full overview of the Service Interfaces of Tactile Dialogues can be found in Table 2.9 in the previous chapter.

Service Interface 1:
Representative visits elderly care service provider

Service Interface 2:
Tactile Dialogues pillow is produced

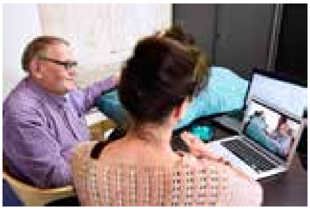
Service Interface 3:
Tactile Dialogues pillow delivery and implementation

Service Interface 4:
Tactile Dialogues information meeting

Service Interface 5:
Introduction during coaching session

Service Interface 6:
Interaction session during family visit

Service Interface 7:
Interaction session, guided by motivational therapist



Service Interface 8:
Evaluating with motivational therapist

Service Interface 9:
Maintaining & recycling Tactile Dialogues pillow

Service Interface 10:
Washing Tactile Dialogues pillow outside layer

Figure 3.31: Summary of the Service Interfaces of Tactile Dialogues Embodied Smart Textile Service. Photos by Bart van Overbeeke.

It should be noted that I will only reflect on the Service Interface that the prototype had an impact on during the development. Some prototypes did not have an impact on all Service Interfaces, and are therefore discussed in less detail.

P1: FeltBall
Personal Reflection Service Interface 2: The traditional felting textile technique allowed the transformation of thin fibres into a translucent round object. This process gave the inspiration to integrate the lights (coloured LEDs) in the textile itself, creating an object where the border between textile and technology faded. This experiment showed that in order to create these hybrid objects it is necessary that collaboration between people with textile and technology knowledge takes place: in this case, between my colleague Design Researcher (S4) and myself (S1).

Personal Reflection Service Interface 6: The FeltBall prototype could be programmed to change colour and intensity based on the interaction. These exploration possibilities led to new ideas about the interaction with textile objects, for example shaking, squishing or throwing the FeltBall to change the colour.

P2: Music Fabric
Personal Reflection Service Interface 1: Music Fabric was the first prototype that was shown to the manager of the eldercare organisation (S12). The demonstration during Me4 led to the insight that having an interactive prototype during such an introduction is an important part of convincing stakeholders to be involved in the Product-service System. Furthermore, the conversation also showed that the textile object was still lacking the subtleties that would make it fit for the healthcare setting. For example, the stiffness of the material was something that would be hard for healthcare practitioners to accept. To be able to convince the care institution to use the service, it is necessary to have a deep understanding about the exact goal of the product, and of all the actors involved.

Personal Reflection Service Interface 2: For the production of the prototype, new techniques were used to explore the possibilities of interactivity within textiles further. By creating a layered structure with conductive and piezoresistive material a pressure-sensitive textile was created. Using digital embroidery, a pattern was sewn on the textile to indicate the four points that could be pressed.

Personal Reflection Service Interface 5: An important element of this prototype was the smartphone application that provided the sound output. The idea of connecting textile objects with other devices would make it possible to update and personalise the product over time. In this case, the music channels could be easily personalised to the user by updating the application during a coaching session.

Personal Reflection Service Interface 6: In the beginning of the prototyping process the Music Fabric was a piece of textile that could be touched, without clear design indications about how to use it. After attaching Velcro straps to the sides of the object during prototyping (Pr2), it suddenly turned into an object that could be attached to the arm. This gave it a rehabilitation purpose, reaching to touch the textile. Another step were the digital embroidery patterns on the textile. The difference in texture and colour gave a feedforward about how to touch and interact with the fabric.

P4: Touch Sleeve

Personal Reflection Service Interface 2: The Touch Sleeve prototype was a fully knitted fabric, with the soft conductive yarn seamlessly knitted in. This first test showed the possibilities of using knits as base material for the prototypes: the stretchability makes it a better fit for the body. This was also the first test with using capacitive touch, making the textile sensitive to light touches.

Personal Reflection Service Interface 3: As a reaction to the prototype, the physiotherapists (S2, S3 and S16) discussed during Me7 how the prototype would be introduced to the client before using it in interaction. An important conclusion was that the form factor of the object would define very much the service procedure. For example, if it was a garment it would be hard to use for multiple clients; if it could be a blanket, it could be given more easily to people whenever necessary.

Personal Reflection Service Interface 6: The prototype had a different approach to the interaction interface than the preceding Music Fabric (P2). Instead of supporting individual rehabilitation exercises, this prototype was meant to help patients in therapeutic group sessions to feel motivated by rewarding light patterns. Based on this prototype, the goal was also further specified during Me7: to support people to play with the textile for some time and to start exploring a larger range of features of the textiles to make the touch more interesting.

Personal Reflection Service Interface 7: For the first time this prototype triggered ideas about involving family members and activity coaches during the activity. This was the basis of a Product Service System where the product could support caregivers in existing caregiving services.

P12: CRISP Modules v1

Personal Reflection Service Interface 2: The first version of the CRISP modules influenced the construction of integrating textile and electronics with each other. First the prototype was constructed by creating a centralised network, where all the sensors and actuators had to be connected to a central microcontroller, resulting in many interconnections when the complexity of the system increases. With the CRISP modules, every sensor and actuator had its own microcontroller, enabling a decentralised approach. This allowed for much more flexibility in where to place sensors and actuators.

Personal Reflection Service Interface 6: Because the CRISP modules enabled flexibility in placing them, the interaction with the product could be explored more easily. For example, just by connecting four threads to the last module a new module could be added to the existing network. There were also a range of actuators enabled new interactions to be explored: for example, lights, speakers and vibration elements.

P15: Blanket
Personal Reflection Service Interface 1: The physiotherapists (S2 and S3) were given the opportunity to try the prototype for one week (T1) preceding the evaluation meeting (Me16). This trial period gave the opportunity to acquire initial experiences with the prototype, and use these experiences to propose chances to the design of the prototype. It became clear that a degree of personalisation would be required for the product to fit into the system of the eldercare organisation. For example, to customise the location of the triggers in the fabric, or even the material and colour to better match a specific person or the interior of the organisation.

Personal Reflection Service Interface 2: Based on the CRISP modules (P12) we started to try new techniques that would enable the modules to be hidden in the textile. For example, tunnels were created to guide the conductive yarns, and on specific points in the tunnels padding was placed to embed the sensors and actuators. The fabric itself was an existing knitted piece of textile with contrasting colours (grey and white) and with decorative elements that could be used to create the tunnels.

Personal Reflection Service Interface 3: During a reflection meeting (Me16) different ideas were discussed about how the product is positioned within the existing services of the eldercare organisation. The product could be used in a care unit within personal treatment programmes; another possibility was to use the product in sessions with activity coaches to activate a person; and finally the product could be directly purchased by the family for the client.

Personal Reflection Service Interface 5: During the same reflection meeting (Me16) with the physiotherapists and manager (S2, S3, S5 and S16), we realised that the potential of Blanket is not only in keeping people active, but rather in opening a new communication channel between family and the person with dementia. Through this fundamental understanding, it will be necessary to think about how people are introduced to using the product and how they can be coached in this process. Different methods were discussed based on the prototype: for example, instructions through videos and brochures. Another important step of the coaching would be a personalisation of the stimuli's behaviour. The idea that the light, vibration and sound should be able to be changed through a USB connection was developed through this prototype.

Personal Reflection Service Interface 6: The interaction between family member and the person with dementia would be the most occurring service element. To explore this Service Interface the prototype incorporated behaviours that could be triggered during the interaction, such as the mirroring and the intensifying of the vibration. Blanket would often be used by people sitting passively in a wheelchair and will therefore most likely be used on the legs, or armrest. The shape could be improved by making it heavier on the sides, and increasing the length so it would cover the legs of the person to keep them warm. Based on this prototype the value became clearer: the service could offer a short activity or game for the partner and the person with dementia to make and keep contact. Another scenario is that the person with dementia uses it individually to receive pleasant stimuli, to get more relaxation, or to practise fine motor skills.

Personal Reflection Service Interface 7: During tests (T3) with Blanket it was necessary to have the physiotherapists (S2 and S3) involved in the interaction. We noticed that some of the informal caregivers and family members found it difficult to use Blanket in their interaction. We realised that in the Embodied Smart Textile Service an interaction between expert and family member would be necessary in order to use Blanket successfully.
Personal Reflection Service Interface 8: The prototype triggered discussion about how family members could assess the effect of interacting with their partner. An expert or caregiver who is specialised in dementia and knows the client could help the family with this, and even make them more aware of signals to observe: for example, by recognising small changes in facial expressions and monitoring the tension in the hands and arms.

P23: Tactile Dialogues v1
Personal Reflection Service Interface 1: While discussing the new prototype during the meeting with the eldercare organisation (Me21), we realised when a representative of Tactile Dialogues visits the eldercare organisation there are important arguments that can be made to convince the care organisation to implement them in their service. For example, how, in the relation between person with dementia and family members, caregivers can influence the well-being of the client. Advantages such as reducing stress for client and environment can also be mentioned. The pillow can be customised to the interior of the organisation, by changing colour, size, and shape. Furthermore, the pillow can be customised to the specific client by deciding to put the vibration elements in specific locations.

Personal Reflection Service Interface 2: The main reason to develop this prototype was to explore the integration of the connecting yarns between the vibration elements directly into the soft padding of the fabric itself. The touch-sensitive material was knitted on the top layer of the fabric by the textile producer

(S24), with which we tried to measure soft touches of the skin. To integrate the vibration elements within the fabric, we produced 3D-printed casings with different tactile structures. These structures could be felt through the textile, and had as a goal to trigger a certain touch sensation. For example, a surface of soft spikes would allow the vibration to move more localised to the hand and also felt nice to explore.
Personal Reflection Service Interface 3: After testing the previous Blanket (P15) prototype, and discussing this prototype together with the caregivers (Me21), we realised that the product needed to be carefully fitted into existing care services. The caregivers involved, such as physiotherapists, behaviour specialists, well-being staff, and motivational therapists, need to receive education and instruction about the methodology before they start to use the pillow with clients.

Personal Reflection Service Interface 5: Through this prototype the methodology of how the pillow could be used in dementia caregiving services became more detailed. The whole process in which volunteers and family members are using the pillow is considered more holistically: the pillow becomes part of the treatment plan for the person with dementia. Ideally the pillow can still be programmed to be used with interaction for individual use, or in social settings with two people. The goals to communicate to the family members are that it can help people to feel less agitation, and that the family member receives a tool to support communication with the client.

Personal Reflection Service Interface 6: For the interaction session it would be ideal if clients with severe dementia have a pillow in their bedroom, which the family and volunteers can easily use during a visit. In addition, a pillow is available in the living room of each care unit that can be used by family or nursing staff. Having these facilities, the Tactile Dialogues service can become a daily treatment in the dementia care process. Because in this prototype the fabric pattern was a series of squares, there was no clear indication of how the pillow could be touched. One of the conclusions was that the graphic pattern on the pillow should match the technical sensors and vibration motors inside the pillow.

P29: Tactile Dialogues v2
Personal Reflection Service Interface 1: Through this prototype we started to propose a vision of how therapeutic tools for a care environment should look aesthetically. By involving the textile designer (S6), an object was created that was meant to look pleasant and respectful, instead of purely medical or childish. With this prototype we explored multiple colours, and even different sizes and shapes. An important requirement based on this prototype was that the care manager (S5) needed the pillow to be affordable for the organisation. In addition, other business models came up, such as selling the pillow in specialist stores selling memory aids or products for seniors.

Personal Reflection Service Interface 2: In this second version of the pillow we combined the visual pattern with the tactile feedback. This meant that a new construction mechanism was explored where the electronics were not located in a grid as before. Instead, we created a middle layer of foam in which the same pattern of the outer layer could be removed with the same digital information, making space for the electronic modules. Within the fabric itself we started to use conductive fibres as a method to sense pressure (instead of touch). This would allow it to sense more expressive hand movements (vs just on/off). We continued the fabrication of 3D-printed casings to embed the vibration elements, now also following the shape of the textile patterns (for example, triangles, crosses, lines). On the casings we integrated the electrodes that would be in contact with the conductive fibres.

Personal Reflection Service Interface 3: Based on this prototype we realised that the pillow needed to be available in every care unit in order to be effective. Furthermore, it would be necessary that all the people in the care process should be aware of the product, including family members, other informal caregivers, volunteers, activity coordinators, motivational therapists and nurses. Following this approach the pillow would become a part of dementia treatment, and possibly to decrease the pressure on caregivers.

Personal Reflection Service Interface 5: In this prototype the vibration was simply reacting to touch: we had not yet been able to integrate any interactive vibratory behaviour yet. During the reflection meeting (Me32) the prototype already triggered many ideas about how to use the vibrations to personalise the behaviour for each individual client. For example, active behaviours (using small games or mirroring patterns) or passive behaviours (massage the hands on the pillow). We realised that clear explanation would be necessary to instruct the caregiver: this could be done through a coach or with instruction videos.

Personal Reflection Service Interface 6: An important development that emerged with this prototype was the different structures in the textile that were meant to trigger different hand movements. An area consisting of a row with smaller, rectangular-shaped pockets would be nice to rub over; a larger square area consisting of one pocket would be nice to squeeze; and a row with three arrows gave a directionality to the interaction, leading the hand to another area. The 3D-printed casings followed the shapes to strengthen the tactile experience. After small tests with the prototype (T7 and T8), we noticed that the vibration was necessary to trigger the exploration. The shapes alone (without vibration) did not have the same effect.

Personal Reflection Service Interface 9: During the iterative process of developing this prototype and testing with clients from the eldercare organisation (T7 and T8) we noticed that the product at this stage was prone to break at some point. Of course this was still a prototype, but we saw that people interact with the pillow as a textile object instead of a technological object (by stretching, pushing and squeezing it). Our conclusion was that even as a more robust product we had to start thinking about repairability of the construction, so that in the event that the product would break, repairs could be offered through a maintenance service.

Personal Reflection Service Interface 10: During testing of Blanket (P15) and Tactile Dialogues v1 (P23) we noticed that using it in the common living areas of the eldercare context would expose the product to many ways of getting dirty. When developing this prototype, we explored a construction that would allow the outer layer to be removed for cleaning. By selecting a connector that could be easily disconnected, and sealing off the casings inside the fabric that contained the vibration motors, they could be cleaned with the textiles.

P33: Tactile Dialogues v2 Behaviour
Personal Reflection Service Interface 1: The business model plays an important role in this interface. The true value proposition of the service became clearer during Me32: because of the interaction with the pillow, the person with dementia can live longer independent at home. The pillow is used for treatment, and interaction is stimulated. The usage of medicines goes down, resulting in more quality of life for both the person with dementia and caregiver. This would allow health insurers to partly finance the service and lower the costs. With the same product we could also target other groups, such as children or patients rehabilitating from a stroke.

Personal Reflection Service Interface 2: In this iteration the software running on the CRISP modules (P12) was further developed in order to conduct the tests (T9). Different programmes would enable the caregiver to switch between different behaviours. Currently this is done through a USB connection and a computer. Further personalisation of the pillow itself was also discussed. By using digital production techniques the textile (and all the other elements) could be created on an individual basis.

Personal Reflection Service Interface 3: In this step the introduction of the pillow to the eldercare organisation was further developed: for example, through meeting the manager (S40) of a different department during Me34. The company selling the product would need to offer training programmes about how to work with Tactile Dialogues. Furthermore, there would be instructions about how to personalise the vibratory behaviour to specific clients, so that the knowledge would become part of the organisation. Best practices about how the product could be used in existing services could be explained based on examples, but this is open to the care institution to implement further.

Personal Reflection Service Interface 4: An important new interface that still came in at this point was the first acquaintance of the family members with the service. We developed this interface when we were testing the pillow (T9). Information evenings for family members of the clients are already used by the care organisation as a way to involve the family in the caretaking process. Therefore this was chosen as a way to effectively reach the people, and explain to them what Tactile Dialogues was about. During this meeting materials such as presentation, brochure and an interactive demonstration needed to be developed.

Personal Reflection Service Interface 5: During the same test (T9) the initial coaching session became more important. The purpose of the product was clear to most informal caregivers; however, the specifics on how to use the product during a visit needed more training. During this step a motivational therapist from the care organisation, who knows the person with dementia, trains the family member to use Tactile Dialogues during a visit. A first vibratory behaviour is chosen together with the motivational therapist. Further instruction videos can be offered in the application that is also used to personalise the vibration.

Personal Reflection Service Interface 7: As defined in Service Interface 5, the coach is playing an important role in the interaction. We noticed during testing the service setting (T9) that it was appreciated if the coach could be present at some visits to observe the interaction and give advice about how to use Tactile Dialogues. The interaction would be recorded on video, so that it can serve as material for an evaluation.

Personal Reflection Service Interface 8: During the evaluation meeting the family member and coach have the opportunity to evaluate the use of Tactile Dialogues during the visits. Besides this, they can discuss more in depth the well-being of the person with dementia, and the symptoms of the disease. By using the recorded video the coach can show specific events during the visit, such as a small change in facial expression, or a small gesture with the hand. By pointing out these events, the family member would become more sensitive to the new way of interaction. During the coaching session the vibratory behaviour of the pillow can be further personalised to the needs of the patient and family using a tablet application.

Personal Reflection Service Interface 9: During the tests (T9) and discussions (Me32 and Me40) it was again emphasised how important a maintenance service is. By making sure the pillow is working, the threshold for actually using the product during visits is lowered. Thinking about a recycling programme for when the pillow is not used anymore is also necessary: for example, changing the outer layer so that it can be used with a different client, but also easy separation of the components for recycling.

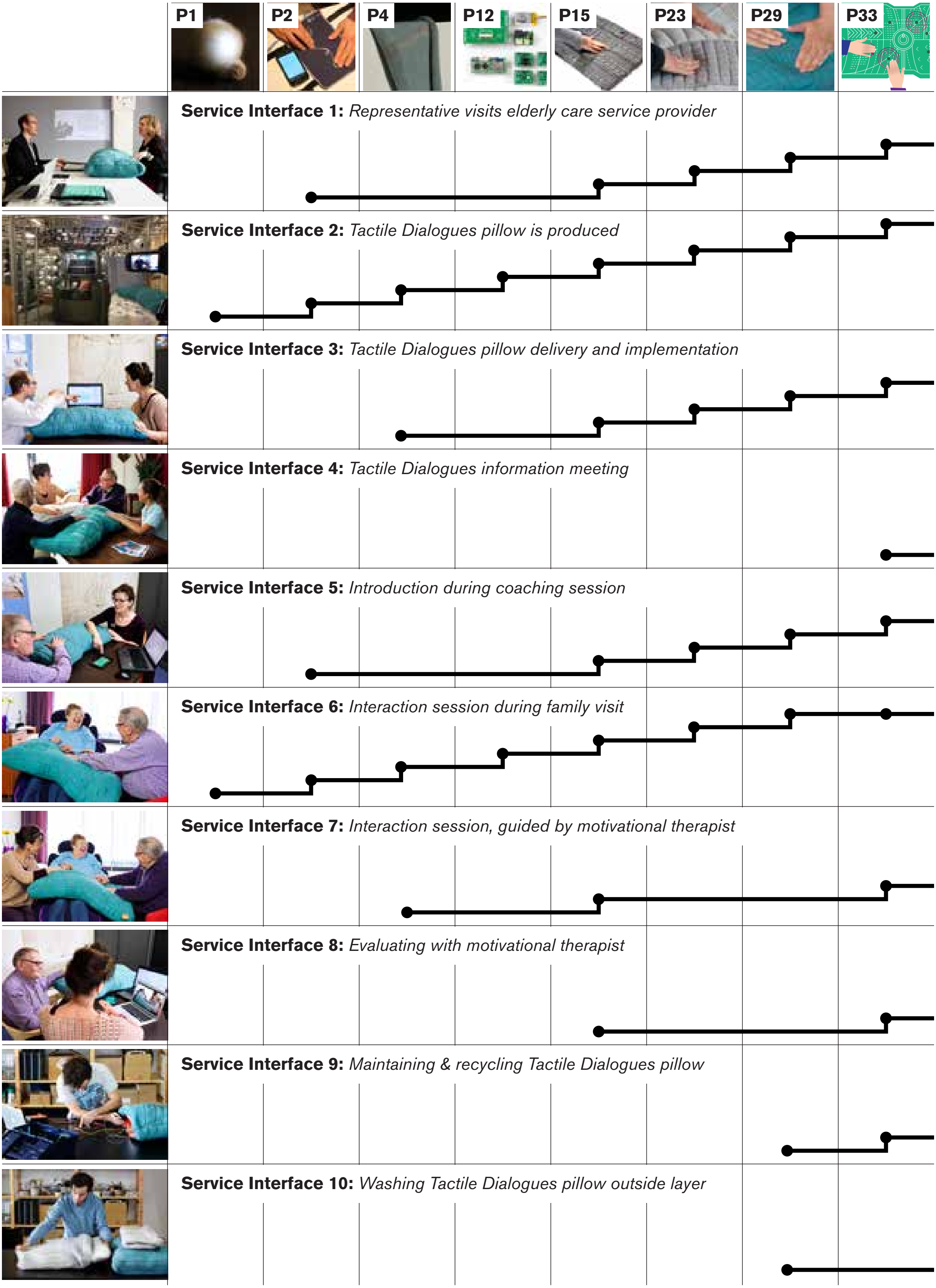

P1
P2
P4
P12
P15
P23
P29
P33
Service Interface 1: Representative visits elderly care service provider
Service Interface 2: Tactile Dialogues pillow is produced
Service Interface 3: Tactile Dialogues pillow delivery and implementation
Service Interface 4: Tactile Dialogues information meeting
Service Interface 5: Introduction during coaching session
Service Interface 6: Interaction session during family visit
Service Interface 7: Interaction session, guided by motivational therapist
Service Interface 8: Evaluating with motivational therapist
Service Interface 9: Maintaining & recycling Tactile Dialogues pillow
Service Interface 10: Washing Tactile Dialogues pillow outside layer

Figure 3.32: Left page: visualisation of the development process of the Service Interfaces (rows) based on the prototypes (columns). A point indicates that the prototype had an impact on the development of the Service Interface based on my personal reflections. The line indicates purely the changes over time, not a quantification of the amount of changes.

3.5 Data Analysis

In this section I will take a step back and describe how the Service Interfaces changed over time, and how the prototypes contributed to the development of them. Based on my personal reflections discussed in the previous section, it is possible to track which prototype contributed to which Service Interface. Figure 3.32 shows the visualisation of this process. It should be clear that this figure does not try to *quantify* the development of the Service Interfaces. This visualisation shows purely how the prototypes and Service Interfaces are related. Whenever the prototype had an influence on the Service Interface (for example, through the Prototyping, Tests or Meetings) the line moves upward to indicate this change. The resulting Service Interface is the accumulation of all these steps. In the previous chapter I determined that Embodied Smart Textile Services can be personalised based on three levels (as discussed previously in Chapter 2). These levels are: personalising the textile material properties; personalising the look, fit and feel of the textile object; and personalising the interaction with the digital data.

Based on the assumption that these three levels of personalisation are a crucial aspect of an Embodied Smart Textile Service, it would be valuable to understand how these three levels came about in the Service Interfaces of Tactile Dialogues. Therefore, I will use the three levels of personalisation to guide this analysis. For each Service Interface I will describe which levels of personalisation are relevant, because not all levels are necessarily touched upon in each Service Interface. Then I will reflect on how the prototype contributed to the development of each level of personalisation for each Service Interface. These reflections are based on my own experiences, and therefore do not aim to quantify the impact of the prototype. I rather try to use my first-person perspective as a designer who was involved in all of the developments to give a detailed account of what happened.

Service Interface 1: Representative visits care home
Personalising the look, fit and feel of the textile object: During the course of developing the prototypes we slowly started to understand that the value of the Embodied Smart Textile Service should not only be considered from the perspective of the person with dementia and the family members, but also of all the involved parties of the eldercare organisation. We realised that personalisation is not only helpful to support the interaction on the level of a specific person with dementia and family, but it could also offer ways to support the organisation to incorporate Tactile Dialogues in the existing services. For example, based on Blanket (P15) we started to think about how to fit the

product in existing services, and through Tactile Dialogues v1 (P23) we came to discussions about how to personalise the pillow to the environment of the organisation. Tactile Dialogues v2 (P29) was designed with a vision about the aesthetics of medical tools in an eldercare context proposed by the textile designer (S6). This vision contributed to this Service Interface because it defined how the pillow could fit into the environment of the service provider. For example, the pattern in the fabric and the shape were more adapted to the interior of a modern care institution, and multiple prototypes with different colours were produced to show this aspect.

> The prototypes enabled the personalisation of the look, fit and feel of the textile object for Service Interface 1 because it challenged stakeholders to improve the quality of the Service Interface to a higher level.

Personalising the interaction with the digital data: The interaction with digital data was already part of the value proposition starting from the early prototypes. It was, for example, clear from prototype Music Fabric (P2) that the sounds could be personalised towards the user. Later, this digital layer of the prototype also started to play a role on the organisational level. For example, when developing Blanket (P15) we started to integrate internal memory in the prototype, so that we could save the digital data that was generated in the interaction. This digital data could be used by organisations to get more insight about how their clients are doing. This is something that we further developed with Tactile Dialogues v2 (P29).

> The prototypes enabled the personalisation of the interaction with the digital data for Service Interface 1 because of the connection between the infrastructure of the organisation and the digital data generated by the prototype.

Service Interface 2: Tactile Dialogues is produced
Personalising the textile material properties: Particularly the first prototypes, such as FeltBall (P1), Music Fabric (P2) and Touch Sleeve (P4), were built using existing electronics such as Arduino. These off-the-shelf components were flexible enough to allow quick changes in the design process. However, starting with the CRISP modules v1 (P12) we started to develop our own materials together with the engineer (S7) from the electronics company. With this new approach we were able to integrate the electronics in a networked way, which made it possible to personalise the technology and fabric to the dementia context in the Blanket prototype (P15). With the textiles we followed a similar approach. In the beginning we used existing fabrics to create the prototypes Music Fabric (P2), Touch Sleeve (P4) and Blanket (P15). This helped to explore different construction techniques, such as creating tunnels and using padding in Blanket. With the lessons learned from using existing materials, we started to develop our own fabric for Tactile Dialogues v1 (P23) and Tactile Dialogues v2 (P29) to personalise the material properties directly to the needs of the end-user. Here we learned that transitioning

between use and production is not always a straightforward process. For example, for creating similar tunnels and padding the machines of the textile producer (S24) had to be taken out of production and adapted.

> The prototypes enabled the personalisation of the textile materials' properties for Service Interface 2 because it allowed the new partners to contribute with their skills and expertise.

Personalising the interaction with the digital data: Embedded in the project from the start was a collaboration between the two PhD researchers: a Fashion Designer (S4) and me, as Industrial Designer (S1). When we first started to collaborate (Pr1) we noticed that, to work together, we needed to break down the border between textile and technology. Our skills directed the project to combine felting, a traditional textile-processing technique, with LED lights. This led to unexpected interaction possibilities with the technology and digital data through the object itself, for example squishing or throwing the object. This approach was followed by other collaborations where the friction of the two disciplines formed direct inspiration for the development of the Service Interface: for example, the combination of adhesive bonded layered textiles and piezoresistive material for pressure sensing (P2), sewing conductive yarns (P15) and eventually knitting conductive yarns in the textile itself to create capacitive touch sensors (P23). Finally, the return to felted conductive wool fibres to create pressure-sensitive surfaces was used in the Tactile Dialogues pillow (P29).

> The prototypes enabled the personalisation of the interaction with the digital data for Service Interface 2 because of the merging of textile and technology disciplines that occurred during the prototyping processes.

Service Interface 3: Tactile Dialogues delivery

Personalising the look, fit and feel of the textile object: Because of the tests with Blanket (P15) and Tactile Dialogues v2 Behaviour (P33) we realised that it was not only the look, fit and feel of the textile object that should be personalised to the organisation. Moreover, the object should fit in with existing treatments, methodologies and services that the provider is already offering. For example, by developing Touch Sleeve (P4), it became clear that designing a wearable application would be very difficult for the caregivers to implement. It would be hard to let all the clients wear a special product just for a short interaction session. In contrast, an object that all caretakers could easily apply in their current methodologies would be easier to implement. This was one of the reasons that Blanket (P15) was designed as a separate object, easier to implement during existing treatments. During Me16 we discussed ways to apply it in individual treatment or sessions with activity coaches, or when used by family members to support communication. Through developing the prototypes in the actual context, we learned that Tactile Dialogues should be integrated as much as possible within the current services of the eldercare organisation.

The prototypes enabled the personalisation of the look, fit and feel of the textile object for Service Interface 3 because it triggered confrontations between the context and the prototype.

Service Interface 4: Tactile Dialogues information meeting
Personalising the look, fit and feel of the textile object: This Service Interface was only developed during the tests with the last prototype: the Tactile Dialogues v2 Behaviour (P33). The major difference of the test (T9) with this prototype was that a new caregiving location was chosen to implement the Embodied Smart Textile Service. During the earlier tests the participating clients were recruited informally through the network of contacts from S2, S3 and S5. During T9 this step had to be designed as an additional Service Interface. When meeting with the coordinator of the new location (Me34) it was mentioned that the caregivers of this location organise information evenings in order to communicate with family of their clients. By personalising how the Tactile Dialogues pillow was presented to the family members, in this case during the information meeting, we hoped that we could reach the family of the clients living in this location. This setting worked out well: after demonstrating the Tactile Dialogues pillow and explaining the purpose, we found enough participants willing to join. After the test we realised that this Service Interface was actually an important piece in bringing the Embodied Smart Textile Service to the end-users, one that we had not considered beforehand.

The prototype enabled the personalisation of the look, fit and feel of the textile object for Service Interface 4 because the actual implementation of the prototype in the context made it real.

Service Interface 5: Introduction during coaching session
Personalising the look, fit and feel of the textile object: The coaching session was introduced during the first tests (T3) with the Blanket prototype (P15). After pilot tests (T2) we immediately found out that the look and feel raised a lot of questions from the informal caregivers and family members who had to use it. Not only does the interaction itself need to be introduced, but also it would help caregivers tremendously if we could give some examples about the purpose of the prototype before actual use: for example, proposing some interaction patterns that could be tried, such as taking the hands of the other person and moving them around on Blanket. For the next prototype (P23) we started to develop the methodology simultaneously with the prototype. During the discussions with the caregivers the prototype was introduced as part of a more holistic treatment approach towards the well-being of people with dementia. Based on Tactile Dialogues v2 (P29) we developed ideas about creating instruction materials such as videos that could be delivered and personalised for the specific interaction that could benefit the person with dementia and the family member. During the tests (T9) with P33 we emphasised the role of a coach in the caregiving

process. This person would be involved in the process, and can therefore offer a personalised treatment in which the Tactile Dialogues pillow plays a central role.

> The prototypes enabled the personalisation of the look, fit and feel of the textile object for Service Interface 5 because it elicited the generation of in-depth knowledge and focus.

Personalising the interaction with the digital data: From the start of the project it was clear that the digital layer of smart textiles would enable the user or service provider to change the experience over time. With Music Fabric (P2) this resulted in the possibility to customise the sound that the fabric would make when interacting with it. Starting from Blanket (P15) the personalisation aspect was developed further as a way to tailor the stimuli better towards the person with dementia. For example, some people would react better to light instead of vibration. After the choice for vibration as main stimuli in Tactile Dialogues v1 (P23), personalisation was used to change between the vibration for individual use (a massage) and social use (to support communication). In the iterative tests (T7 and T8) and development cycles that followed in order to develop Tactile Dialogues v2 (P29), we realised that the personalisation needed to become much more specific than that. The vibrotactile behaviour needed to be specifically changed to how each person with dementia used the Tactile Dialogues pillow. For example, some people used it horizontally and reacted positively to vibration directly on their bodies, while other people put their hands further towards the centre of the pillow and needed vibration specifically in that area. Therefore, during T9 we extended this Service Interface with a step where the coach would personalise the vibrotactile behaviour very specifically to the capabilities and needs of the person with dementia and communication partner.

> The prototypes enabled the personalisation of the interaction with the digital data for Service Interface 5 because of the continuous process of refinement and striving for perfection throughout the iterations of the prototypes.

Service Interface 6: Interaction session during family visit
Personalising the textile material properties: Starting with the FeltBall (P1) the material informed the interaction possibilities of the prototypes. For example, the felt invited the user to throw or squeeze the object. This was further explored with Music Fabric (P2), where the Velcro straps enabled the object to be worn on the body and as result made it possible to involve the whole body in the interaction. Starting with the introduction of the CRISP modules v1 (P12) the technology became a material in itself. The easy integration of actuators enabled the new interaction possibilities in Blanket (P15). From Tactile Dialogues v1 (P23) onwards the approach started to shift. Instead of the material informing the interaction, decisions were made based on the interactions that the Tactile Dialogues should offer: for example, the decision to move from a blanket to a pillow to provide continuous sensorial stimuli (pressure on the legs) to the

person with dementia. The tactility of the fabric and the graphic patterns of Tactile Dialogues v2 (P29) were personalised based on the observation of the hand movements of the people using the pillow.

> The prototypes enabled the personalisation of the textile material properties for Service Interface 6 because they triggered dialogues between the material properties and interaction possibilities.

Personalising the look, fit and feel of the textile object: During the course of the process the interaction session became increasingly detailed. Through developing FeltBall (P1), Music Fabric (P2) and Touch Sleeve (P4), the scope focussed on stimulating small movement and providing exercises for people with dementia. This focus was mainly possible because the interactive prototypes triggered the physiotherapists (S2 and S3) and the manager (S5) from the eldercare organisation directly to make strong links to the context. The prototype of Blanket (P15) with all its actuators integrated (light, sound and vibration) did not make much sense immediately. It was only by placing Blanket in the context during T1, T2 and T3 that we started to grasp the value and were able to go into more depth for the next prototypes. Similarly, we imagined the pillow to work as a canvas with different preprogrammed interactive vibratory behaviours when we were developing Tactile Dialogues v1 (P23) and Tactile Dialogues (P29). But after the tests such as T7, T8 and T9 the ideas emerged that the vibrations could be personalised in detail to the people who were using the pillow.

> The prototypes enabled the personalisation of the look, fit and feel of the textile object for Service Interface 6 because it offered a bridge between the designer and the experts from the service provider.

Service Interface 7: Interaction session, guided by expert
Personalising the interaction with the digital data: Personalising the digital vibratory behaviour to the specific interaction between family member and person with dementia needed to be closely connected to the actual interaction that occurred. When developing Touch Sleeve (P4) we discussed the involvement of activity coaches and family members to guide the activities. Next, when testing Blanket (P15) during T3, we realised that family members appreciated it when an expert was there during the test to guide them. However, we did not fully develop this step until the Tactile Dialogues v2 Behaviour (P33) prototype. During the longitudinal test (T9) we realised that the motivational therapist should be part of the interaction from time to time in order to help in personalising the interaction in the best way possible to the users.

> The prototypes enabled the personalisation of the interaction with the digital data for Service Interface 7 because it helped the stakeholders to blur the boundaries between development and deployment of the PSS.

Service Interface 8: Evaluating with care professional
Personalising the interaction with the digital data: The origin of this Service Interface can be traced back to the two longer tests conducted with the Tactile Dialogues Embodied Smart Textile Service: T3 and T9. During T3 with the Blanket prototype (P15) we were confronted with the challenge of how to assess the effects of the interaction. We found out that the effects are often too small to observe for an untrained person, and also varied per person. Video Interaction Analysis is a method applied in eldercare services to help experts to monitor the effect of a treatment. We decided to apply a similar methodology for Tactile Dialogues. With Tactile Dialogues v2 Behaviour (P33) we implemented a Service Interface where the coach and family members would use the video that was recorded and the data that was logged from the sensors during the interaction to evaluate the effect of the Tactile Dialogues pillow. The discussions that arose from this video evaluation during T9 proved to be not only a help to improve the interaction using Tactile Dialogues, but also a way to talk about the dementia process with family members. Additionally, the evaluation session was a moment when the Tactile Dialogues' vibrotactile behaviour could be further personalised to the observations of the video and based on the data from the sensors. The coach could, for example, introduce new interaction patterns that the family member can try on the next visit.

> The prototypes enabled the personalisation of the interaction with the digital data for Service Interface 8 because it combined the knowledge from the service provider (Video Interaction Analysis approach) with a technological data approach.

Service Interface 9: Maintaining & recycling Tactile Dialogues
Personalising the look, fit and feel of the textile object: Gradually the prototypes we developed started to become more complex, and needed to be tested for longer periods of time. With Tactile Dialogues v2 (P29) and Tactile Dialogues v2 Behaviour (P33) in particular we had many problems: for example, during T7 and T8 the prototype would suddenly stop working. We realised that part of these problems could be solved after more development time was spent in building the prototypes, but at the same time there would always be the risk that the products would stop working. People perceived the smart textile products not as technological products, but as textile objects. This means that the products have to be able to withstand interactions commonly associated with textile objects. As a solution for this problem, and for the future of the Tactile Dialogues pillow, we started to think about repairs as part of the Embodied Smart Textile Service. These new ideas were reflected when developing how the look and feel of Tactile Dialogues v2 (P29) could be personalised. For example, the textile outer layer was separated from the inside layer which contained most of the electronics. Furthermore, the electronics and connections to the textile were developed in such a way that they could be more easily replaced.

The prototypes enabled the personalisation of the look, fit and feel of the textile object for Service Interface 9 because it combined the requirements for usage with engineering developments.

Service Interface 10: Washing Tactile Dialogues
Personalising the textile material properties: The issue of washability of the smart textile object had been on our radar from the beginning: it was often the first question that people asked. However, for the sake of practicality we decided not to focus on it. Since the prototypes were normally used for a shorter time period, it was not an issue that needed to be resolved in order to test the other parts of the Embodied Smart Textile Service. During the later developments of the Tactile Dialogues v2 Behaviour (P33) we started thinking about modular constructions of the object and the material properties in order to help the repairability in Service Interface 9. At that moment we realised that making the prototype easier to repair would also result in an easier way to clean it. For example, by making sure that all the electronics could be separated from the textile material that needed to be cleaned. The outer layer of the pillow can be removed by a professional cleaning service provider. At the same time this would allow the electronics within the inside layer of the pillow to be used with different outside layers with other material properties, personalised to different people. Furthermore, we changed the connectors of the electronics in order to enable the service provider to replace the layer with a clean one while the other one is washed.

The prototypes enabled the personalisation of the textile material properties for Service Interface 10 because it helped to bridge solutions from separate Service Interfaces.

3.6 Findings

As set out at the beginning of this chapter, I am focussing on the following research question: "How do prototypes support the bottom-up infrastructuring approach process that enables the design of the Service Interfaces to move forward?" In the previous Data Analysis section I discussed how the prototypes played a role in the level of the Service Interface. In this section I will try to generalise these roles one lever higher, in order to identify the main roles of the prototypes which are applicable to the overall PSS development of Tactile Dialogues.

I will show that the prototypes can be divided into three main roles: (1) prototypes assure the situatedness of the PSS; (2) prototypes increase the quality of the PSS; (3) prototypes enable the community to create horizontal collaboration. I will describe each of these roles in more detail and give examples from the separate Service Interfaces that contributed to the grouping based on the analysis. Table 3.10 shows the overview of how I transitioned from the Service Interface level role of the prototype to the three main roles of the prototypes.

Service Interface	Level of personalisation	Role of the prototype for the Service Interface	Roles of the prototype for the PSS
Service Interface 1 (Representative visits care home)	Personalising the look, fit and feel of the textile object	It challenged stakeholders to improve the quality of the Service Interface to a higher level.	Quality
	Personalising the interaction with the digital data	The connection between the infrastructure of the organisation and the digital data generated by the prototype.	Situatedness
Service Interface 2 (Tactile Dialogues is produced)	Personalising the textile material properties	It allowed the new partners to contribute with their skills and expertise.	Quality
	Personalising the interaction with the digital data	Merging of textile and technology disciplines that occurred during the prototyping processes.	Horizontal Collaboration
Service Interface 3 (Tactile Dialogues delivery)	Personalising the look, fit and feel of the textile object	Triggered confrontations between the context and the prototype.	Situatedness
Service Interface 4 (Tactile Dialogues information meeting)	Personalising the look, fit and feel of the textile object	The actual implementation of the prototype in the context made it real.	Situatedness
Service Interface 5 (Introduction during coaching session)	Personalising the look, fit and feel of the textile object	It elicited the generation of in-depth knowledge and focus.	Quality
	Personalising the interaction with the digital data	The continuous process of refinement and striving for perfection throughout the iterations of the prototypes.	Quality
Service Interface 6 (Interaction session during family visit)	Personalising the textile material properties	It triggered dialogues between the material properties and interaction possibilities.	Quality
	Personalising the look, fit and feel of the textile object	It offered a bridge between the designer and the experts from the service provider.	Horizontal collaboration
Service Interface 7 (Interaction session, guided by expert)	Personalising the interaction with the digital data	It helped the stakeholders to blur the boundaries between development and deployment of the PSS.	Situatedness
Service Interface 8 (Evaluating with care professional)	Personalising the interaction with the digital data	It combined the knowledge from the service provider with a technological data approach.	Horizontal collaboration
Service Interface 9 (Maintaining and recycling Tactile Dialogues)	Personalising the look, fit and feel of the textile object	It combined the requirements for usage with engineering developments.	Horizontal collaboration
Service Interface 10 (Washing Tactile Dialogues)	Personalising the textile material properties	It helped to bridge solutions from separate Service Interfaces.	Horizontal collaboration

Table 3.10: Relations between each Service Interface, the levels of personalisation, the role of the prototype for each Service Interface personalisation and finally the higher abstraction role of the prototype on the level of the PSS.

Prototypes assure the situatedness of the PSS
In multiple Service Interfaces the prototypes had a strong link with the context of the PSS, and therefore assured that the PSS would be strongly situated. Perhaps this is obvious to most designers, since prototypes usually help to make things concrete in the design process. Nonetheless, it is important to make explicit that this also counts for the design of Product-service Systems. Based on the individual roles, this grouping combines some important insights: the prototype creates a connection between the infrastructure of the organisation and the digital data (Service Interface 1); the prototype triggers confrontations between the context and the prototype, leading to a more complete overview of all the stakeholders who need to be involved in the service (Service Interface 3); by implementing the prototype in the actual context, the PSS becomes real (Service Interface 4); and the prototype helps the stakeholders to blur the boundaries between development and deployment of the PSS (Service Interface 7).

By making interactive and experienceable prototypes we found connections between the digital data and the infrastructure of the service provider that we could not have imagined by just designing on a conceptual level. For example, we used a memory chip in the prototype to save the sensor data during an interaction session in order to analyse the data for research purposes. Because we started talking about how the PSS was introduced and delivered to the service provider (Service Interface 1) we discovered that this digital data can actually be very valuable for an organisation: for example, to acquire more insight into how active the clients are.

The constant confrontation of prototypes with the actual context makes sure that the PSS links to the stakeholders' existing practices. Through tests and discussions with the stakeholders we learned that for Service Interface 3 (the service delivery) to succeed we needed to create links with existing services and treatment methodologies of the eldercare organisation. This resulted in the involvement of motivational therapists as coaches from the start when the PSS was delivered.

The prototypes helped to make the PSS real, and made the PSS happen. Service Interface 4 (the information meeting) was only developed at the moment when the last prototype was being tested. This late development was caused mainly because we did not test a crucial part of the PSS before the test, and it had therefore remained hidden. By implementing the PSS in a new department of the service provider we suddenly realised that, in order to introduce the service to the clients, this Service Interface was necessary.

All the stakeholders involved in the development are also required to deploy the PSS. Because of this, all the insights gained during the development of the PSS can directly benefit the integration of the PSS in the context. For example, in Service Interface 7 (the interaction session guided by the coach) the role of the coaches became clear because we started to collaborate with actual coaches to help the family members. The coaches became part of the development with their knowledge and skills, and therefore also part of the PSS.

Prototypes increase the quality of the PSS

The refining process of a PSS is never finished. A prototype triggers the perfection of a craftsman, which is reflected in the quality of the whole PSS. The prototypes increase the quality of the whole PSS to a level which cannot be achieved if it remains a concept. This grouping consists of the following roles of the prototype: the prototype challenges stakeholders to improve the quality of the Service Interface to a higher level (Service Interface 1); the prototype allows new partners to contribute with their skills and expertise (Service Interface 2); the prototype elicits the generation of in-depth knowledge and focus (Service Interface 5); the prototype drives a continuous process of refinement and striving for perfection (Service Interface 5); the prototype triggers dialogues between the material properties and interaction possibilities (Service Interface 6). Quality attracts quality in the PSS. At one stage we reached the limit of what could be developed in the current constellation of the stakeholders regarding the fit to the organisation of Service Interface 1. The state of the PSS at that point attracted new stakeholders (such as the Textile Designer) to be involved, who were challenged by the prototype to improve the quality of the PSS. At some point the available resources are no longer sufficient to reach a certain requirement in quality. In this situation clear steps are necessary to go to the next stage, such as attracting new expertise or new resources.

Instead of creating a concept first and finding production partners to realise it later, we aimed from the beginning to integrate the skills and expertise from the stakeholders involved. This had a significant impact on Service Interface 2, the production of Tactile Dialogues. For example, the textile producer brought in expertise on creating circular knitted textile materials. With this it became possible to personalise the patterns and structure of the fabric to the desired interaction based on the hand movements.

Developing a prototype makes issues concrete for all stakeholders, and also elicits new knowledge from everybody involved. For example, the development of Service Interface 5 (the introduction during a coaching session) started as a small activity which was necessary to introduce the prototype at the beginning of a test. During the discussions afterwards with the caregivers and family members we learned that the introduction by the coach was quintessential for the success of the whole PSS. This resulted in a much clearer proposal about the role of the coach, from a simple explanation to a holistic treatment plan in which training is a recurring element.

Because the prototype is there, and can be experienced, stakeholders get into the process of refining and perfection. For example, the vibrotactile feedback of Service Interface 5 became more and more subtle and refined with each prototype. In some sense, each prototype opened up possibilities to develop more in-depth interaction styles. The stakeholders were driven to go further in the development and to do every iteration better, fuelled by the achievements reached after every step.

The developments of the material properties and the interaction within Service Interface 6 (interaction session) were closely related. In the beginning the material properties inspired the interaction, and later in the process it often went the other way around. Most importantly, the material dialogue drove the developments and improvements of the Service Interface. This gave a sense of energy and made us eager to achieve a higher level of quality with every iteration.

Prototypes trigger horizontal collaboration in the PSS
By taking a prototyping approach the boundaries are blurred between fields which are normally quite separate. Horizontal collaboration between people emerges, which is not possible in a vertical value chain where people operate separately from each other. This leads to the insight that prototyping helps to leverage and integrate design, production, development and deployment, and thereby also blurs the differences. The roles of the prototypes that contributed to this group are: the prototyping process merges the textile and technology disciplines (Service Interface 2); the prototype offers a bridge between the designer and experts from the service provider (Service Interface 6); the prototype combines the knowledge from the service provider with a technological data approach (Service Interface 8); the prototypes combine the requirements for usage with engineering developments (Service Interface 9); and the prototype helps to bridge solutions from separate Service Interfaces (Service Interface 10).

The friction of combining a textile approach with a technology approach formed a direct inspiration for the development of Service Interface 2 (the production of Tactile Dialogues). For example, by producing the modular electronics a new toolset emerged. Switching from centralised to decentralised electronics inspired us to take a different approach in the textile design. We started to use circular knitting to create tunnels in which we could flexibly place the electronics wherever the sensing and vibration were required.

There is a continuous exchange between design experiments with the material and production, in relation to the interaction that is created. This dialogue offers other stakeholders the opportunity to embed their expertise during the development. In order to develop Service Interface 6 (the interaction session) the experts of the eldercare organisation needed to react constantly to the new ideas in the prototype. For example, when we placed multiple vibration elements in the pillow, they reacted with the idea to adapt these vibrations to the specific people using the pillow.

Caused by the prototype, contextual knowledge is merged with technical approaches. For example, in the case of Service Interface 8 (evaluating the interaction) we found out that video analysis, combined with showing the data from the sensors, is a very effective method to analyse the interaction during a communication session. This insight was further applied in order to help the family member to evaluate the interaction together with an activity coach. The family member even took a proactive role in finding out more and gathering information based on the video observations.

Based on all the testing and demonstrations of the prototype, we noticed that the prototypes were under quite some pressure. This drove us to develop Service Interface 9 (maintaining and recycling Tactile Dialogues) and take repairability into account within the service.

Because multiple Service Interfaces are built around the same prototype, there are occasions when certain elements influence other Service Interfaces. For example, solutions from the maintenance (Service Interface 9) also influenced the washing procedure of Tactile Dialogues (Service Interface 10).

3.7 Conclusions

The beginning of this chapter introduced a key challenge in the design of Embodied Smart Textile Services: how do prototypes move the Product-service System that does not exist yet? I introduced the design process of the Service Interfaces of a specific type of PSS: the Tactile Dialogues Embodied Smart Textile Service. As shown, this was often a rich and complex mixture of tangible and intangible aspects, digital and physical, knowledge distributed among stakeholders from often separate disciplines and many different agendas originating from different contexts. Therefore, instead of defining clearly what the object of design is, the design challenge is rather to see how the process can move forward, while still deepening the questions in every iteration, and maintaining a vision about the value of the process. The more detailed research question in this chapter was:

> "How do prototypes support the bottom-up infrastructuring approach process that enabled the design of the Service Interfaces to move forward?"

In this section I will bring the answer to this question forward based on the preceding analysis in two parts: the different roles of the prototypes in relation to the design of the Service Interfaces, and secondly, a reflection about our take on the bottom-up infrastructuring approach: the Growth Plan.

Roles of the protoypes
Within the findings section of this chapter I identified three main roles of prototypes that I observed based on the development of the Service Interfaces of Tactile Dialogues: prototypes to assure the situatedness of the PSS; prototypes to increase the quality of the PSS; and prototypes to trigger horizontal collaborations in the PSS. I will discuss how these three roles relate to the prototypes that were shown in the overview in Table 1.1.

The prototypes assured the situatedness of the PSS through different mechanisms. Similar to questioning the "role" of the product through the prototype, as discussed by Houde & Hill (1997). In their study they argue that a prototype can be used to investigate what the role of the final product will be in a user's life, and how it is useful to them. The prototypes of Tactile Dialogues had a similar goal, by integrating the prototypes in the actual context the PSS became real. However, the situatedness of the prototype questioned the role of the PSS not only for the end-user, but also for the other stakeholders involved in the PSS, such as the caregivers, designers, engineers and producers. A related perspective on prototypes by Lim et al. (2008) makes this more specific by describing the use of prototypes to filter a dimension out from other ones, which also enables designers to see relationships among different dimensions. One element that their framework does not take into consideration, but which is critical when designing PSS's, is the social component. I see the social situation as a part of the embodied prototype, and as a result this can also be used as a filtering dimension. Consider, for example, Service Interface 7 (the interaction session, guided by motivational therapist): by changing the dimensions of the prototype (between Blanket, Tactile Dialogues v1 and Tactile Dialogues v2) the social interaction between the person with dementia, the partner and the coach was directly influenced. Based on this "filtering", we chose in the end for a prototype where the pillow could be placed on the legs of the person in the wheelchair, while they could still sit next to each other.

In the process the prototypes played an important role to increase the quality of the PSS. This aspect gave the stakeholders an intrinsic motivation to improve and build the PSS together. Some elements described in experience prototypes (Buchenau & Suri, 2000) certainly have an influence here. By exploring and evaluating ideas, experience prototypes provide inspiration, confirmation and rejection. In the development of the PSS this led, for example, to the generation of in-depth knowledge and focus (for example, the role that the coach should play during the interaction session in Service Interface 5) and to a continuous process of refinement and striving for perfection (such as the refinement of the vibrotactile feedback in Service Interface 5). A characteristic of Provotypes is their ability to embody tensions, and with this provoke reactions and insights from the stakeholders (Mogensen, 1992). During the development of the PSS the prototypes clearly provided a challenge for partners to integrate their own knowledge and expertise, such as the knitting producer who developed a way to embed the conductive yarns in the tunnels with padding. This tension also attracted quality from outside: for example, the textile designer who contributed to the overall vision and aesthetic quality of the PSS.

The prototypes helped to establish horizontal collaboration in numerous ways and on different levels. In the case of Boundary Objects (Star & Griesemer, 1989), it could be enough that the prototype just offers a bridge between disciplines. An example is how the new vibrotactile canvas that was introduced in Tactile Dialogues triggered the service provider partners to come up with new ways that the vibration canvas could be used in their practice. It is important to realise that we did not necessarily understand the others' discipline in totality. Rather, by making it concrete and tangible we could grasp the value of the knowledge from the other discipline. Conscription Devices go one step further, as these actually allow the stakeholders to take part in the generation, editing and correcting, and with this form active links between the object and the context (Henderson, 1991). This was happening within Service Interface 2: here the technology and textile disciplines merged into a new transdisciplinary practice. Within this practice new solutions emerged, not necessarily part of either one of the disciplines. For example, the combination of a modular electronics toolset together with the knitted tunnels and padding created a totally new way of constructing the Tactile Dialogues v2, which none of the individual disciplines could have realised alone. A provotyping (Mogensen, 1992) approach can also recognised in the beginning of the process. By consciously embodying critical parts of the PSS, reactions from the different stakeholders could be elicited. For example, the personalisation of the digital layer that played an important role in Service Interface 6 (during the interaction) was a new element for many of the stakeholders. The prototypes in the beginning of the project, such as Music Fabric, Touch Sleeve and Blanket probed different ways to interact with the digital layer: for example, the sound, lights and vibration. These elements were provoking in the sense that they triggered critical reactions from the service provider, for example about the qualities of the material, the form factor of the object, and even the purpose of the product.

Bottom-up infrastructuring

One of the guiding theoretical frameworks which informed this chapter was the related work on Participatory Design. Based on Participatory Design, as a starting point for the design approach we took inspiration from a bottom-up infrastructuring approach. Within an infrastructuring approach the boundaries between use, design, implementation, modification, maintenance, and redesign are blurred (Karasti, 2014). Because of this, the focus of the design process moves from designing only for the end-user to a process where the infrastructure itself is designed. As a result, the direction in which the PSS is taken is also largely driven by the expertise and knowledge embedded within the infrastructure itself. The Growth Plan informed this approach, and particularly helped in setting clear expectations between the different stakeholders. In this section I will share a few speculative reflections on my experiences with the Growth Plan.

First of all, the Incubation phase was mainly defined by the set-up of the consortium itself. I have not been talking about this element, because it is outside the scope of the documented design research process. However, it is certainly clear that the way that the community was created in the beginning of the project through the platform of the CRISP project (CRISP, 2015) had an impact on the rest: for example, the fact that there were partners involved from the different disciplines such as technology, textile and service providers, and also the fact that these partners made an initial investment in order to have resources available in the form of hours to use in the collaborations.

During the Nursery phase we realised that our research-through-design approach actually resembled the PSS. Not only was the object of design embodied during the design process, but also the PSS itself was embodied during the whole design process. The project took place within a real context, in which the real community of practice was developing the PSS for the real experience: for example, by involving the disciplines that would eventually be involved in the PSS implementation itself, and by meeting with the partners in the context in which the PSS was located. This is strongly related to the embodiment starting point, where first-person perspectives and situatedness are crucial in the design approach. This is in line with other research projects from the Designing Quality in Interaction research group. For example, in order to do research about aesthetic interactions, the whole research project should be set up to focus on an aesthetic approach (Ross, 2008).

Within the Growth Plan, the Adoption phase has always been a source of confusion for me and the rest of the research team, and led to many discussions. The idea of transitioning to the Adoption phase certainly worked as a stimulus to drive the process. However, some questions remained. What are the critical conditions for this transition? And can we speak of one Adoption phase, or is this actually different based on which perspective we look at it from? One of the reflections based on the Adoption phase is that there are different types of Adoptions that can be identified within the process. Tactile Dialogues v2 transformed into a research vehicle, where it was adopted by the eldercare organisation for a longitudinal study with their clients (T9). They involved a different department for testing the prototypes. This study has been presented at an academic conference (Schelle et al., 2015). We could argue that at this point for us as researchers the PSS has matured to a point of *Academic Adoption*, and we do not need to continue the development any further. However, partners from the service provider would probably disagree with this perspective. For them, the PSS has not been fully adopted as a service. The *Service Adoption* is still ongoing as it is not yet in daily use. The CRISP modules transformed into a market-ready platform (P35), which has been distributed and sold among 2000 visitors to a technology fair in The Netherlands by the technology stakeholder: this can be seen as a form of *Commercial Adoption*. However, the Tactile Dialogues PSS as a whole has not reached the stage of commercial adoption where it is sold in a service context. The textile designer (S6) and I continued to collaborate in projects and developed prototypes such as the BB.Suit (P26) and the BB.Suit Clean Air (P31). These have been presented during various design events, and elicited many responses from press and other societal channels, which could be seen as a form of *Societal Adoption*. What these have in common is that my role as designer has faded into the background, not being totally involved as a driver of all the subprojects. The stakeholders implemented various aspects from the PSS in different ways (very different than expected in the beginning).

4.Scale of the community: How prototypes embed the knowledge of the people who are not present

4.1 Introduction

Within Chapter 3 I established three roles of how the prototypes move the design process of the Embodied Smart Textile Services forward: prototypes assure the situatedness of the PSS; prototypes increase the quality of the PSS; and prototypes trigger horizontal collaboration in the PSS. In this chapter I am going to zoom in on how the prototypes triggered these horizontal collaborations in the community that was involved in the design process of the Tactile Dialogues and Vigour Embodied Smart Textile Services. From the process overview figure shown in Appendix A, it is visible that a bottom-up infrastructuring process consists of a rich dynamic between meetings with stakeholders, testing and prototype development. Key to this process was the incorporation of multiple types of skills, a variety of knowledge and different viewpoints.

Based on the literature introduced in Chapter 1, it is clear that a designer is not able to integrate all these different viewpoints alone, but requires collaboration and participation of a range of other stakeholders during the design process. The main challenges in these types of collaborative approaches are to cross the boundaries of several organisations, manage the expectations of all the stakeholders involved, and meet the demands on all the different levels (Telier et al., 2011). Within these challenges, knowledge sharing and knowledge integration are critical characteristics of a successful collaborative design project (Kleinsmann & Valkenburg, 2008).

As observed in the previous chapter, it was the transitions between the phases of the Growth Plan that played a particularly critical role in the development. In these transitions it was necessary for the stakeholders to readjust to the changes in the process. For example, to bring the quality of the Blanket prototype (P15) to a next level, the textile designer (S6) had a significant impact on some of the decisions that led to the design of Tactile Dialogues v2 (P29), such as the pillow form factor and the specific graphic pattern. In this chapter I will zoom in on these transitional moments, and investigate in detail how the collaboration between the stakeholders and me took place. The prototypes that were used in these meetings will be the main lens to investigate these collaborations. I will try to answer the following question:

> "How did prototypes support the collaborative design process within a community during critical transitions of the process, leading to the design of Embodied Smart Textile Services?"

Research Approach
In order to answer the research questions I will investigate how the stakeholders and I shared and integrated relevant knowledge, supported by the prototype, during the critical phases of the design process. Recent studies (Deken, Kleinsmann, Aurisicchio, Bracewell, & Lauche, 2009; Deken, Kleinsmann,

Aurisicchio, Lauche, & Bracewell, 2012) that focussed on knowledge sharing and integration between novice and expert designers determined two main variables to study in these processes: the Conversational Balance (*how* things were said) and the Design Activity (*why* things were said). In this chapter I will introduce a new category to codify *what* things are said: Design Content. Conversational Balance has a history within studies of information technology to determine the information flow within technological systems (Cybenko & Brewington, 1999). Similar concepts can also be mapped to conversations to determine how the conversation "flows" over time. Design Activity within a team has been described as a combination of content-oriented activities (for example, generating new solutions) and process-oriented design activities (such as planning the group process) (Stempfle & Badke-Schaub, 2002). As previously established, within the development of PSS's the collaboration takes place between partners with different disciplinary backgrounds. To reflect this specific nature of the collaboration I added a third variable to the definition of knowledge sharing and integration: the disciplinary knowledge that is communicated (what was said). It consists of the important domains of knowledge that people used in the meetings, and can help to find out how the prototype triggers people to use their knowledge about specific domains, and how it changes over time.

Eventually the relations between the three variables can explain how knowledge was integrated and shared during the PSS design process. Through the relations between the three variables (also visualised in Figure 4.1) I will pursue the main research questions of this chapter:

1. The relation between the Conversational Balance (how things are said) and Design Activity (why things are said) leads to the question: How do the prototypes support the partners to contribute to the PSS design process?
2. The relation between the Conversational Balance (how things are said) and Design Content (what things are said) leads to the question: How do the prototypes support the partners to share their disciplinary knowledge?
3. The relation between the Design Activity (why things are said) and Design Content (what things are said) leads to the question: How do the prototypes support integrating disciplinary knowledge for the PSS design process?

Structure of the chapter

To approach the previously outlined sub-questions I will zoom in to the collaboration process to unravel how this dynamic process between prototypes, stakeholders and myself lead to the design of Embodied Smart Textile Services. As a first step I will introduce in more detail the *Data Selection* procedure. I have selected eight design meetings that took place during the critical transitions. I will indicate in more detail why these were critical transitions, and discuss how the prototypes changed during these transitions. In the *Data Documentation* section I will explain in more detail how the design meetings were structured and documented. I will provide some examples of the richness of data that comes from these meetings, and also my personal reflection as designer about why

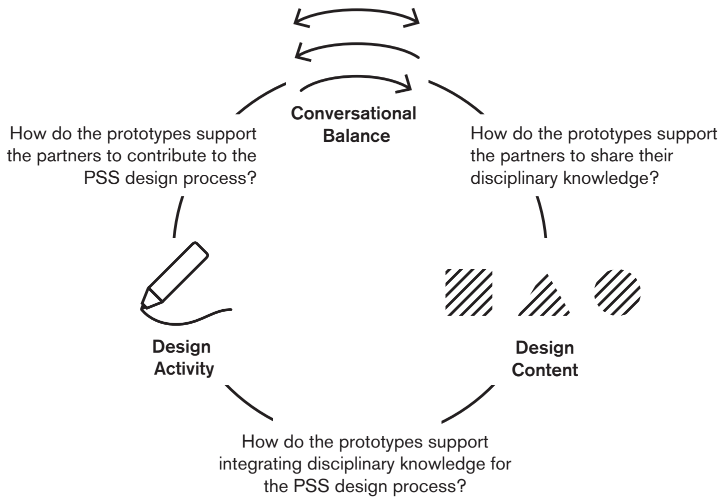


Figure 4.1: Overview of how the three research questions relate to the three variables.

those particular meetings were important. Within the *Data Codification* section I will discuss the three coding schemes that were used to conduct the protocol analysis. This codified data functioned as the main input for the *Data Analysis* section. I will introduce the correspondence analysis method, which I used to analyse the different possible correlations between the coding schemes. In the *Findings* section I will discuss the findings for each prototype, and for the overall conclusion per correlation per cluster that emerges. Finally, in the *Conclusions* section I will try to answer the three research questions by triangulating between the result of the data analysis, the excerpts of the design meetings, and my own reflections.

4.2 Data Selection

To gain further insights about how the prototypes supported the collaboration between the partners, a subset of eight design meetings was selected from the design process. The reason for choosing these meetings is that critical choices were made in all of them that preceded the transitions between the phases of the Growth Plan.

Transitions
I will first go into more detail to describe the important transitions between the phases of the Growth Plan, based on my reflections as a designer, and particularly focus on the collaboration related to these transitions. More insights and the descriptions about the phases of the Growth Plan itself are described in Chapter 3. The main insights from these transitions are shown in Table 4.2.

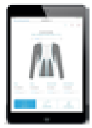
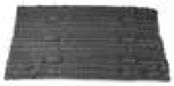
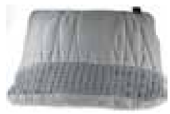
Incubation	Incubation – Nursery	Transition 1 characteristics	Nursery – Adoption	Transition 2 characteristics
 Stretch Sweater (P3)	 Vigour v1 (P14)	- From exploration to deepening the questions - From inside the lab to moving outside the lab - From multiple textile techniques to selecting knitting - Off-the-shelf to custom-made textile and electronics	 Vigour v2 (P25)	- From broad-expertise to in-depth expertise - From proof-of-products to proof-of-services - From product with service elements to ecosystem - From one-offs to larger series of prototypes
 Touch Sleeve (P4)	 Vigour v1 Interface (P13)		 Vigour v2 iPad application (P21)	
 Knee Band (P5)	 Blanket (P14)		 Tactile Dialogues v1 (P23)  Tactile Dialogues v2 (No electronics, P20)	

Table 4.2: Overview of the different prototypes and the important transitions.

Transition 1 (Incubation to Nursery): The Incubation phase started mainly with discussions with the partners from the eldercare organisation (S2, S3, S5, S16). Eventually the Vigour v1 (P14) and Blanket (P15) prototypes emerged from this collaboration during the transition. These prototypes had in common that they focussed on movement and dementia, a choice based on the expertise in this topic from the eldercare stakeholders. Practically, in order to develop the prototypes, I started with making textile samples in the Wearable Senses Lab, using different textile techniques such as felting (Pr1), sewing, adhesives, embroidery (Pr2) and eventually knitting (Pr3, Pr4 and Pr5). It became clear that I was transitioning into a different phase because this focus on knitting as a textile technique was happening. This offered the possibilities to create stretchable materials, which matched the need for comfort in the context of physical rehabilitation. After the first prototypes made inside the Wearable Senses Lab (P3, P4, P5) I started the collaboration with knitting experts S18, S34 and S44 and designers S6 and S15. The first prototypes were made with off-the-shelf technology such as Velostat material for pressure sensitivity, XBee for wireless communication, conductive yarns for stretch and touch, and vibration for feedback. I used an off-the-shelf platform (LilyPad) to connect these elements. In the transition to

Nursery I took the integration of conductive thread as stretch and touch sensors in knitted textiles as a starting point for the exploration together with engineer S7. Soon after this we developed a first version of custom-made electronics to process touch and actuate light, because we found that the centralised approach of LilyPad was not sufficient for the prototypes we were developing. Based on the reflections about the transition from Incubation to Nursery I came to the following characterisations of the transition:

- From exploration to deepening the questions: it was necessary to stop developing my personal explorative projects in order to be able to focus on deepening the context that combined the skills and expectations from the partners.
- From inside the lab to moving outside the lab: inside the Wearable Senses Lab was about exploring the available machines and obtaining the basic skills underlying these techniques. At some point I reached the limitations of the facilities in the lab and my own skills. Other facilities and partners with specific expertise needed to be involved.
- From multiple textile techniques to selecting knitting: eliminating techniques that I did not want to focus on, such as weaving and embroidery. This choice was related to the fit for the context (wearability and comfort) and the available facilities outside (the textile developers and designers who became involved).
- Off-the-shelf to custom-made textile and electronics: develop an understanding based on off-the-shelf materials, but this needed to become specific. Off-the-shelf components had too many capabilities which made scalability difficult and expensive.

Transition 2 (Nursery to Adoption): After the first tests with the clients of the eldercare provider we started to develop the new prototypes. This was a collaboration between many stakeholders from textile, engineer, service provider and Industrial Design disciplines. The goal was to deploy the two PSS's on a larger scale in order to be able to discover the implications of Embodied Smart Textile Services. This process took many iterations of the prototypes and smaller explorative tests. Eventually, Tactile Dialogues v2 (P29) was tested over a longer period of time, and new details of the service surfaced during these use phases. We realised after the tests with Vigour v1 (P15) and Blanket (P14) that the detailing and aesthetics of the garment and textile were crucial for acceptability. Insights from the design of the product had an impact on the design of the Product-service System. To develop the new prototypes we involved two designers in the project, who focussed on textile and fashion elements (S6 and S15). Not only did they define the physical appearance of the PSS's, but also at the same time new ideas about the customisation and personalisation of the services emerged, such as the personalisation of the vibrotactile behaviour of Tactile Dialogues, and the customisation of the sounds for Vigour. To be able to scale up the prototypes we involved industrial partners from the textile industry. With this involvement we aimed to take the constraints of a production environment into account during the design process. This collaboration was not easy: we underestimated the amount of development and design the textiles needed. The technology platform that we developed with the technology partner was used in new ways that we did not imagine beforehand. For example, new software functionalities needed to be added, and new connectors to connect the textile with the technology had to be created. Finally, the experiences from using the first version of the electronics platform were transferred back to the electronics partner, who developed a new generation for commercial production (P34). Based on the reflections about the transition from Nursery to Adoption the following characteristics come forward:

- From broad-expertise to in-depth expertise: during this transition the PSS was driven by the in-depth expertise of the involved stakeholders. In addition, new people needed to be involved in order to continue the development: for example, for the eldercare provider it was not enough to only involve physical therapists, we also needed to involve motivational therapists. From the textile side we started to work with textile designers and producers. This meant for me that I could also focus on my own expertise, and pay more attention to the smart textile integration and Interaction Design.
- From proof-of-products to proof-of-services: the prototypes in the Nursery phase functioned mainly to clarify the value of the PSS: for example, the different iterations of Tactile Dialogues (P20, P23, P29, P33) were necessary to prove the value. In the transition to the Adoption phase this also changed to discovering the implications of further deployment of the services: for example, through the test T9.
- From product with service elements to ecosystem: it became more important to implement the product into the existing service of the eldercare provider. In addition, the involvement of the textile designers showed the possibilities of implementing the service elements, starting with production (for example, to customise the fabric to the eldercare organisation).
- From one-offs to larger series of prototypes: by involving the manufacturing partners in this iteration we tried to scale up the production of the prototypes. One of the lessons was that before scaling up it is necessary to be clear about the basic elements of the PSS, because it is harder to develop together with production stakeholders.

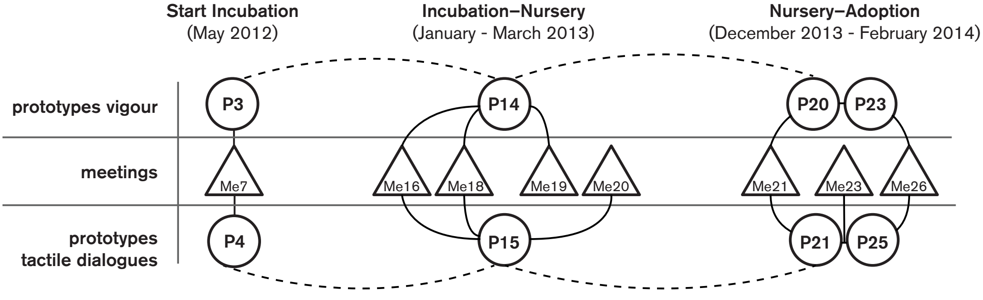


Figure 4.2: Overview of the eight design meetings that were selected. The triangles represent the meetings, the squares represent the different prototypes.

Meetings overview
In order to answer the research questions outlined in the introduction of this chapter, a set of meetings was selected from the overall design process discussed in the previous chapter (Process Visualisation). The main criterion for selecting these meetings was that they took place during the transition between the phases of the Growth Plan: for example, because prototyping processes or tests had finished and new steps needed to be taken. In some sense, the prototypes at that stage "asked" for a transition: a new step in the process was necessary to move the development of the design forward. These meetings often evaluated the current status of the PSS: "this can be done better", "this has to be improved" and "it would be nice if we have this" were common statements during these meetings. Furthermore, the meetings that were selected discussed the same prototype from different viewpoints (eldercare organisation, technology and textile stakeholders).

The goal of selecting these meetings was to investigate the role of the prototypes during transitional moments for both the Vigour and Tactile Dialogues Embodied Smart Textile Services. Furthermore, the set contains meetings during the transition with all the stakeholders who were involved at that point: for example, sometimes these were stakeholders who were just getting involved in the process, and sometimes these were stakeholders who were already involved in the phase before the transition. The resulting dataset of eight design meetings contains three meetings (Me7, Me16 and Me21) with stakeholders from the eldercare service provider: two meetings (Me18 and Me26) with the technology partner, and three meetings (Me19, Me20 and Me23) with the textile partners. Meeting Me7 was not identified as a transition from one Growth Plan phase to another. However, this meeting triggered a crucial transition within the Incubation phase. After this meeting we moved from multiple explorative prototypes to two clear PSS directions. Figure 4.2 shows the moment in the process that the selected meetings (the triangles in the Figure) took place, and the prototypes of the specific Embodied Smart Textile Service (the circles) that were present during those meetings. Table 4.3 shows the details of the selected meetings: the discipline of the partners in the meeting, the phase of the Growth Plan that the meeting was in, the prototypes that were present during the meeting, and the date the meeting took place. Before analysing these meetings, I will introduce how the meetings were documented, how the meetings were structured, and describe in more detail what happened during the meetings with the help of some examples.

4.3 Data Documentation

From the beginning of the project I started to document the design meetings that took place. Since the research methodology was not yet defined from the early stages of the project, the documentation's method also grew along with the project. During the Incubation phase I mostly relied on recording audio and taking

Figure 4.3: The footage resulting from the two-camera set-up used during meeting Me16.

written notes. During the Nursery phase I started to add video to these methods. Figure 4.3 shows the two-camera viewpoint that was used to document important reflection meetings. During the Nursery phase I also started to use a more structured approach to document and structure the meetings. In this chapter I will describe and reflect on the documentation of each phase. For these reflections I will make a distinction between *design* reflections, to indicate what I learned for the design process and *design research* reflections in order to discuss how the meetings during the phase influenced the design research process. These reflections have been written a posteriori the actual process.

Code	**Partner**	**Growth Plan**	**Prototypes**	**Date**
Me7	Eldercare Organisation (S2, S3, S16)	Incubation	Stretch Sweater (P3), Touch Sleeve (P4), Knee Band (P5)	21-May-12
Me16	Eldercare Organisation (S2, S3, S5)	Incubation – Nursery	Vigour v1 Interface (P13), Vigour v1 (P14), Blanket (P15)	22-Jan-13
Me18	Technology (S7)	Incubation – Nursery	Vigour v1 Interface (P13), Vigour v1 (P14), Blanket (P15)	05-Mar-Me13
Me19	Textile (S6, S24)	Incubation – Nursery	Blanket (P15)	28-Mar-13
Me20	Textile (S15, S25)	Incubation – Nursery	Vigour v1 (P14)	01-May-13
Me21	Eldercare Organisation (S2, S3, S5, S13)	Nursery – Adoption	Tactile Dialogues v1 (P23), Vigour iPad application (P21), Vigour v2 (P25)	05-Dec-13
Me23	Textile (S6)	Nursery – Adoption	Tactile Dialogues v1 (P23), Tactile Dialogues v2 (No electronics, P20)	28-Jan-14
Me26	Technology (S7)	Nursery – Adoption	Tactile Dialogues v1 (P23), Tactile Dialogues v2 (No electronics, P20), Vigour iPad application (P21), Vigour v2 (P25)	20-Feb-14

Table 4.3: Detailed overview of the eight design meetings that were selected.

Incubation

Goal of the meeting: Within the Incubation phase one meeting was selected (Me7). The main reason for choosing this meeting was because of the transition it triggered within the Incubation phase itself. Before this meeting the process had mainly consisted of explorative prototypes, quite broad in aim and looking for direction. Directly after this meeting the process converged into exploring two main directions: exploring tools and services for activating people with severe dementia (which became Tactile Dialogues), and the other one exploring motivating young, independent people in the beginning stage of dementia to move (which became Vigour). The details of the meeting can be found in Table 4.4. The purpose of the meeting was to discuss the three prototypes that were developed: Stretch Sweater (P3, measuring movement and communicating with sound with family), Touch Sleeve (P4, eliciting social communication and the feeling of achievement during group rehabilitation exercises), Knee Band (P5, tactile feedback to help people with Parkinson's disease walk). During the meeting the physiotherapists showed a product from their practice, an electric muscle stimulation device (TENS).

Code	Participants	Objects	Excerpt
Me7	Physiotherapists (S2, S3, S16), Design Researcher (S1)	Stretch Sweater (P3), Touch Sleeve (P4), Knee Band (P5), visualisations of the three concepts, electric muscle stimulation device	Physiotherapist (S2): This could be something fun that the motivational therapist could use, or the family. Certainly the family in that phase, what I just mentioned about people with severe dementia, those people who just sit in a chair and cannot talk anymore, then it is very nice to offer the family something that they can do. Sometimes they have these pillows they use to play. But I can also imagine if there is something, with a light, then they could do it together, even if it is for a short time, because they cannot keep using it for hours.

Table 4.4: Details of the meeting that took place during the transition within the Incubation phase.

	0 min	14 min	25 min	45 min	52 min – 63 min
Me 7					
Objects	*Stretch Sweater (P3)*	*Touch Sleeve (P4)*	*Knee band (P5)*	*TENS demo*	
Steps	Demonstration				Finishing

Figure 4.4: Overview of structure of meeting Me7 during the Incubation phase. The objects layer shows the name of the prototype or object being discussed. The steps layer shows the purpose of the discussion: for example, a demonstration when the prototype was demonstrated during the discussion.

Reflection as designer: During meeting Me7 the prototypes were demonstrated, tested and reflected on. Concrete steps to develop the PSS's were made: for example, from the Touch Sleeve (P4) the direction of developing textiles focussing on sensory stimuli emerged (shown in the excerpt). The physiotherapists

Figure 4.5: Physiotherapist A is controlling an electric muscle stimulation device, while physiotherapist C shows how to connect the electrodes.

introduced one of their tools, a TENS muscle stimulation device (one of the physiotherapists holds the device in her hand in Figure 4.5). By their explaining how this tool is bought by the organisation, how they need to buy new electrodes for each client, I started to understand some of the underlying business models in the physiotherapy world.

Reflection as design researcher: During the meetings in the Incubation phase of the process it became clear that the prototypes very much guided how the meeting progressed. The meeting was almost automatically structured according to the prototypes, as the structure in Figure 4.4 shows. Each prototype was briefly demonstrated, after which there followed an evaluation by the therapists and me, which led to the conclusions and a discussion about the next steps to take. It was during this meeting that we realised the potential of using the prototypes to drive the process and trigger the collaboration further.

Incubation – Nursery

Based on the insights from the meetings during the Incubation phase we decided to structure the design meetings more. The underlying reason for this decision was that it would help to compare the data better between sessions, but also to guide the discussion to help the design process directly. As introduced in Chapter 1 I will use co-reflection as a method to guide the design meetings and trigger sense-making. In this chapter I will not go further into the sense-making approach, this will be further discussed in Chapter 5. However, I will shortly introduce the phases of co-reflection, in order to understand why the meetings were structured in this way. Co-reflection is a collaborative critical thinking process which aims to trigger sharing knowledge, intersubjective understanding and relationship building between people (Yukawa, 2006). It can be used in meetings with multiple stakeholders to reflect on different ideas and to trigger a change in the frame of reference for both stakeholders and design researcher (Tomico & Garcia, 2011). Co-reflection consists of an Exploration, an Ideation, and a Confrontation phase (Tomico, Frens, & Overbeeke, 2009).

In order to document both the individual perspectives of the stakeholders and the discussion, the participants were asked to document their reflections on a form before discussing their findings together. In these meetings I was also a participant: next to guiding the structure of the meeting, I followed the same steps as the other participants as much as possible. After the prototype was introduced by me and the stakeholders, who developed parts of the prototype, the meeting would be structured in four steps. Based on the Exploration phase of co-reflection, the goal of the first two steps of the meeting was to explore the reflections about the prototype which was currently being evaluated. This was done in the first step by asking the participants to reflect on their individual contributions, and write down their thoughts on their forms. During the second step of the workshop, the participants were asked to indicate positive and negative aspects of the current prototype on their individual forms. Based on the Ideation phase of co-reflection, in the third step of the meeting the participants were asked to individually use these positive and negative aspects to describe an “ideal future service” and sketch it out on separated papers. Based on the Confrontation phase of co-reflection, in the final step of the meeting it was the goal to collaboratively decide on concrete activities for the stakeholders to continue working on. An example of the filled-in forms for one of the participants for the second and third steps is shown in Figure 4.6. Table 4.5 shows an overview of my interpretation of the co-reflection phases that I started to adapt, starting from meeting Me16.

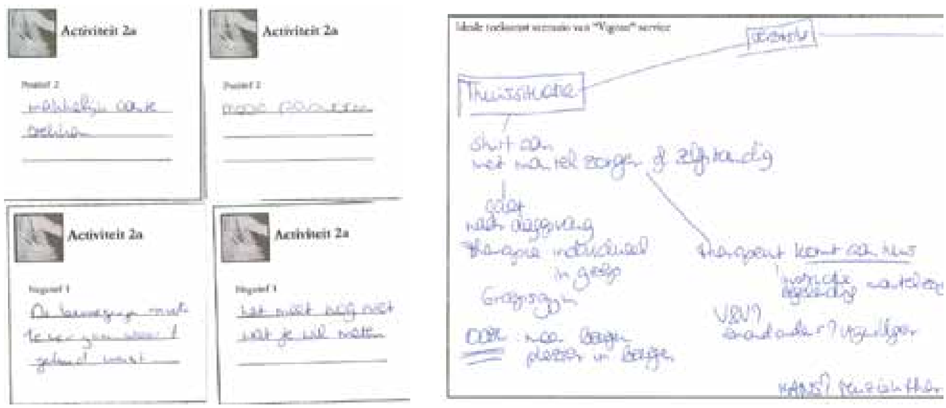


Figure 4.6: Example of the filled-in forms. The left part shows the positive and negative aspects, part of step 2: for example, “easy to wear”, “nice fit”, “the movements need to go to far before the sound starts working”, “it does not measure yet, what we want it to measure”. The right form shows the description of a participant about their ideal future service as part of step 3. This particular scenario discusses different possibilities of the Vigour PSS: for example, the possibility of a physiotherapist doing house visits to instruct both the client and the informal caregiver to do the exercises together, and the possibility of wearing the shirt for group activities, where the overall goal is to make moving more fun.

Meeting Step	Purpose	Question
Step 1	Reflect on origin design decisions within prototype	Can you use the prototype to indicate your contribution to the project?
Step 2	Reflect on positive and negative aspects of current prototype	Write down two positive and two negative aspects of the current prototype
Step 3	Generate ideal future service	Sketch ideal future service, including important elements from previous questions
Step 4	Generate concrete next steps	Which requirements can we take from the ideal service which are a priority to test first?

Table 4.5: Overview of the four steps that were used to structure the meeting starting from the Nursery phase.

Goal of the phase: The meetings selected from the Nursery phase took place after two new prototypes had been developed: Vigour v1 Interface (P13), Vigour v1 (P14) and Blanket (P15). An overview of the meetings can be found in Table 4.6. The meeting with the stakeholders from the eldercare organisation (Me16) was planned to discuss the preparations for the upcoming user tests based on the prototypes. Before this meeting, the two therapists used the prototypes during the course of one week to become familiar with the product. The meeting with the technology stakeholders (Me18) had as its main goal the evaluation of the integration of the electronic modules that were developed, and the new software that needed to be created. The textile designer and textile producer had their first meeting (Me19) to discuss the new iteration of Blanket. In the meeting with the fashion designer and the other textile producer the meeting (Me20) was also planned to kick-start the collaboration, but in this case about the new iteration of Vigour.

Code	Participants	Objects	Excerpt
Me16	Physiotherapists (S3, S16), Eldercare manager (S5), Design Researcher (S1)	Vigour v1 Interface (P13), Vigour v1 (P14), Blanket (P15)	Physiotherapist (S3): And I also thought that you could perhaps make these fringes a little thicker, or use rustle material. I like it a lot that there are so many different small things. That it also feels different, it could be perhaps a little more on some pieces. And I find it positive that you can make contact. So if you have one person there, you feel more on the other side. You could also let people place their hands. That caregivers can really make contact, and they use it together. And we should perhaps make an instruction of this, or demonstrate all the possibilities. And that they have to be happy with small effects. People are always looking for large effects, but it is the small things which are very important.

Me18	Engineer (S7), Design Researcher (S1)	Vigour v1 Interface (P13) Vigour v1 (P14), Blanket (P15)	Engineer (S7): Well, I think it is an idea to place the modules very locally, especially because you can save a lot of wires. In that case you would have only four wires which have to be placed in the garment. But if you take a LilyPad with nine motors, then you already would require ten wires in your garment, so I really think the modules are a good idea.
Me19	Textile Producer (S24), Textile Designer (S6), Design Researcher (S1)	Blanket (P15), scarf designed by label Textile Designer, samples of different textile qualities from Textile Producer A, different conductive yarns brought by design researcher	Textile Designer (S6): Perhaps it is better to say that for this one we use separate pattern parts, so one can be a very soft cotton and the other a more raw wool, so that you also get a different tactile feeling or a different sense. That could be done within the framing that we have, then I think we can look afterwards if it is technologically feasible. And if it just works, than we can play afterwards with the shape and see how far we can get.
Me20	Textile Producer (S25), Fashion Designer (S15), Design Researcher (S1)	Vigour v1 (P14), sample book textile qualities from S25, inspiration board with research from S15, vibration module and electronics from S1	Fashion Designer (S15): What I was thinking about, I'm not sure if it is technically feasible, and if it works, what if you made a double-knit with on the backside a solid structure. You could use wool yarns, and on the front a more open knit structure, to limit the amount of conductive yarns. Textile Producer (S25): That's possible. Fashion Designer: Although I'm not sure if the stretch measurements will be sufficient. Design Researcher: We would have to test it, I think.

Table 4.6: Overview of the four design meetings that took place during the Incubation – Nursery transition.

Reflections as designer: Figure 4.7 shows the actual structures of the different meetings in this phase. The challenge in this phase was to introduce new partners to the existing group of stakeholders, and bring them into the ongoing development process. This was particularly hard, as the first prototypes were still being developed and evaluated, and the value for the clients of the eldercare provider still had to be fully understood (as the selected Excerpt from meeting Me16 shows). Simultaneously the prototypes showed the first uses of the electronic modules, and by this we could grasp the implications of a decentralised approach (shown in the excerpt of meeting Me18). The early integration of the electronics helped to discuss the problems with the hardware, and even triggered the engineer to give advice about the electronic circuits in the prototypes. A large part of meetings Me19 and Me20 were about understanding the goals of each other in the project. The prototypes and objects played a role in bringing in my expectations (the prototypes would be extensively touched, inspected and tested in the meetings with the textile partners, as shown in Figure 4.8). On top of that, all the other textile partners brought in their own objects to make their expertise and expectations tangible (such as material samples and yarns). Finally, the textile producers and designers also managed to go into depth, and decide on an approach to take.

Reflections as design researcher: The meetings in this phase were the first time to use the structured co-reflection approach, with forms that the participants had to fill in. The structure helped particularly to let all the people express their opinions (including voicing my own opinion) and to keep the conversation balanced. A valuable insight about the use of prototypes during the session was that the therapists would take responsibility to explain the prototypes to me (instead of the other way around, which it was in previous meetings). One of the physiotherapists started to wear the shirt, and explained by demonstration which things worked and which parts needed improvement. Furthermore, there was an extensive use of different types of objects by the textile stakeholders during the meeting that drove the discussion more than the meeting structure itself.

Figure 4.7: The four meetings that were included in the Incubation-Nursery transition. As visible in the steps layer, there are some moments in the meetings where no prototype was discussed. In Finishing during meetings Me16, Me18, Me19, and Introduction in Me19. During these moments the conversations often went in the direction of more managerial processes (making appointments), or off-topic conversations. Another side note is that during meeting Me19 the steps structure was not followed as planned. This has to do with how the meeting progressed over time. Some of the participants were not comfortable with filling in the form.

Figure 4.8: The stakeholders examining and touching the Blanket prototype during Me19.

Nursery – Adoption
Goal of the phase: The structure and documentation methods of the meetings for this phase have stayed the same as the Incubation-Nursery transition. Most meetings in this phase were already nearing the end of the larger CRISP project, in which this research was embedded. As a result, the goal of these meetings was not so much anymore on the development of new elements, but rather on deepening the service aspects and evaluating the Embodied Smart Textile Services in their current form. For this round of meetings the new prototypes of the Vigour and Tactile Dialogues Embodied Smart Textile Services were demonstrated and evaluated. An overview of the meetings and the prototypes used is shown in Table 4.7. The physiotherapist (S2) from the eldercare organisation already had experience with the new Vigour prototype during the development and testing of the iPad application with the Interaction Designer. The goal of meeting Me21 was to evaluate the iPad application (P21); the new prototype of Vigour (P25) and the first version of the Tactile Dialogues pillow (P23) was evaluated as well. The meeting (Me23) with the textile designer had as a goal to particularly evaluate the interactivity within the Tactile Dialogues pillow. With the engineer we aimed to evaluate the two prototypes during meeting Me26, with a special focus on the connections between the electronics and textiles, and the business plan.

Code	Participants	Objects	Excerpt
Me21	Physiotherapists (S2, S3), Eldercare manager (S5), Interaction Designer (S13), Design researcher (S1)	Vigour iPad application (P21), Vigour v2 (P25), Tactile Dialogues v1 (P23)	Physiotherapist (S3): My ideal was: all residents receive a garment, they wear the cardigan. Data is being collected, for now without music. The data is collected about how much they currently move, because this is being monitored. As a result of this, a movement plan is drafted. The movement plan can be very broad, so not necessarily just physiotherapeutic, but also volunteers, caregivers, family. The plan includes exercises with the garment and the music; also walking exercises if the client can still do this, or sport activities that they did before, activities they liked to do, because this is also moving. Then, by wearing the cardigan, the movement activities are being evaluated, to see if it is more. Because this could be visualised in a nice graph. And if they move for a longer time, then the healthcare will remain easier, and the care will be less heavy, the care will be cheaper and affordable. Prevention!
Me23	Textile Designer (S6), Design Researcher (S1)	Tactile Dialogues v1 (P23), Tactile Dialogues v2 (No electronics, P20)	Textile Designer (S6): We also need those fibres, which vibrate! Okay, how are we going to fix that? Who can we ask for that? That's why I think South by Southwest will be a good opportunity, because there those people walk around there. I think we need to do something fun, to make that very clear, and also by using this project as a basis. I would love to give a presentation there about this project. That we bring it in an attractive way, and also show the commercial opportunities, but then in the shape of a suit.
Me26	Engineer (S7), Design researcher (S1)	Vigour iPad application (P21), Vigour v2 (P25), Tactile Dialogues v1 (P23), Tactile Dialogues v2 (No electronics, P20)	Engineer (S7): For the cardigan I can imagine a company. If you want to start a company for the cardigan, you are already quite far with the development of the concepts of the service. But I think that the pillow at this moment is still less strong, based on what I hear now. What is really the goal of the pillow and the interaction, and what should the user do or how should it be used? Yes, I think that it is very interesting to use, but I cannot imagine yet what it could offer for me, besides that it is fun to play with it for a while.

Table 4.7: Detailed overview of the three meetings that took place in the Nursery – Adoption transition.

Reflections as designer: During the meetings in this phase much effort was needed to synchronise the projects between all the partners. For example, the physiotherapists had been involved in the development of the iPad application. However, the development of the garment itself took place with the fashion designer and the textile producer. Because of this, the prototypes became even

Figure 4.9: The structure of the three meetings that were included in the Adoption phase.

more the object that embodied the new developments of the PSS, and drove the explanation that was necessary to update the partners: for example, in Figure 4.10 where the engineer is inspecting the connectors used in the new Vigour prototype to connect the modules to the stretch sensors. On the other hand, the projects in this phase showed the promises, and fuelled the imagination of everybody involved. The eldercare partners dreamed about integrating the Vigour aspects in a holistic approach to helping people move more. The textile designer in meeting Me23 talked about his vision to bring the lessons learned in the Tactile Dialogues pillow to whole new applications (which would become the BB.Suit, P26).

Reflections as design researcher: For Vigour we could move in the details of how the application worked together with the shirt, and even how the different parties such as insurers were involved (see the excerpt in the table for both the physiotherapist in meeting Me21 and the engineer in meeting Me26). The prototype of Tactile Dialogues was at this point not as far developed. The electronics still needed to be integrated into the fabric. Therefore the feedback was still much more about establishing the initial value of the PSS, instead of moving to a next stage in which other parties could be involved. This raises many questions about the design for Embodied Smart Textile Services: for example, about which fidelity these prototypes need to be developed. Is it true that with the increasing development of the prototypes of the PSS's, the discussions also become more in-depth, and partners are better able to voice their expertise and integrate their specialist knowledge in the design of the PSS?

Figure 4.10: Engineer (S7) and myself are looking at the current connectors used in the Vigour prototype.

4.4 Data Codification

During the design meetings I noticed as a designer that the prototypes played a crucial role in developing the Embodied Smart Textile Services. For example, how the Touch Sleeve (P4) led to a focus on the Tactile Dialogues direction during a turning point in the Incubation phase. And how the Vigour v1 (P14) and Blanket (P15) prototypes helped to bring in the textile producers (S24 and S25), textile designer (S6) and fashion designer (S15) when transitioning from Incubation to Nursery. This led to the hunch that, in order to move this collaborative process forward, the prototype actually plays a large role in sharing knowledge between the stakeholders. In order to investigate these notions I chose a method that integrated elements of qualitative and quantitative analysis, which would allow me to get a more objective insight into what happened during the meetings.

Protocol Analysis was chosen as the methodology to make sense of the data because of its long tradition in empirical design research, and its applications in the middle ground between experimental methods of natural sciences and the purely observational methods of social sciences, and is applied in design to analyse collaboration (Dorst, 1995). Within design research, *Protocol Analysis* i s a method used to study collaborative practices: for example, by codifying conversations. Within this analysis I will use a specific methodology within protocol analysis called *verbal analysis*. The subtle difference lies in the fact that protocol analysis tries to capture the processes and sequences of actions of solving a problem or making a decision, with a predefined model to test in mind.

The goal of verbal analysis is to find out what the subject is actually doing, to seek the model that underlies their actions (Chi, 1997). An advantageous characteristic of the method is that it functions as a bridge between the macro-level analysis of the previous chapter, and the micro-level analysis to come in the succeeding chapter. In previous studies it was shown that this type of bridging analysis can lead to a more comprehensive understanding of the discourse (Hmelo-Silver & Barrows, 2008; Hogan, Nastasi, & Pressley, 1999). Related studies show that it is possible to come to an understanding of conversational behaviour and shared information by analysing the verbal interpersonal communication during design meetings (Deken et al., 2012; Luck & McDonnell, 2006). Rather than zooming in on the team dynamics underlying the interactions, it is my goal to better understand what the role of the prototype was when the partners from various disciplines and I exchange information during the design meetings. This positions the prototype as the main lens through which the data is analysed. Within verbal analysis methods there has not been much emphasis on taking the object as the starting point. I propose the combination of insights that can be gained from a verbal analysis study, with the knowledge about the prototype itself. Together these layers can provide a unique perspective on how the stakeholders used the prototypes in order to share their knowledge in the design process.

To get a deeper understanding about the role of the prototypes, the data was combined per prototype. The conversations during the selected eight design meetings were captured with audio and video recordings. The verbal communication was transcribed and functioned as the basis to codify the interactions. With the coding schemes I aimed to capture the Conversational Balance (how things were said), the Design Activity (why things were said), and finally which Design Content was communicated (what was said). These three coding schemes are visualised in Figure 4.11.

Figure 4.11: Visualisation of the three coding schemes.

The underlying model of my approach is shown in Figure 4.12: the prototype (P) has a certain influence over the conversation between the two stakeholders (S1 and S2). The three coding schemes are used to model these conversations, with a goal to better understand the role of the prototype. For the Conversational Balance and Design Activity coding schemes, earlier studies focussing on the information exchanges between novice and experienced design engineers during consultation meetings were examined (Deken et al., 2009, 2012). The codes within a coding scheme are mutually exclusive, meaning that a segment could only be codified with one code from within a coding scheme, but could be simultaneously codified by two or three coding schemes. The coding schemes were allowed to evolve during the analysis: if a segment could not be captured

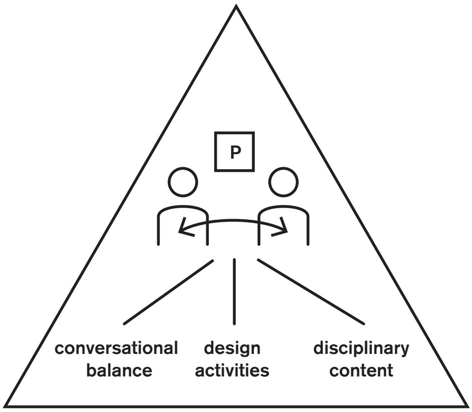


Figure 4.12: Visualisation of the role of the prototype during the design meeting, from the perspective of the three coding schemes: Conversational Balance, Design Activity and Design Content.

with the existing coding scheme a new category was introduced or an existing category was redefined. I will introduce my coding categories in the next section.

Conversational Balance
Conversational Balance functions as a way to codify how the conversation "flows" over time. Within the field of information technology, useful concepts have been developed to model information flow in technological systems: information push and information pull (Cybenko & Brewington, 1999). In previous protocol analysis studies these definitions have been applied to model conversations between people (Deken et al., 2012; Hmelo-Silver & Barrows, 2008).

Within a conversation a distinction can be made between whether a person is requesting and receiving a specific piece of information, which is defined as information pull. For example, in the excerpt in Table 4.8, one of the therapists is asking me how the data that is generated by the garment can be accessed by them. Another option is that a piece of information is sent in anticipation of the other person's need, or when information not directly related to the information pull which is sent out. The excerpt in Table 4.8 describes how the engineer is proactively providing information about sensing touch using capacitive sensors, based on the prototype that is being discussed. The third option is when people get involved in an interactive discussion of alternating multiple shorter push and pull utterances and is codified as an interactive pattern. This is shown in the excerpt in Table 4.8 with an example where the textile designer and textile producer are discussing how and where to construct the seams in the Vigour garment. For push and pull the codification is based mainly on sequences of related conversation in which one person mainly provides information, and the other person only supports this with minimal response, also determined as the discourse unit (Houtkoop & Mazeland, 1985). The interactive sequences are different in the sense that more people are contributing to the interaction, and generally following up on each other's information. Besides the conversation direction, this coding also included a code to indicate who was related to the specific utterance. The “example” column in Table 4.8 shows “Therapist Pull” for the first row, indicates that it was in fact a therapist who was requesting the information. In the interactive row “Textiles Interactive” indicate that it was an interactive discussion between people with a textile background (the fashion designer and textile producer). Ultimately, after identifying the sequences of utterances, adding an information code and defining who is the person responsible, the Conversational Balance is derived which defines the conversational flow.

Conversational Balance	**Description**	**Excerpt**
Information Pull	Information is requested by the person: for example, “Therapist Pull”	Physiotherapist (S16): Do I have to do this with a computer, or is this done through a website? How are you currently imagining it? Design Researcher (S1): Well, now I implemented it on a phone.
Information Push	Information is provided by the person: for example, “Technology Push”	Engineer (S7): Capacitive sensing, you know that there is no isolation layer around, this is directly short-circuiting the sensor.
Interactive	Interactive discussion between people: for example, “Textiles Interactive”	Fashion Designer (S15): Ideally there would be as few seams as possible, that you just have a front and back panel, sleeves and collar. Textile Producer (S25): And that the conductive thread is exiting, more or less, where the modules are placed for the measurement.

Table 4.8: Overview of the codes used for Conversational Balance, and excerpts that occurred during the design meetings.

Design Activity

An important element in the inquiry about the role of the different prototypes in the design meetings is to understand how they relate to the Design Activity categories that take place during such a meeting. The prototype might serve a very different role when people are generating new solutions, in comparison to when they are just trying to share knowledge about their discipline. The Design Activity coding functioned as a way to understand better why certain things were said.

The starting point of this coding was a generic model of design team activity, which combined a set of content-oriented activities (for example, generating new solutions) and process-oriented design activities (such as planning the group process) (Stempfle & Badke-Schaub, 2002). This generic model has been adapted to be used for protocol analysis in studies to understand the communication pattern between expert designers and novice designers (Deken et al., 2012). Using this classification as a starting point resulted in the coding to describe Design Activity between multiple stakeholders in design meetings (shown in Table 4.9). Design Activity 1 to 11 has been adapted from the previous studies. Design Activity 12, 13 and 14 emerged during the coding, out of the need to describe activities which were not covered in the previous model.

Design Activity	Description	Excerpt
1. Problem Understanding (PU)	Discussing the problem the prototype is trying to solve, its background, the causes, implications and context	Engineer (S7): It is not totally clear for me how this one is connected, but I will make a circuit anyway of how I think it can be done
2. Requirement Finding (RF)	Defining, adjusting or sharing the requirements of the current prototype	Physiotherapist (S16): Well, I would like to know the difference in movement range, if it used to be less than before
3. Past Design Discussion (PDD)	Discussing a past solution, or a solution of an existing product which is related to the current prototype	Design Researcher (S1): In the previous version of Blanket the vibration would become more intense if you put your hands on both sides
4. Solution Explanation (SE)	Explaining the latest steps that were made before the design meeting to come to the current prototype	Design Researcher (S1): This is a test that was made in our lab, from a pre-made piece of textile. We tried the tubular structure, to insert the modules by hand in it
5. Solution Generation (SG)	Generation of new (sub-) solutions for the current prototype	Physiotherapist (S2): No, I would keep it calm. Calm, but with a focus on the tactile information that it gives as a trigger, so not triggering by its colours
6. Solution Analysis (SA)	Predicting of behaviour, discussing judgements, or evaluating of (sub-) solutions in relation to the prototype	Fashion designer (S15): Intarsia is a particularly good technique to work with in this case, that you also position the stretch measurements very specifically
7. Decision-Making (DM)	Deciding regarding the design or design process of the prototype	Textile designer (S6): We can try to knit a piece and insert the modules afterwards with the filling thread
8. Design Process (DP)	Discussing the process of the current prototype	Physiotherapist (S3): Did you already think about approaching insurance companies, inviting them for a brainstorm
9. Communication Process (CP)	Metacommunication, introducing people, discussing meeting objectives	Design Researcher (S1): Shall we write down the positive and negative points? Two from each
10. Organisational Information Sharing (OIS)	Discussing company procedures, information sources, or expertise distribution in the company	Physiotherapist (S16): We have to pass this to the scientific committee, and then I have to send the project plan, because that will be discussed by the ethical committee
11. Team Coordination (TC)	Discussing the current and/or future collaboration between the designer and the stakeholders, or internally between the stakeholders	Fashion Designer (S15): When could you do the first tests with right-right? Textile Producer: We can start with that next week, first test with straight pieces
12. Solution-Testing Procedures (STP)	Deciding on procedures, or improvements to be made, in order to be able to test the current prototype in context	Eldercare Manager (S5): If we are going to test it at one of our locations, we have to ask specific questions, which people have to rate. We had lists of this, right?

13. Disciplinary Information Sharing (DIS)	Discussing specialised knowledge, procedures or events related to the discipline of the person	Engineer (S7): When you go to order thousands of modules, the prices will drop further. Because of the start-up costs, you have to source cheap components
14. Off Topic (OT)	Discussion between the participants that is not directly related to the project	Eldercare Manager (S5): During the week there was something very funny, you would not believe it. There was somebody, and I'm not sure who it was

Table 4.9: Overview of the codes used to indicate the Design Activity.

Design Content

The main motivation for involving the different stakeholders in the design process is that they all embody a part of the knowledge that is necessary to develop the PSS. With this verbal analysis study I want to find out how the prototype triggers people to use their knowledge about specific domains, and how it changes over time. To codify this flow of information I created a new coding scheme, which emerged during the codifying process. It consists of the important domains of knowledge that stakeholders used in the meetings. An overview of the coding is shown in Table 4.10.

When the participants in the meetings are talking about people, the code "Human" is used to indicate these elements. This includes, for example, descriptions from experiences within the eldercare context or even very specific physiotherapeutic knowledge, such as in the excerpt, where the therapists discuss how different symptoms can be treated during meeting Me7. Text is coded as "Textile" when specific details about the textiles are discussed, such as the fit of a garment, or the hand of the textile. But also more in-depth conversations about textile is placed in this coding, as, for example, shown in the excerpt where the fashion designer describes an idea for a specific knit with the conductive yarn during meeting Me20. The "Technology" coding is used to indicate verbal utterances dealing with technology, such as answering questions about how a particular solution works, or feedback from an expert as a reaction to a prototype. The excerpts in the table show how the engineer describes a possible solution to use the stretch sensor for multiple measurements during meeting Me18. During coding the meetings it became clear that there were occurrences that the conversations were discussing topics on the intersection of Technology and Textile. Instead of using the existing coding these instances have been coded using the "Smart Textiles" classification. These include, for example, discussions about how the technology was integrated in the fabric, or more specifically how to produce textile with conductive yarns integrated during the process. This is exemplified in the excerpt in the table where I propose to add the filling threads within the lines in the circular knit, and later add the technology. During the meetings finance and economical value was discussed and subsequently coded with the "Business" code: for example, in meeting Me21 when the physiotherapist and manager were talking about the financial value of Vigour for the insurers, which lies mainly in reducing physiotherapy sessions. The "Service" code is used to indicate how the

PSS is placed in existing services and how other people relate and use the PSS in their practices. In meeting Me16 the physiotherapist and manager brainstorm about how the cardigan can support independent living clients, by creating a service in which multiple people can help with the exercises at home, instead of only with therapists.

Design Content	**Description**	**Excerpt**
1. Human	Descriptions from experiences within the eldercare context, physiotherapeutic knowledge or knowledge about the clients	Physiotherapist (S3): Now you are talking about strokes. But with which goal do you mainly stimulate here? That is with a stroke. And now, with all the others you are working more centrally, even from the shoulders
2. Textile	Details about the textiles are discussed: for example, the fit of a garment, or the hand of the textile and in-depth conversations about textile fashion	Fashion Designer (S15): Yes, or what I thought is, if you have a knit in which you, for example, integrate the conductive yarns using a Fisherman's Rib stitch and outside the Fisherman's Rib stitch a normal flat knit. I do not know if that is technically possible?
3. Technology	Technology-related topics, such as answering questions about how a particular solution works or feedback from an expert as a reaction to a prototype	Engineer (S7): I do not know if you have a dedicated ground and dedicated power supply in this circuit in this line. But I can imagine that if you put GPIO (General Purpose Input/Output) pins there, there and there, then you can make all possible combinations
4. Smart Textiles	Intersection of Technology and Textile: for example, discussions about how the technology was integrated in the fabric, or how to produce textile with conductive yarns	Design Researcher (S1): We can make the lines we had in mind first. Then, in there we put a filling thread, and afterwards we put the electronics behind the filling thread, by making a cut. Then the electronics will still feel soft
5. Business	Discussions related to finance and economical value: for example, about the value of the PSS or the financial implications of production	Eldercare Manager (S5): If you can bring this back to 150 in three years. Physiotherapist (S3): Exactly, or reduce the exercises to once in every three weeks, exercise individually. You know, it is these kinds of things that health insurers are very keen on
Service	How the PSS is placed in the context and how people and existing services are involved in the service exchange: for example, how the PSS might support independent living	Physiotherapist (S2): It could also be of course that in the morning the community caretaker visits the house or somebody else, a volunteer who visits. They should receive instructions, and have to know what to expect in the house

Table 4.10: Overview of the codes used for Design Content.

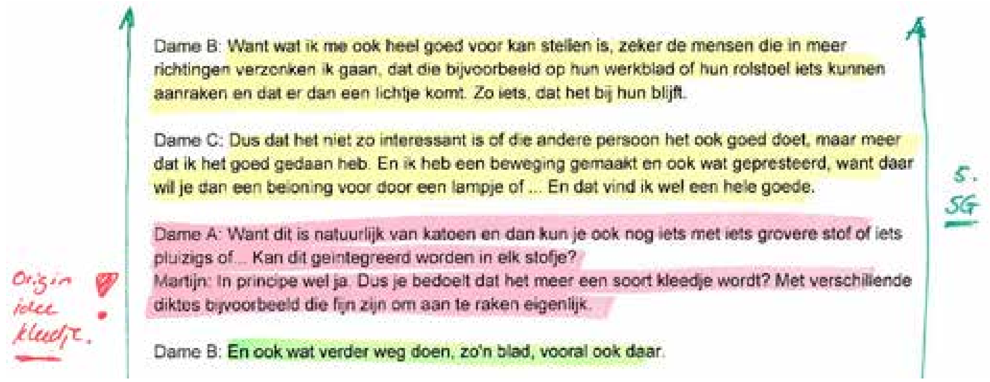
4.5 Data Analysis

To be able to reflect on the research questions it is necessary to interpret the qualitative data. As described by Chi (1997), it is possible to carefully quantify the qualitative data to capture certain impressions and trends within the data. This could be achieved by coding verbal occurrences of a certain category, and to compare the frequencies of these categories quantitatively. In this analysis I will use this quantitative-based qualitative approach in order to further investigate my subjective impressions. In order to analyse the data using the verbal analysis method, the conversations during the meetings had to be coded using the previously explained three coding schemes. The data was coded using NVivo, a qualitative data analysis tool that supports the coding of data such as transcripts.

As a first step, the selected meetings were transcribed by an external transcriber. Based on these transcripts, two researchers (including myself) started with the codification of the data, meaning that for each utterance a code from the three coding schemes was applied. We each codified 50% of the data on paper: an example is shown in Figure 4.13. An important part of the process was to give each other regular updates about how the coding was applied. These meetings helped to define the criteria about how to code the content, and also helped to develop new categories that did not fit in with the current coding schemes. We continuously checked these new categories by discussing them between the two researchers. After the codification on paper had been completed, all the data was inserted into the NVivo database, taking care that all codification would follow the rules agreed upon. Since I am interested in the role of the prototypes, I took the discussions during the design meetings about the prototypes as the main lens to look at the data. This selection resulted in Table 4.11 where the total word frequency for each code is queried. I chose word count as a unit of analysis because the three coding schemes are based on different unit of analysis, and the codes often start in different moments in the transcripts. Furthermore, other studies have shown that word count can be correlated with the actual time that was spent to say the words, and therefore can be considered as a good representation (Deken et al., 2012). However, this also brings the consequence that I assume for this study, that the amount of time spent to discuss a certain topic relates to the importance this had during the conversation. I will take this limitation into account when interpreting the results, and coming to conclusions for this study.

	First tests (P3, P4, P5)	Blanket (P15)	Tactile Dialogues (P20, P23)	Vigour v1 (P13, P14)	Vigour v2 P21, P25)
Conversational Balance					
Interactive — Martijn + De Wever	2104	1833	2007	2235	2715
Interactive — Martijn + Metatronics	0	648	807	3202	2027
Interactive — Martijn + Textiles	0	740	521	1946	0
Pull — De Wever	369	362	1168	873	1438
Pull — Martijn	283	877	336	1365	569
Pull — Metatronics	0	269	339	212	286
Pull — Textiles	0	200	19	1048	0
Push — De Wever	2398	4286	6052	5403	5749
Push — Martijn	1378	1247	2566	2743	3210
Push — Metatronics	0	1147	1439	1101	202
Design Activity					
Problem Understanding	163	27	419	775	64
Requirement Finding	125	283	913	2583	449
Past Design Discussion	0	427	137	680	87
Solution Explanation	686	917	1903	731	3760
Solution Generation	2816	3042	2945	7526	1991
Solution Analysis	2024	3588	4051	4825	4556
Decision Making	37	395	0	77	0
Design Process	468	338	943	1641	743
Communication Process	0	662	477	1744	987
Organizational Information Sharing	0	446	699	1971	575
Team Coordination	0	48	452	1946	1179
Solution Testing Procedures	94	751	1372	493	353
Disciplinary Information Sharing	128	290	329	1024	1572
Off-topic	0	716	2404	344	1479
Design Content					
Human	3554	3404	5662	6101	4111
Textiles	306	1578	1340	7714	1149
Technology	417	1122	1523	3912	1414
Smart Textiles	1100	2526	3319	2251	2269
Business	19	372	785	1348	1020
Service	1574	1108	1224	2472	3356

Table 4.11: The word frequencies of each code, separated for the discussions about each prototype.


Dame B: Want wat ik me ook heel goed voor kan stellen is, zeker de mensen die in meer richtingen verzonken ik gaan, dat die bijvoorbeeld op hun werkblad of hun rolstoel iets kunnen aanraken en dat er dan een lichtje komt. Zo iets, dat het bij hun blijft.

Dame C: Dus dat het niet zo interessant is of die andere persoon het ook goed doet, maar meer dat ik het goed gedaan heb. En ik heb een beweging gemaakt en ook wat gepresteerd, want daar wil je dan een beloning voor door een lampje of ... En dat vind ik wel een hele goede.

Dame A: Want dit is natuurlijk van katoen en dan kun je ook nog iets met iets grovere stof of iets pluizigs of... Kan dit geïntegreerd worden in elk stofje?
Martijn: In principe wel ja. Dus je bedoelt dat het meer een soort kleedje wordt? Met verschillende diktes bijvoorbeeld die fijn zijn om aan te raken eigenlijk.

Dame B: En ook wat verder weg doen, zo'n blad, vooral ook daar.

Figure 4.13: Example of the first round of coding on paper.

Correspondence Analysis

Ultimately, to be able to answer the three research questions outlined earlier in Figure 4.1, it is necessary to investigate the relation between the three coding variables. It is hard to make sense of the table because of the many variables. To be able to get a better understanding of such a large dataset, a descriptive statistical method can be used to leverage to complexity. In particular, multivariate statistical methods can be helpful since they allow the observation of multiple outcome variables at a time. Correspondence Analysis is such a technique which allows the understanding between two variables and their frequencies (Greenacre, 2007). This method has been recently applied in other design research projects to help interpreting qualitative data (Deken et al., 2012; Stokmans & Snelders, 1994; Valencia, Person, & Snelders, 2013). This method is a dimension reduction technique which aims to understand whether there is a correspondence between the observed frequencies and the variables. One of the advantages of correspondence analysis is that it can work with data described in a nominal scale, such as the three coding schemes. The result of the correspondence analysis is a set of solutions (different dimensions) which show the result of a calculation of the distances between the different categories. It is possible to show these solutions in a perceptual map, such as a biplot. The map offers the possibility to discuss the associations between the categories, and even allows one to carefully interpret the associations. I will explain the process of creating such a perceptual map with one of the relations between the coding schemes.

- *Step 1:* The first step of the process is to create a frequency table (also called contingency table) in which the rows and columns show the two coding schemes to compare. Since the number of words is my basic unit of analysis, the cells of this table contain the word frequency for this particular occurrence. The T1-a, T2-a and T3-a prefixes are used to codify the transitions between the phases of the Growth Plan (explained in Table 4.12). With T1-a being the first textile samples (used during meeting Me7), T2-a the first version of Vigour (used during meeting Me16, Me18 and Me20), T3-a the second version of the

Vigour prototype (used during meeting Me21 and Me26). A similar system is used for Tactile Dialogues, and is shown in Table 4.13. Table 4.14 Shows the contingency table of the Conversational Balance coding (rows) and the Design Content (columns) for the Vigour design process. The Conversational Balance coding is further specified per transition of the Growth Plan using the previously explained prefixes.

Transition	Prototypes	Meeting
T1-a (Incubation)	Stretch Sweater (P3), Touch Sleeve (P4), Knee Band (P5)	Me7
Incubation — Nursery (T2-a)	Vigour v1 Interface (P13), Vigour v1 (P14)	Me16, Me18, Me20
Nursery — Adoption (T3-a)	Vigour iPad application (P21), Vigour v2 (P25)	Me21, Me26

Table 4.12: The prefixes used to indicate the transitions between the Growth Plan phases and the prototypes for Vigour in the analysis.

Transition	Prototypes	Meeting
Incubation (T1-b)	Stretch Sweater (P3), Touch Sleeve (P4), Knee Band (P5)	Me7
Incubation — Nursery (T2-b)	Blanket (P15)	Me16, Me18, Me19
Nursery — Adoption (T3-b)	Tactile Dialogues v1 (P23), Tactile Dialogues v2 (No electronics, P20)	Me21, Me23, Me26

Table 4.13: The prefixes used to indicate the transitions between the Growth Plan phases and the prototypes for Tactile Dialogues in the analysis.

	Bus.	Hum.	Ser.	SmaTex.	Tech.	Tex.	Totals
T1-a—Int: Martijn + Eldercare	0	1192	453	385	126	50	2206
T1-a—Pull: Eldercare	0	181	160	40	43	0	424
T1-a—Pull: Martijn	0	157	0	43	39	22	261
T1-a—Push: Eldercare	19	1827	301	339	18	58	2562
T1-a—Push: Martijn	0	189	660	293	189	176	1507
T2-a—Int: Martijn + Eldercare	0	1072	180	55	153	243	1703
T2-a—Int: Martijn + Technology	458	334	240	197	1740	66	3035
T2-a—Int: Martijn + Textiles	91	292	0	205	102	1121	1811
T2-a—Pull: Eldercare	0	567	51	92	35	0	745

T2-a—Pull: Martijn	54	225	108	68	378	175	1008
T2-a—Pull: Technology	0	0	19	29	164	0	212
T2-a—Pull: Textiles	182	0	0	270	14	549	1015
T2-a—Push: Eldercare	36	2599	1468	255	90	653	5101
T2-a—Push: Martijn	22	644	205	623	271	240	2005
T2-a—Push: Technology	0	115	0	69	911	0	1095
T2-a—Push: Textiles	505	231	201	388	54	4628	6007
T3-a—Int: Martijn + Eldercare	39	347	127	264	235	107	1119
T3-a—Int: Martijn + Technology	95	125	291	617	312	40	1480
T3-a—Pull: Eldercare	115	161	295	57	86	388	1102
T3-a—Pull: Martijn	84	140	0	22	43	0	289
T3-a—Pull: Technology	31	65	46	70	74	0	286
T3-a—Push: Eldercare	200	2384	1388	368	194	289	4823
T3-a-Push: Martijn	394	160	1011	634	191	285	2675
T3-a-Push: Technology	37	80	14	21	48	0	200
Totals	2362	13087	7218	5404	5510	9090	42671

Table 4.14: Contingency table which shows the different Conversational Balance codes per Vigour iteration in the rows, and the different Design Content codes in the different columns.

– *Step 2:* As a second step different models can be calculated based on the relation between the row, the column and the frequency. Simply said, this can show the summary of the similarities of the different rows and columns. Through a series of calculations a generalised singular value decomposition is applied (Greenacre, 2007), which exposes the underlying structure of the frequency table. This results in a number of dimensions that are needed to represent the different solutions (this is shown in Table 4.15). For each dimension the percentage of inertia that it accounts for is displayed, which gives an idea of how coherent the contingency table is. In this example, Dimension 1 accounts for 44.6% of the total inertia, and Dimension 2 accounts for 33.9%, which means that these two dimensions combined explain 78.5% of the relations between rows and columns. If the inertia explains a high proportion of the total inertia, then this dimension accurately "explains" the relation between the rows and columns. To make a graphic representation, the two highest values are included in the next step of the analysis.

Dimension	Singular Value	Inertia accounted
1	.678	.446
2	.591	.339
3	.350	.119
4	.248	.060
5	.194	.036
Total		1.000

Table 4.15: Overview of the different dimensions from the above contingency table.

– *Step 3:* In this step the two most contributing dimensions are selected, and the coordinates of these dimensions further interpreted. Table 4.16 shows the coordinates for Dimension 1 and Dimension 2. From this table it is also visible which variables are contributing most strongly to the inertia of the model. As a general rule the variables which explain more than 3% of the inertia can be considered to have a high impact on the distribution of the variables on the dimension. For example, this is the case for all Design Content variables, except Business (which only contributes 0.6% to the inertia). When looking to the coordinates of Dimension 1 it is visible that there is a division between Textiles (located on the positive side of Dimension 1: I choose to ignore the Business code because it only accounts for 0.6% of the inertia) and the other content (all on the negative side). For Dimension 2 there is a division visible between Human and Services content on the positive side, and particularly Technology on the negative side.

	Mass	D1	D2	Inertia	Contribution to D1	Contribution to D2
Business	0.055	0.435	-0.647	0.06	0.015	0.039
Human	0.307	-0.553	0.67	0.181	0.138	0.233
Services	0.169	-0.407	0.404	0.097	0.041	0.047
Smart Textiles	0.127	-0.123	-0.063	0.071	0.003	0.001
Technology	0.129	-0.698	-1.765	0.289	0.093	0.68
Textiles	0.213	1.502	-0.01	0.332	0.709	0
Active Total	1			1.03	1	1

Table 4.16: Overview of the columns' dimensions from the above contingency table.

– *Step 4:* Finally, as a last step it is possible to plot the coordinates in a two-dimensional scatter plot and try to interpret and attach meaning to the data carefully. Figure 4.16 shows the result of this plot, from which the distances of the points in the two-dimensional model can be observed. For this step it is important to be able to give a label to the dimension, to explain what the dimension means. In the example plot it is visible that Dimension 1 shows a continuum from Technology-related content to Textile-related content, with Smart Textiles in the middle. Dimension 2 shows a continuum from Technology-related topics, to Human-related topics (with Smart Textiles in the middle). What is important to note is that it is not appropriate to evaluate the distances between row and column coordinates directly in the plot. However, it is possible to use the interpretations of the dimensions for explaining the points. To interpret the data further I annotated two extra visual guides in the plot. The three lines are used to group the variables to the iteration of the prototype to belong. For example, the blue line connects all the points related to the first iteration (indicated with T1-a). Secondly, the circles around the groups of points show the interesting clusters that arise from the data (a method applied in other studies as well (Valencia et al., 2013). Based on these clusters, further meaning can be interpreted. For example, in the example cluster 3 (C3) shows that on the same side of the origin (the positive side) are the Textile content, as well as all of the conversations with the textile partners (Push, Pull and Interactive). A possible observation from this could be that the prototypes used during the Incubation — Nursery transition from Vigour (T2-a) played an important role to trigger the textiles partner to discuss Textile-related content. On the other hand, the textile partners were only confronted with the prototypes during the Incubation — Nursery transition (T2-a), which could also explains the similar pattern. Based on this example it is visible that the correspondence analysis is a descriptive method. It helps to show patterns, but the actual interpretation of the subjective explanations is crucial. In the next sections I will present the different correlations between the coding schemes for each PSS, and interpret the labels.

Design Activity vs Conversational Balance

Vigour: The correspondence analysis of the Conversational Balance (how the partners communicated) and Design Activity codes for Vigour resulted in the biplot shown in Figure 4.14. The goal of this co-relation is to find out how the prototypes supported the partners to contribute to the PSS design process. The data related to the “information pull” coding of the technology partner for the Nursery – Adoption transition (T3-a) is removed from the visualisation because it was an outlier. This data amounted to 0.6% words of the total meeting. The overall explanation of the total inertia by the two dimensions is 48.7%. On the negative side of dimension 1 are the Design Activity categories related to implementation in the actual context of the service: for example, knowledge about the organisation, the discipline and fit of the solution. On the positive side are the activities related to the design process: for example, explaining previous design solutions and team coordination. On the negative side of the second dimension are activities related to managing the process, for example the communication and testing procedures. On the positive side are the activities related to the sharing of skills, such as sharing information about the discipline and discussing existing solutions.

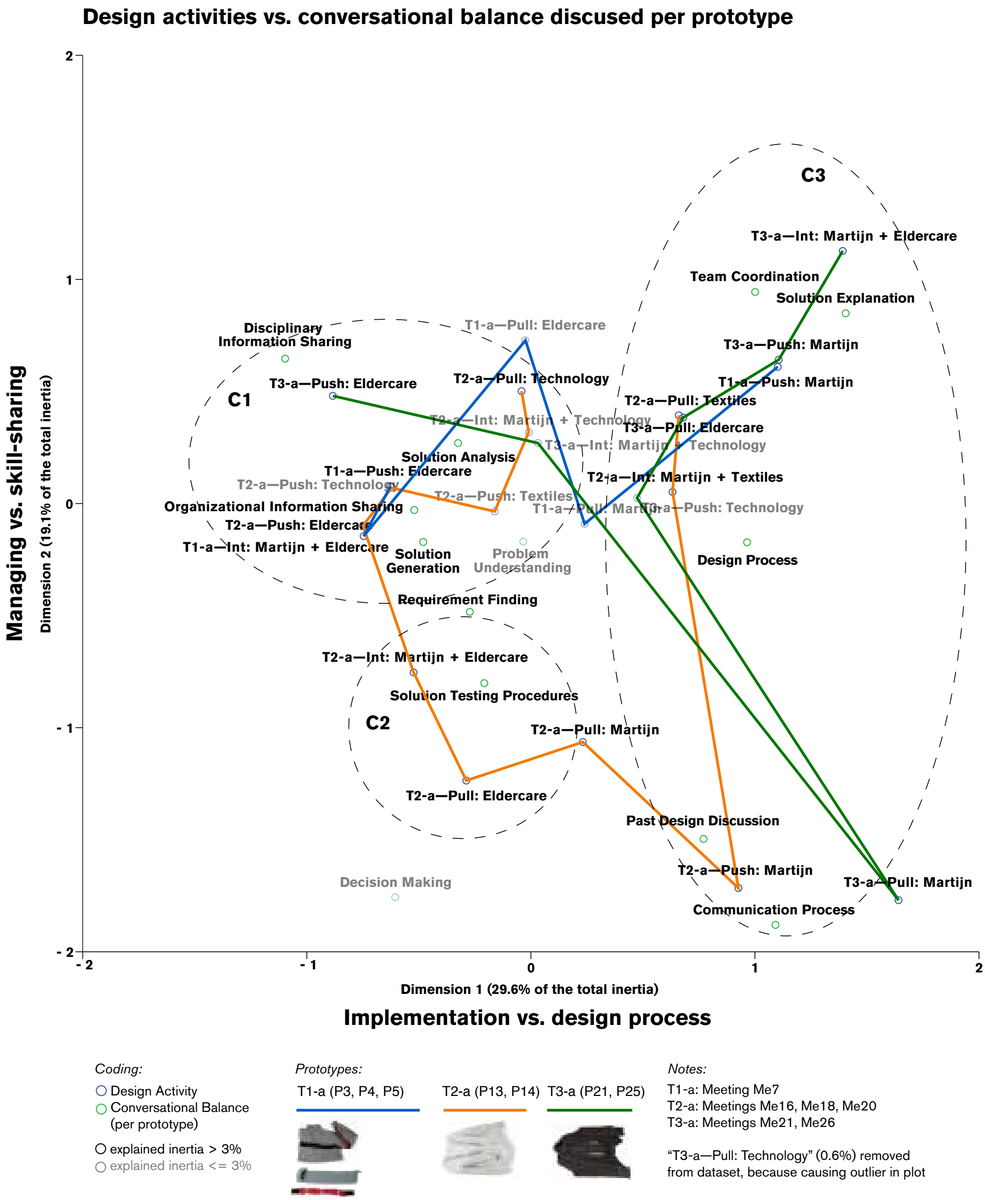


Figure 4.14: Biplot showing the relation between Conversational Balance and the Design Activity for the three prototypes of Vigour.

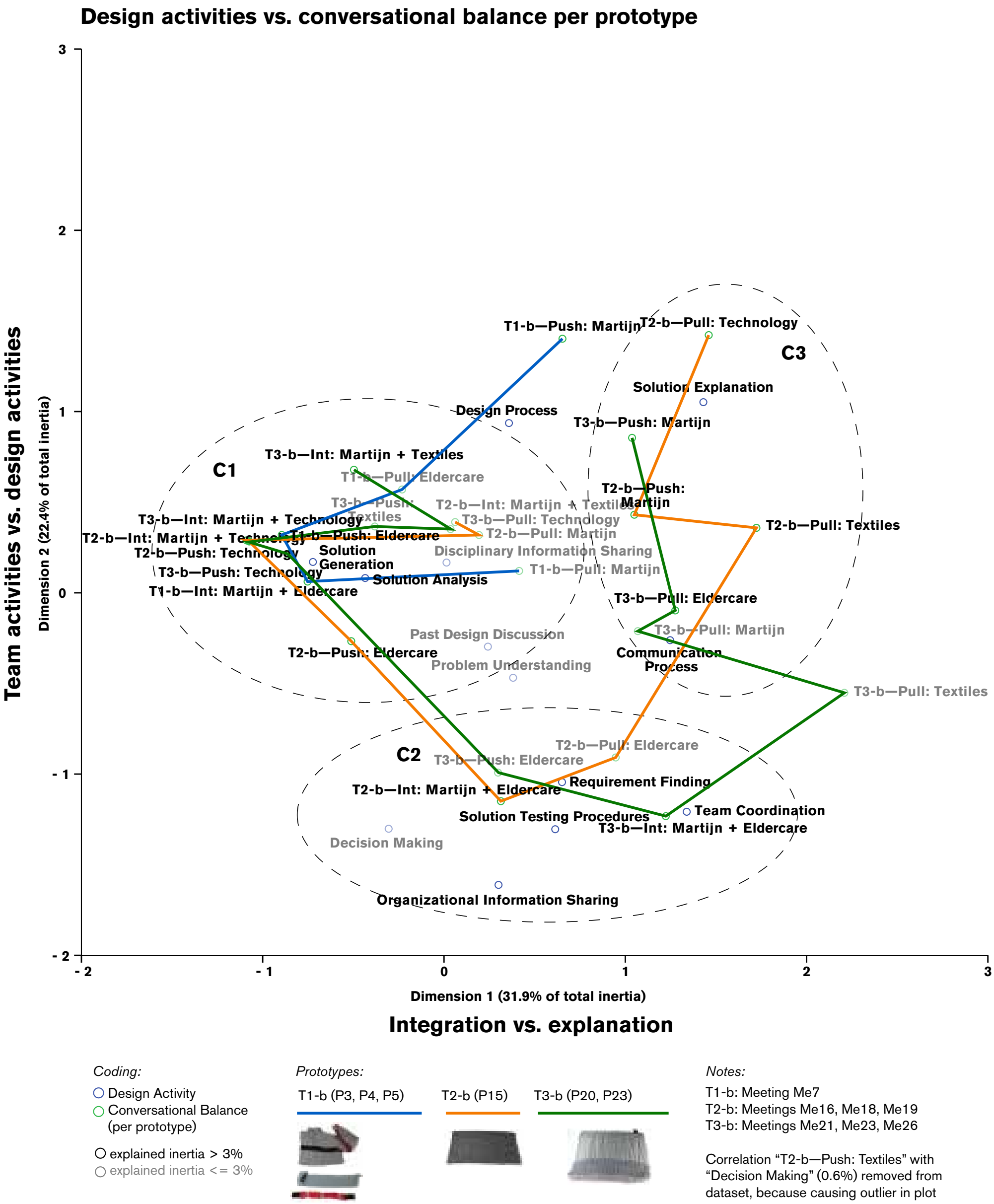


Figure 4.15: Biplot showing the relation between Conversational Balance and the Design Activity for the three prototypes of Tactile Dialogues.

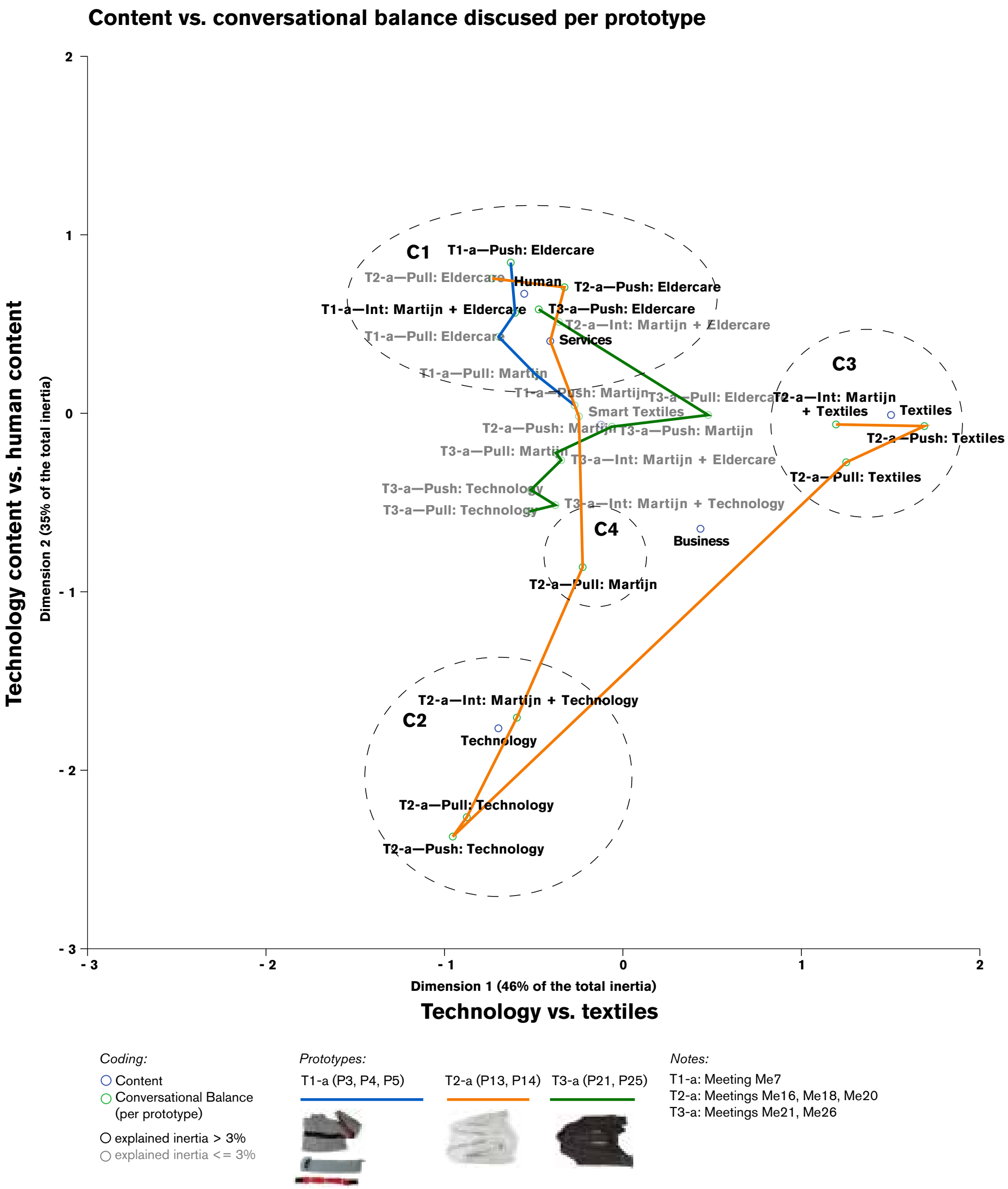


Figure 4.16: Biplot showing the relation between Conversational Balance and the Design Content for the three prototypes of Vigour.

Content vs. conversational balance per prototype

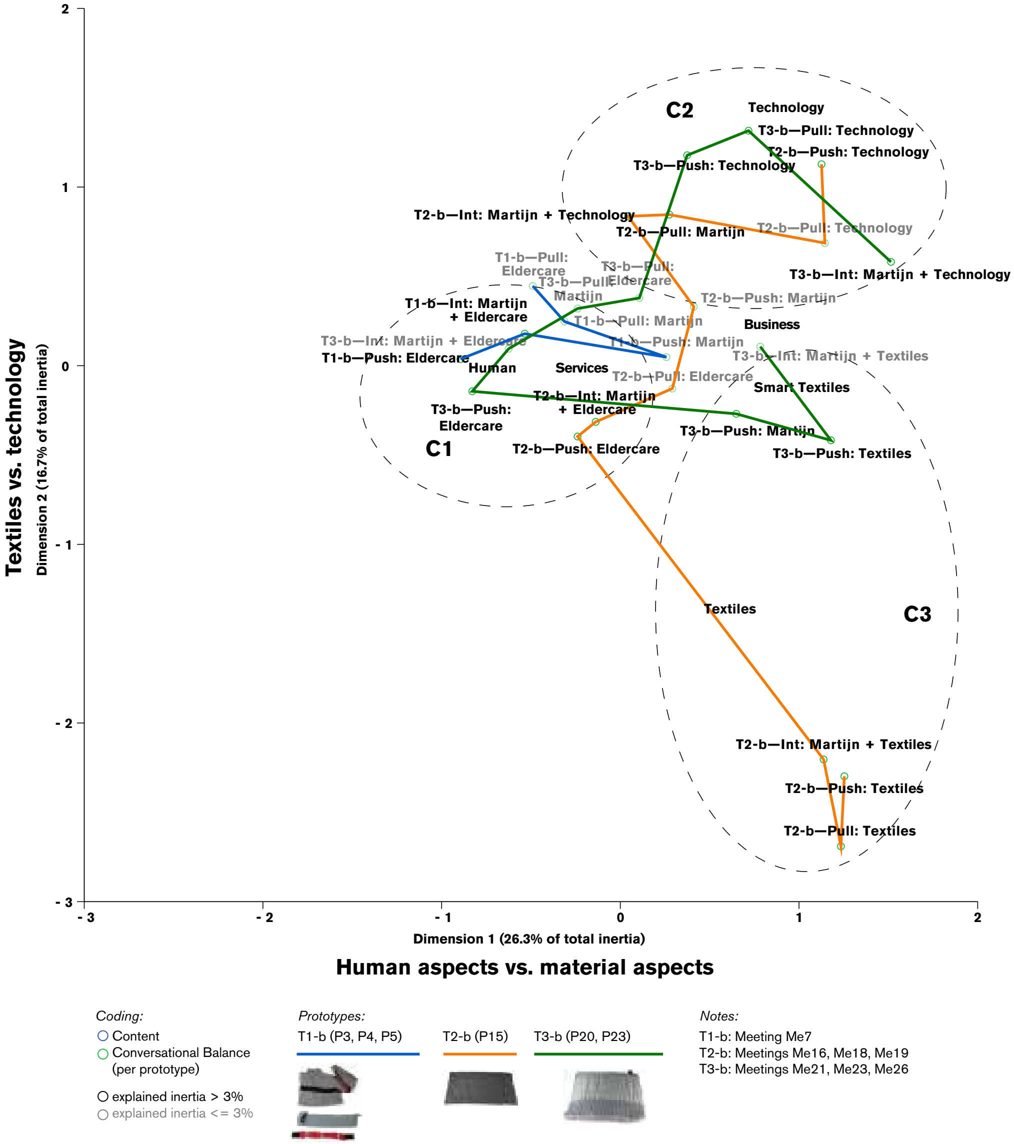


Figure 4.17: Biplot showing the relation between Conversational Balance and the Design Content for the three prototypes of Tactile Dialogues.

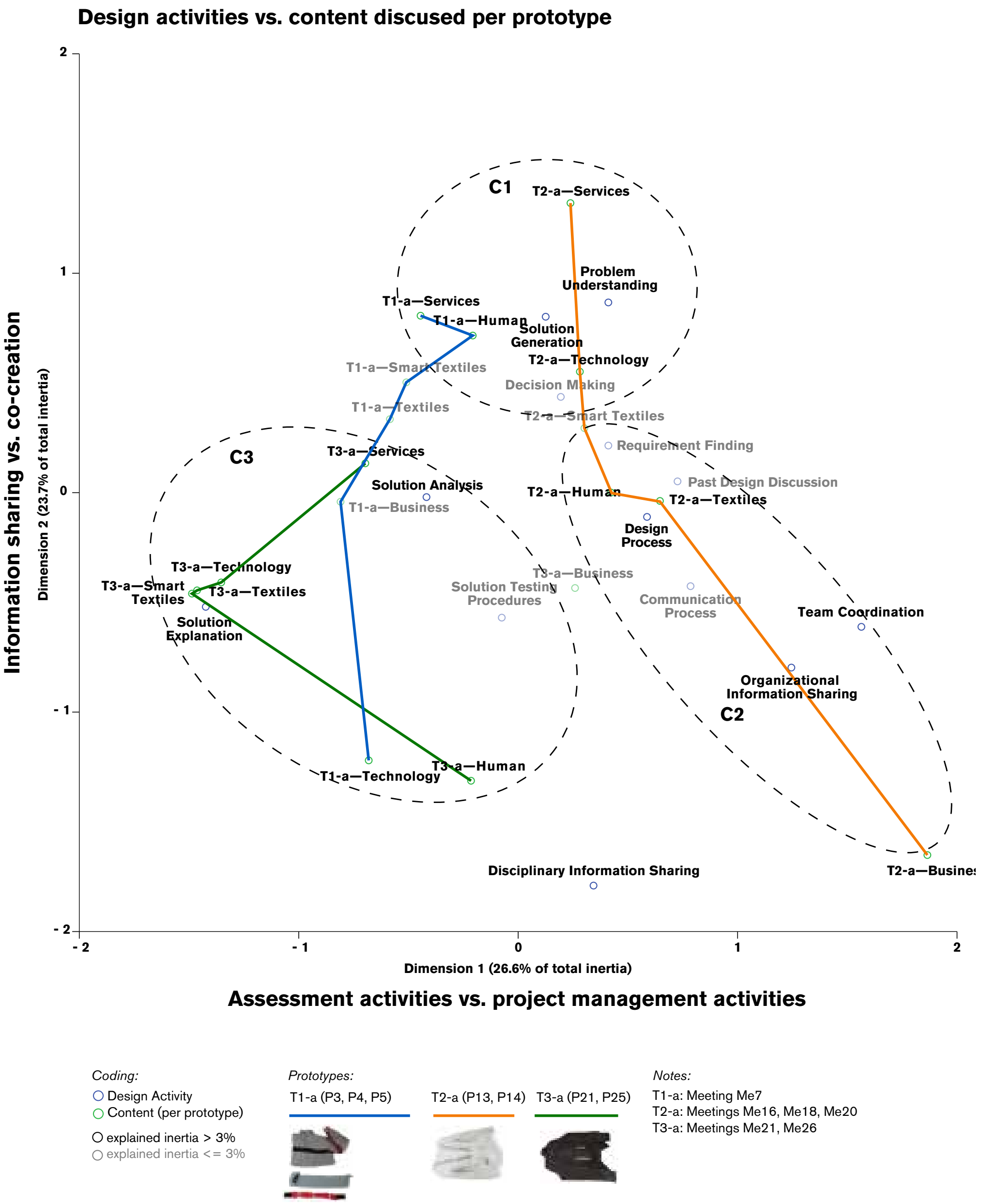


Figure 4.18: Biplot showing the relation between Design Activity and the Design Content for the three prototypes of Vigour.

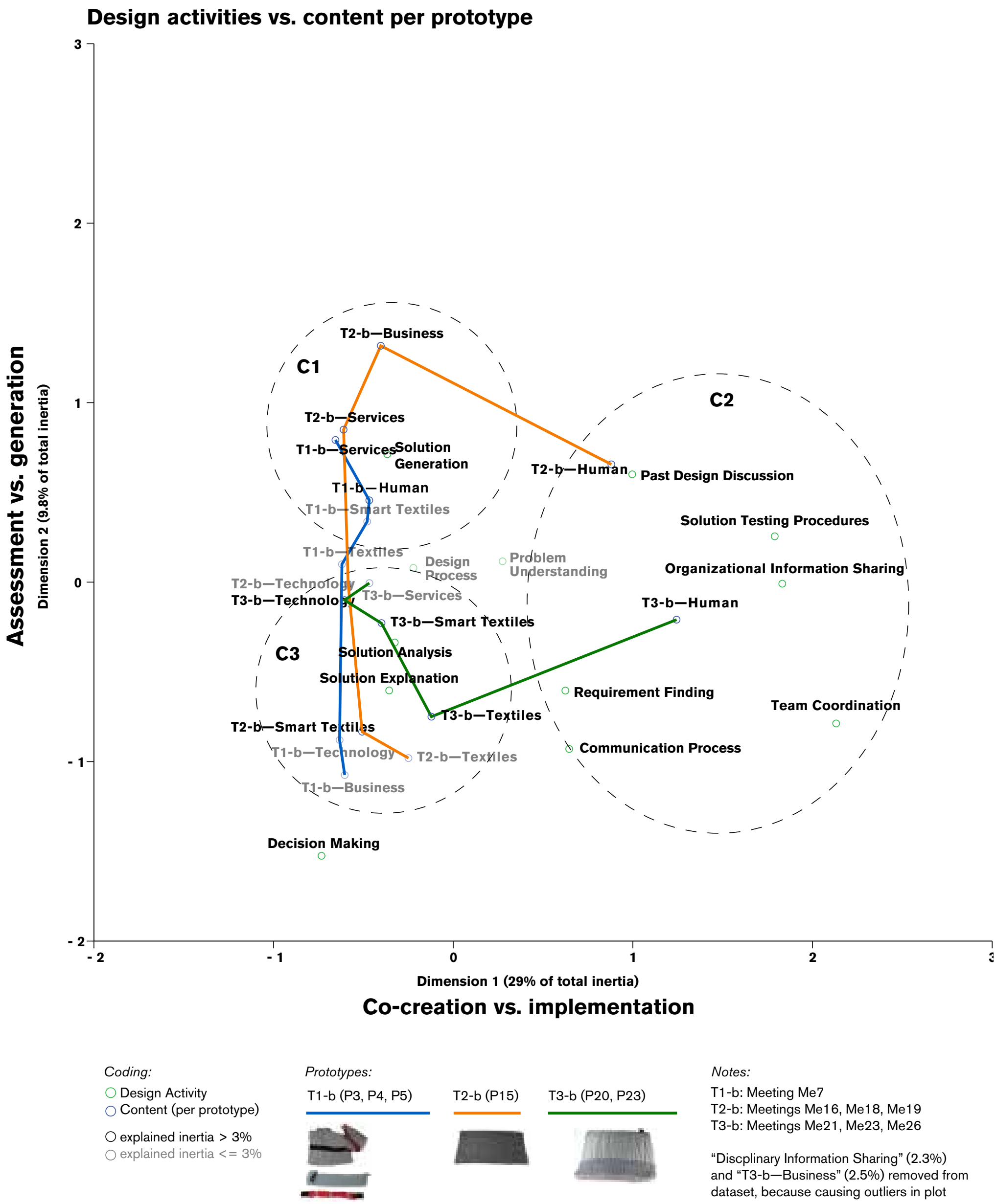


Figure 4.19: Biplot showing the relation between Design Activity and Design Content for the three prototypes of Tactile Dialogues.

Tactile Dialogues: The relation between Conversational Balance and the Design Activity for the three iterations of Tactile Dialogues are shown in Figure 4.15. The relation of the Design Activity "Decision-Making" with the information push by the textile partner was removed for the Nursery – Adoption transition (T3-b) because it caused an outlier out of the range of the graph. This data consisted of 0.6% of the total content of the meeting. The two dimensions of the graph explain in total 54.3% of the total inertia. Dimension 1 shows on the negative side conversations related to integrative activities: for example, solution generation and analysis. On the positive side it consists of conversations that deal with explanations: for example, about design solutions and processes within the team. Dimension 2 shows on the negative side the Design Activity categories related to the team, such as defining solution-testing procedures and coordination within the team. On the positive side are design-related activities such as solution generation and design process.

Design Content vs Conversational Balance

Vigour: The biplot in Figure 4.16 is the result of the correlation of the Conversational Balance code (how the dialogue flowed between people) for the three prototypes of Vigour with the Design Content code (the content they are talking about). The goal of this correlation was to find out how the prototypes support the partners to share their disciplinary knowledge. The correspondence analysis resulted in two dimensions that account for a large part of the total inertia (81%). Dimension 1 shows a division with, on the negative side, conversations related to technology, and, on the positive side, conversations related to textiles (in the middle are conversations related to smart textiles). Dimension 2 can be interpreted as a distinction between interactions more related to technology on the negative side (the discussion relating to technology, and the technology partner itself) and on the positive side the interactions related to human topics (human and service Design Content, and the eldercare organisation partner are located here).

Tactile Dialogues: The correspondence analysis for the Design Content topics with the Conversational Balance of the three prototypes resulted in the biplot shown in Figure 4.17. The two dimensions explain 43% of the total inertia. Dimension 1 shows on the negative side the human Design Content, and on the positive side the more material based Design Content such as technology, textiles and smart textiles. Dimension 2 shows on the negative side the conversations related to textile, and on the positive side technology-related content.

Design Activity vs Design Content

Vigour: The correspondence analysis between the Design Activity and Design Content codes of the three prototypes aimed to investigate how the prototypes support integrating disciplinary knowledge for the PSS design process. This resulted for Vigour in a two-dimensional representation that accounts for 50.3%

of the total inertia. Figure 4.18 shows the plot on which I will base the following analysis. Dimension 1 represents an axis that describes assessment-related activities on the negative side (for example, conversations in which solutions are explained and also analysed by the stakeholder) to project management-related activities on the positive side (topics such as communication within the team, or sharing organisational information). Dimension 2 describes prototypes which are on the negative side more related to information sharing (covering information related to disciplinary knowledge to information about the organisation) and on the positive side related to prototypes in which co-creation-related Design Activity plays a more important role (for example, co-creating new solutions and acquiring a better understanding of the actual problem).

Tactile Dialogues: When plotting the relation between the Design Activity and Design Content coding for the evolution of Tactile Dialogues, Figure 4.19 emerges in which the two dimensions account for 38.8% of the inertia. Dimension 1 shows a distribution with, on the negative side, Design Activity related to co-creation, such as solution generation and solution analysis. The positive side represents Design Activity related to implementation: for example, solution-testing procedures, organisational information sharing, and team coordination. Dimension 2 only represents 9.8% of the total inertia and therefore could be harder to interpret. When taking a closer look a distribution between, on the negative side, assessment-related activities (analysis, explanation and decision-making) and generation activities (for example, generating solutions) could be described.

4.6 Findings

Based on the previous analyses I have been able to show the interpretations of the different dimensions for each correlation between the coding schemes. Within this section I will reflect on the original research questions, by discussing the findings for each individual prototype (the lines in the plots). Then I will take a macro perspective and discuss the clusters in more detail (the circles in the plots).

Design Activity vs Conversational Balance
The relation between the Conversational Balance (how things are said) and Design Activity (why things are said) leads to the question: How do the prototypes support the partners to contribute to the PSS design process? These findings are based on the plots shown in Figure 4.14 and Figure 4.15.

Prototypes: With the help of explanations of these axes it becomes possible to better understand the role of the different prototypes. The three lines in the figure show how the prototypes relate to the way the partners communicated during certain Design Activities.

- Vigour prototypes used in Incubation (T1-a, blue line) supported the partners from the eldercare organisation to provide knowledge about their organisation, and enabled me to explain design solutions.
- Vigour prototypes used in Incubation — Nursery transition (T2-a, orange line) supported the partners from the eldercare organisation to provide organisational knowledge, and request information about managing and implementing the PSS by means of testing. The technology partner discussed skill-based and organisational information. The prototypes supported the textile partners to provide organisational information: they requested information mostly about the design process. The prototypes during this transition supported me mainly with the managerial role, supporting the testing procedures and design process.
- Vigour prototypes used in Nursery — Adoption transition (T3-a, green line) supported the eldercare company to provide organisational information, and discuss information about the design process. The prototypes supported the technology partner to push information about the design process, and discuss the implementation. The prototypes supported me to share design-related information and request managerial information.
- Tactile Dialogues prototypes used in Incubation (T1-b, blue line) supported the eldercare partners and myself mostly for Design Activity categories such as solution generation and solution analysis. The prototypes helped me to provide information about the design process and explain previous solutions.
- Tactile Dialogues prototypes used in Incubation — Nursery transition (T2-b, orange line) supported all the partners to provide design-related knowledge, such as solution generation and analysis. At the same time, the prototypes also supported the partners to request information about the design solution, and supported me to provide this information. Finally, the prototypes supported the eldercare organisation to discuss testing-related procedures.
- Tactile Dialogues prototypes used in Nursery — Adoption transition (T3-b, green line) supported the technology partner to provide and request information related to Design Activity categories such as solution generation. The prototypes supported the eldercare partner to provide information and discuss solution testing. Furthermore, the prototypes supported myself to provide and request information about the design process.

Clusters: From the two graphs that describe the role of the prototypes from both Vigour and Tactile Dialogues (Figure 4.14 and Figure 4.15) there are three clusters that emerge as a basis to explain how the prototype supports the partners for the role they took during the design process.

- C1 contains for both PSS's the conversations that deal with Design Activity categories such as solution generation and solution analysis. For Vigour this cluster also contains knowledge-sharing activities (Disciplinary and Organisational). This cluster groups most of the partners' conversations that provide knowledge.

- C2 is a smaller cluster which contains activities related to implementation; these are mainly solution testing-related conversations. For Tactile Dialogues the cluster also contains other activities' organisational information, team coordination and requirement finding. The main partner who contributes to the conversations in this cluster is the eldercare provider.
- C3 contains mostly Design Activity categories related to communication about design solutions. Within this cluster it is mostly myself providing information to the other partners, and the other partners requesting information.

Design Content vs Conversational Balance
The relation between the Conversational Balance (how things are said) and Design Content (what things are said) leads to the question: How do the prototypes support the partners to share their disciplinary knowledge? The goal of this analysis is to find out whether the interactions triggered by the prototypes between the actors can be related to the type of Design Content being discussed. I will base this analysis on the plots shown in Figure 4.16 and Figure 4.17.

Prototypes: By analysing the position of the prototypes on the representation of the two dimensions, it is possible to come to some conclusions about the roles of the prototypes in the interactions that the stakeholders had. Within the biplot I connected the different conversional balance codes, related to the same prototype with a line. These three lines are indicated with different colours to aid the sense-making process.

- Vigour prototypes used in Incubation (T1-a, blue line) supported the stakeholders from the eldercare organisation to communicate about Human- and Service-related topics: for example, the discussion about how the Stretch Sweater (P3) could be used in group physical therapy sessions. These were also the only partners involved at that point in the process, and therefore the prototypes did not support the other stakeholders.
- Vigour prototypes used in Incubation — Nursery transition (T2-a, orange line) supported each partner to communicate their own Design Content. The textile partners communicated about Textiles, the technology partner about Technology, and the eldercare partner about Human and Services. The prototypes enabled me to have discussions with each partner about their area of expertise, and also allowed me to pull information evenly from all disciplines through Smart Textiles.
- Vigour prototypes used in Nursery — Adoption transition (T3-a, green line) enabled the eldercare partners to push eldercare-related content. However, the discussions between them and me moved more in the area of Smart Textiles. The discussions with the technology partner also moved in the direction of Smart Textiles, very close to the content discussed with the eldercare partners. The meeting with the textile partner is not included for these prototypes, and therefore not visualised in the overview.

- Tactile Dialogues prototypes used in Incubation (T1-b, blue line) supported the eldercare partner to discuss Design Content related to their expertise, such as Human and Service. The other partners were not yet involved in the project, and therefore not represented.
- Tactile Dialogues prototypes used in Incubation — Nursery transition (T2-b, orange line) supported the partners to communicate about Design Content related to their own disciplinary knowledge, the textile partners about Textiles, and the technology partner about Technology. For the eldercare partners there is a stronger relation between Smart Textiles and Textiles, and requesting information and discussion. I am using the prototypes to ask for more technical-related information, and the information I provide is moving closer to the Service content.
- Tactile Dialogues prototypes used in Nursery — Adoption transition (T3-b, green line) supported the eldercare and technology partner to share their own related Design Content (Human and Services for the eldercare partners, and Technology for the technology partner). The textile partner shared more information related to Smart Textiles instead of Textiles. The information I shared is also more closely related to Smart Textiles, as well as the discussion between the technology partner and me.

Clusters: Based on the conclusions of Figures 4.16 and 4.17 three clusters emerge with similar characteristics, and one cluster is only visible in the evolution of Vigour.

- C1 represents in both figures the combination of the Human and Services content. For both PSS's all the prototypes trigger the eldercare organisation to discuss this content, visible in this cluster. However, for the Vigour prototypes used in the Nursery — Adoption transition (T3-a), and Tactile Dialogues prototypes used in the Incubation — Nursery transition (T2-b) the eldercare partners are more strongly related to Textiles.
- C2 represents a cluster where the technology content is discussed. For both PSS's it is mainly the technology partner who contributes to this cluster. The exception is that for the prototypes used in the Nursery — Adoption transition (T3-a) the technology partner moves much more in the direction of Smart Textiles and Services.
- C3 shows a cluster in which all the Textile-related content is grouped. For Vigour and Tactile Dialogues, all the Textile-related partners are grouped in this cluster for the prototypes used in the Incubation — Nursery transition (T2-a and T2-b). For the prototypes used in the Nursery — Adoption transition (T3-b) the conversations of the textile partners moved more in the direction of Smart Textiles and Business (this is only possible to conclude from Tactile Dialogues, because the meeting data for the Vigour prototypes used in Nursery — Adoption (T3-a) of the textile partners is not included).
- C4 shows a cluster most clear in PSS development of Vigour, in the centre of all the Design Content clusters. This cluster shows that, supported by the

prototypes used in the Incubation — Nursery transition (T2-a) I requested information from all partners. Not relating more strongly to one of the specific disciplines, it means that this was a moment in the process when I needed input from all stakeholders.

Design Activity vs Design Content
The relation between the Design Activity (why things are said) and Design Content (what things are said) leads to the question: How do the prototypes support integrating disciplinary knowledge for the PSS design process? This analysis is based on the plots shown in Figures 4.18 and 4.19.

Prototypes: Based on the interpretations of the dimensions in combination with the Design Content information of each prototype, it becomes possible to discuss the characteristics of the prototypes. The three iterations of the prototypes are indicated by three lines with different colours.

- Vigour prototypes used in Incubation (T1-a, blue line) helped to support the co-creation of Service and Human aspects. The technology is more related to the information sharing and assessment quadrant of the plot.
- Vigour prototypes used in Incubation — Nursery transition (T2-a, orange line) supported the co-creation of Service and Technology aspects. For the other Design Content such as Textiles, Human and Business, the prototypes triggered more project management-related conversation, such as discussing the process and team coordination. Smart Textiles is located in the middle, between co-creation and information sharing.
- Vigour prototypes used in Nursery — Adoption transition (T3-a, green line) triggers mainly Design Content within the assessment – information sharing quadrant of the plot. The topics Textiles, Smart Textiles and Technology are particularly closely related to explaining solutions. Services is more closely related to the direction of co-creation, and Human more closely to project management.
- Tactile Dialogues prototypes used in Incubation (T1-b, blue line) supports co-creation activities for all Design Content. For Services, Human and Smart Textiles the co-creation particularly focuses on the generation of solutions. For Technology and Business, the co-creation is focussing more on assessment activities and decision-making.
- Tactile Dialogues prototypes used in Incubation — Nursery transition (T2-b, orange line) is also related to the co-creation type of activities with Business and Services related to solution generation, and Smart Textiles and Textiles more related to assessment. Content about human knowledge is more closely related to the implementation side of the plot, where it relates more closely to past design discussions and towards solution-testing procedures.
- Tactile Dialogues prototypes used in Nursery — Adoption transition (T3-b, green line) has a different profile: Technology, Smart Textiles and Textiles-related content are discussed within assessment activities (solution explanation

and solution analysis). Human knowledge is more related to the implementation side, particularly organisational information sharing and solution-testing procedures.

Clusters: For both Vigour and Tactile Dialogues three clusters of Design Activity and Design Content emerge from the plots (C1, C2 and C3 in Figures 4.18 and 4.19). Based on the previous analysis of the prototypes, it is possible to discuss the clusters in more detail.

- C1 is in both plots a cluster that groups Design Activity related to solution generation. For both PSS's it includes mainly Services and Human-related content, for the Incubation (T1-a and T1-b) and Incubation — Nursery transition (T2-a and T2-b).
- C2 is a cluster that contains Design Activity more related to managerial and implementation: for example, organisational information sharing, team coordination, and communication process. For Vigour these are mainly the prototypes used in the Incubation — Nursery transition (T2-a) in which the Design Content is used for these activities. For Tactile Dialogues these are mainly the prototypes used in the Incubation – Nursery transition (T2-b) and Nursery – Adoption transition (T3-b) and most strongly for Human content.
- C3 is a cluster in which assessment-related Design Activity is located, mainly solution analysis and solution explanation. For Vigour a large part of the Design Content is assessed with the prototypes used in the Nursery – Adoption transition (T3-a), and to a lesser extent to Technology for the prototypes used in the Incubation (T1-a) (Technology). For Tactile Dialogues, all prototypes are used to support assessment-related activities, particularly in the area of technology, smart textiles and textiles.

4.7 Conclusions

The main challenge of achieving horizontal collaborations between stakeholders who are involved in the design process of Embodied Smart Textile Services is to incorporate multiple types of skills, a variety of knowledge, and different viewpoints. In this chapter I approached this challenge by focussing on the research question: "How did prototypes support the collaborative design process within a community during critical transitions of the process, leading to the design of Embodied Smart Textile Services?" Knowledge sharing and knowledge integration are key topics in the field of collaborative design. Therefore, to investigate this question further I focussed on how the prototype supported the stakeholders and myself to share and integrate relevant knowledge. I used a type of protocol analysis called verbal analysis, which is typically used in collaborative design studies to analyse how teams design together. Based on studies within the collaborative design field (Deken et al., 2009, 2012), two important variables of such conversations were chosen: Conversational Balance (*how* things were said) and Design Activity (*why* things were said). In order to make the knowledge relevant for the design of Embodied Smart Textile Services, in which the multidisciplinary approach is key, I added the variable Design Content (*what* things were said). Eventually the relations between the three variables can explain how knowledge was integrated and shared during the PSS design process. In the chapter I used a descriptive statistical method called Correspondence Analysis to make sense of the conversations. This process consisted of five steps:

1. Codification of the transcriptions of the design meetings.
2. Word counts to find out how often each code was used during the design meeting.
3. Creating biplots based on the result of the Correspondence Analysis.
4. Interpreting the biplots by focussing on the difference between the prototypes.
5. Coming to higher-level findings by creating clusters out of the differences between the prototypes.

In this section I will try to interpret the results that I described in the findings on a higher level and put these in relation to the relevant literature about the roles of prototypes. Because the Correspondence Analysis should be used as a descriptive statistical method, the interpretations should be carefully addressed. In order to take into account the different viewpoints, I will triangulate between different sources to discuss the findings: my first-person reflections, excerpts from the design meetings, and the results of the Correspondence Analysis. The conclusions are divided into three topics, based on the initial relation between the variables and the research questions:

1. The relation between the Conversational Balance (how things are said) and Design Activity (why things are said) leads to the question: How do the prototypes support the partners to contribute to the PSS design process? This leads to the insight that “Prototypes focus discussion about the content”.
2. The relation between the Conversational Balance (how things are said) and Design Content (what things are said) leads to the question: How do the prototypes support the partners to share their disciplinary knowledge? This leads to the insight that “Prototypes make the knowledge meaningful and applicable for others”.
3. The relation between the Design Activity (why things are said) and Design Content (what things are said) leads to the question: How do the prototypes support integrating disciplinary knowledge for the PSS design process? This leads to the insight that “Prototypes embed the knowledge of the different stakeholders”.

Prototypes focus discussion about the content
By correlating the variables about Design Activities and Conversational Balance, the main finding was that the prototype can support the stakeholders to focus the

discussion about the content. Three main examples were found that supported this finding. The prototype supported the new stakeholders to grasp the PSS, and focus on the elements that are important for their discipline. The prototype supported the stakeholders to focus on in-depth details that could only be solved with their specific skills. The prototype supported the triggering and framing of discussions about existing issues, which helped the conversations to become in-depth.

In the beginning of each design meeting with the stakeholders there was always the moment I would introduce the new iteration of the prototype. If the stakeholders were involved in the previous iteration, they would be curious about the new elements that were created by other stakeholders or by me. If it was a new person being involved in the project, they would have to grasp the whole project in this short time. As discussed in the Design Activity vs Conversational Balance section, it is visible from the third cluster in both graphs (Figure 4.14 and Figure 4.15) that the prototypes played an important role in this explanation. It helped me to provide information about the Embodied Smart Textile Service, and also helped the partners to request information, particularly when they were new to the process. Excerpt 4.1 shows an example where I introduce the Blanket prototype (P15) for the first time to the textile producer (S24). In this situation I try to explain the context and interaction to the producer; however, soon after the conversation switched to one about how the textile in Blanket was developed. In this case this example shows how the prototype helps to focus the discussion about the parts of the large PSS which are relevant for that particular stakeholder. In this situation the prototype acted mostly as Boundary Object (Star & Griesemer, 1989). The textile producer was able to understand the PSS ideas behind the Blanket prototype on a level that was enough for him to participate in the design process. However, the prototype had a different meaning for him than for the other partners. He paid attention to the knit in the textile, the creation of tunnels by manually stitching the seams. In other words, the prototype was flexible enough to accommodate a different interpretation, but still robust enough to maintain a common identity.

> Design Researcher (S1): You did not see this one yet, I think. This is a test made in our lab, from a piece of pre-made textile. We tried to create the tunnel idea, to integrate the modules and close the seams by hand. These are the electronic modules we use for that. Textile Producer (S24): Yes. Design Researcher (S1): And in this one there is a vibration element integrated: you will feel it when you touch it with your hand. Do you feel the vibration? Textile Producer (S24): hmm hm. Design Researcher (S1): It is the plan to test this with people living around Tilburg, people who are in a severe stage of dementia.

Excerpt 4.1: In the beginning of the meeting Me19 I demonstrate the Blanket prototype to the textile producer (S24), who sees the prototype for the first time.

Another insight from the clusters discussed in the Design Activity vs Conversational Balance section is that the prototypes had a crucial role to support the other partners to use their knowledge in the co-creation process. In cluster 1 (Figure 4.14 and Figure 4.15) there are strong connections visible between the partners providing information, and discussing information during solution generation and solution analysis. This shows that the prototypes work as a catalyst for the partners to be involved in the process more easily, and start sharing their knowledge based on the prototype. This happened, for example, during meeting Me18 (Excerpt 4.2), where the electronics engineer (S7) analysed the current construction of the prototype, and proposed a different way to integrate the sensors, whereas, as designer, I would not have started to discuss how I created the sensors in the prototype, but focussed more on the application. The prototype did the work for me to let the engineer discuss the most relevant details. This specific role of the prototype is closely related to the concept of filters, which Lim et al. (2008) discuss in their framework of the anatomy of prototypes. By using prototypes as filters, certain aspects of a design idea that a designer tries to represent can be more emphasised: for example, appearance, data usage, functionality, interactivity and spatial structure. Here it was not necessarily me who tried to bring in a filter through the design of the prototype. Nonetheless, the engineer reacted to the appearance and functionality aspects by focussing on how the stretch sensors were constructed.

> Engineer (S7): Exactly, these are now three separate sensors in one line, but you could also integrate them into one long sensor. You have to do this with an analogue input, because you want to measure an analogue value and not just 1 or 0. The trick is to switch between analogue and digital input, and this one goes from power supply to ground.

Excerpt 4.2: The engineer proposes a method to change the circuit of the sensors in Vigour, to be able to measure the stretch on one line instead of different separated sensors (meeting Me18).

Finally, the third cluster combines solution testing with discussions particularly with the eldercare partner. Here the prototype supported us to start discussing the preparation of the tests: for example, to discuss improvements to be made to the prototype before testing could take place, or to discuss the procedures and parameters to test. During meeting Me16 we were preparing the procedures to test the first prototype of Vigour with the clients of the eldercare organisation, shown in Excerpt 4.3. The possibilities and limitations of the prototype served as a way to trigger the discussion, but also to frame the discussion about which testing parameters to take into account. In this example, the prototype really enlisted the eldercare stakeholders to think about how to test whether the prototype would work for their use case. This is similar to the theory of Conscription Devices (Henderson, 1991), as these allow the stakeholders to take part in generating, editing and correcting the object of design.

Eldercare manager: Can we in the beginning make a list of which movements to do, and do a baseline measurement for those? Or we can make that measurement with the shirt [Vigour v1]? That could also be a baseline measurement, right? Physiotherapist B: Yes, but what do we measure? Is it that people take a coffee cup themselves to drink? Or take some food? Or do we do a specific shoulder exercise? Or an exercise for the torso?

Excerpt 4.3: The partners from the eldercare organisation discuss a baseline measurement with the shirt, and a standardised testing procedure.

Prototypes make the knowledge meaningful and applicable for others
The relation between the Design Content and Conversational Balance variables led to the insight that prototypes make the knowledge meaningful and applicable for others. This was shown in the analysis in two surprising ways. First of all, the prototypes supported the stakeholders to see the meaning in the expertise of the other, allowing them to communicate with each other as equals. Secondly, the prototypes supported the stakeholders to integrate the knowledge and in some cases moved to a transdisciplinary approach where even knowledge of others was applied in the design process.
An important element of the community of partners during the projects was that everybody had a specific set of skills that was necessary to develop the PSS. During the meetings the prototypes helped the partners to share their disciplinary knowledge through their skills. This is visible from the C1, C2 and C3 clusters discussed in the Design Content vs Conversational Balance section where the Conversational Balance of the partner is strongly related to the Design Content. This shows that partners give feedback, ask questions, and discuss topics related to their unique knowledge. I experienced this during the meetings by the fact that partners would often react to the prototype with very specific disciplinary knowledge. For example, Excerpt 4.4 shows an example where the textile producer (S25) reacts to the textile quality of the prototype on the table, and proposes a technique that he eventually implemented to knit a new test sample.

Textile Producer (S25): You can also think of a technique in which you can implement this in a rib knit. If you can process this ribbing in a normal stitch, you can also create a ribbed intarsia. Then you keep it more elastic, and also the length will be more elastic than this [the prototype on the table]. Fashion Designer (S15): But you cannot process that on your machines, or can you? Textile Producer (S25): Yes, we can process that as well.

Excerpt 4.4: The textile producer explains how the current prototype (Vigour v1, P14) could be improved with a different technique during meeting Me20.

Another example of this can be found in the graphs in Figures 4.16 and 4.17. These graphs show that within the communication we treated each other as experts talking to each other. This is a surprising insight, because in collaborative design processes it is not always easy for stakeholders with different disciplinary backgrounds to be able to communicate. This equality was mainly triggered because the prototype helped us to talk about our expertise. This also counted for me: for example, in the meeting with the engineer (shown in Excerpt 4.5) the prototype offered the engineer an opportunity to ask questions about details of the construction, helped me to explain these details by pointing out and showing the prototype. The previous two examples the prototypes have most in common with are Boundary Objects (Star & Griesemer, 1989), as they integrated the knowledge from different disciplines during the design process. Moreover, the prototypes helped the people from certain disciplines to discover the meaning of other disciplines for themselves, because the object as Boundary Object helped with this translation. However, there is also a certain similarity with how a provotyping approach works (Mogensen, 1992). Certain tensions between disciplines necessary to implement the PSS (for example, the confrontation between producer S25 and designer S15, and engineer S7 and design researcher S1) emerged because these were clearly visible in the prototype itself. In the end, these tensions triggered the stakeholders to collaboratively find solutions.

> Engineer (S7): And how did you connect these parts? This is connected there, I assume? Design Researcher (S1): Yes, here you see the two copper yarns, attached with a needle and then fused with a type of glue to attach it firmly. This is again a tube in which the copper yarns can move freely to the sensors. Engineer (S7): Cool, very nice that it's like that, this is… this is attached afterwards? Or is this knitted into the fabric?

Excerpt 4.5: The engineer (S7) asks me how the connections in the prototype of Tactile Dialogues are made during meeting Me26.

Another trend that can be observed from the data as discussed in the Design Content vs Conversational Balance section is that the partners during the last prototype are discussing not only their own Design Content, but also knowledge from other areas. When we take a closer look at the biplot in Figure 4.16 showing the different prototypes of Vigour, we can see that it moves to the middle of the three disciplinary knowledge areas. Based on this, it can be concluded that there was no strong relation between Conversational Balance and Design Content for this prototype. This means that the conversations must have been a mix of multiple disciplines, and therefore more integrative. I experienced this to some extent from some of the partners. For example, Excerpt 4.6 shows a particular moment during the meeting that the physiotherapists and eldercare manager among themselves started to discuss the position of the electronics in the garment. Not only did they take into account how their clients would react, they also integrated previously established knowledge about the technical requirements of the stretch sensor. This can be related to theories about Experience prototypes. These typically are used to understand, explore or communicate what it might be like to engage with the product, space or systems being designed (Buchenau & Suri, 2000). In the case of the previous two examples, it is visible that the prototypes support the stakeholders to experience and find meaning in the practice of another disciplines. Which leads in the end to a more integrated PSS.

> Physiotherapist (S3): As a negative point I had the sensor position in the collar, and that is quite hard: some people already find a label annoying. We should take a good look at where to place it. Eldercare manager (S5): We could put it a little lower? 10 cm or 15 cm lower, around here. Physiotherapist (S2): But it depends how much stretch there will be. Because most people sit like this, so you get this.

Excerpt 4.6: The physiotherapists and eldercare manager are discussing the casing for the electronics on the back, and the best placement of the sensor areas during meeting Me21.

For the prototypes used in the Nursery — Adoption transition (T3-b) of Tactile Dialogues not all the partners changed their disciplinary communication: for example, the eldercare and technology partners stayed closer to their own disciplines. A possible explanation could be that the third iteration of Tactile Dialogues was not yet as far developed as the Vigour Embodied Smart Textile Service at the time of the meetings. The human and technology areas in particular were still under heavy development, and needed a lot of input from these partners. Nonetheless, the textile partner moved from the textile side of the axis towards the technology side, ending up in an area strongly related to smart textiles. The change of his mindset towards a more integrative way of thinking about textiles and technology is also visible in Excerpt 4.7. From these experiences I can conclude that the prototypes drive the process: they helped the partners to integrate their own disciplines, but also to become more integrative of the other disciplines involved.

> Textile Designer (S6): Ideally, it would become a kind of touch screen. It could be thin films with a module on top, and integrate these films every 2 cm.

Excerpt 4.7: The textile designer explains what would be his ideal smart textile integration of technology into the textiles during meeting Me23.

Prototypes embed the knowledge of the different stakeholders

The findings based on the coding of the Design Activity and Design Content variables led to the insight that prototypes embed the knowledge of the different stakeholders. This finding is substantiated by two main examples. Firstly, as a designer you don't need to have knowledge of all the elements of the Embodied Smart Textile Service: much of it is covered because of collaborating with different stakeholders. Secondly, we first co-created the directions to develop within the project based on people's expertise and skills. Later we needed project management processes to guide these developments.

One of the assumptions in the beginning of this design process was that the prototypes could support the stakeholders to co-create services in the early stages of the design process. This insight is confirmed by cluster C1 as discussed in the Design Activity vs Design Content section that is formed for both PSS's in the analysis. This cluster shows a clear relation between co-creation activities (such as solution generation) with Design Content of service and human. A good example was the following moment during meeting Me7, which is shown in Excerpt 4.8. After introducing the Touch Sleeve (P4) prototype, the therapists started to discuss how the different stakeholders would relate to the product. In the end the discussion about these relations turned out to be the first ideas for Blanket.

> Physiotherapist (S2): But no, this could be something fun that the motivational therapist could use, or the family. Certainly the family in that phase, what I just mentioned about people with severe dementia, those people who just sit in a chair and cannot talk anymore, then it is very nice to offer the family something that they can do. Sometimes they have these pillows they can use to play. But I can also imagine if there is something, with a light, then they could do it together, even if it is for a short time, because they cannot keep using it for hours.

Excerpt 4.8: Physiotherapist explains her idea to use a Smart Textile for a social activity.

Based on this experience it can be debated that as a designer of PSS's you do not need to have a full overview of the whole ecosystem. During the meetings with De Wever, many of the service aspects were designed before there was a clear embodiment of the service in the prototype. The first prototypes triggered the imagination of the people to start thinking about the service, and, by using their skills as physiotherapist they were able to integrate their knowledge, and co-create the service elements. However, for the assessment of the service component in services the PSS needs to be embodied physically and be situated in context. This becomes clearer when focussing on the assessment cluster (cluster 3) more closely in Figures 4.18 and 4.19. For both PSS's the prototypes used in the Incubation (T1-a and T1-b) and Nursery — Adoption transition (T3-a and T3-b) are being assessed, during the Incubation phase the assessment focussed more on the material side, the technology and the textiles. And later during the Nursery — Adoption transition the assessment moved to the services component. This observation points to reflect that it is necessary to embody some parts of the service component before it can be implemented and a service can be fully assessed. This insight can be mainly related to the theories that see the prototypes as tools to ask design questions (Houde & Hill, 1997), and examine an idea's quality without having completed the final design (Lim et al., 2008). The stakeholders were able to voice their own design questions, and embed their knowledge in order to answer these design questions. The strength is that it is not necessary to have a finished prototype of a PSS for this. As the findings show, it can also happen with the prototypes that only hint at the functionality of the PSS.

Another insight that the correspondence analysis highlighted was the fact that the three clusters discussed in section Design Activity vs Design Content (C1, C2 and C3) all embody a specific kind of Design Activity. When looking at how the prototypes are distributed among these clusters, the profile of the design process of the PSS's becomes visible. One of the observations from the analysis is the evolution that both PSS's follow in their development. With the prototypes used in the Incubation phase (T1-a and T1-b) the focus was on co-creation, and on using the prototype as a probe to gain insight from the different stakeholders. This probing function remained, but at the same time it is visible in the plots (in Figures 4.18 and 4.19) that project management (cluster 2) started to play a more important role during the during the Incubation — Nursery transition. Assessment-related activities were most clearly related to the prototypes used in the Nursery — Adoption transition of both projects (cluster 3).

This evolution corresponds with my subjective experience of the process. In the beginning there were no clear defined directions (Vigour and Tactile Dialogues did not exist), therefore we had to use the prototypes to co-create these directions. During the Incubation — Nursery transition it became clear what we were doing, and project management was necessary to collaborate with all the stakeholders. During the Nursery — Adoption transition the project was nearing the step that the prototypes were fully developed, and the main goal was to evaluate the PSS's. For example, during meeting Me23, the textile designer (S6) evaluated the specific vibration behaviour of Tactile Dialogues, and concluded that from his perspective the element to bring people together was missing (Excerpt 4.9).
At the same time he is using the assessment to propose this playful element for a new project (BB.Suit, P26) that started as a spin-off from Tactile Dialogues. The major difference with other collaborative processes is that normally the project would have started with managing the process, then design would have followed, and finally assessment. This finding shows that it is necessary to keep using filters (based on the anatomy of the prototype framework proposed by Lim et al. (2008)) during the different transitions in the design process. The filters can be approached from different levels based on the fidelity of the prototype. In the beginning it was enough to discuss the "appearance", "functionality" and "interactivity" filters on a basic level. Later, after more knowledge accumulated thorough the prototype, we needed to reconsider the filters and assess which direction to pursue.

Textile Designer (S6): It's vibrating, but doing the same thing when you're alone. It's not yet bringing people together. Because it does not bring people together, there is no playful element yet. That's something for South by Southwest, to have a playful element.

Excerpt 4.9: Textile designer assessing the effect of the vibrations during meeting Me23.

5.Scale of the stakeholders: How prototypes support making sense of Service Interfaces that are not there

This chapter is based on the following publications:

ten Bhömer, M. ten, Brouwer, C. E., Tomico, O., & Wensveen, S. A. G. (2013). Interactive prototypes in the participatory development of product-service systems. In *Proceedings of the 3rd Participatory Innovation Conference* (pp. 36-42).

Brouwer, C. E., & ten Bhömer, M. (2013). Imagining the prototype. In *Proceedings of the 3rd Participatory Innovation Conference* (pp. 43-51).

Brouwer, C. E., ten Bhömer, M., Tomico, O., & Wensveen, S. A. G. (2015). Assessing smart textile services using bodily knowledge of tangibility. In *Proceedings of the 5th Participatory Innovation Conference* (pp. 99-106).

5.1 Introduction

Similar to other Product-service Systems (PSS's), Embodied Smart Textile Services are PSS's that exist from combinations of tangible products and intangible services designed so that they jointly are capable of fulfilling specific customer needs (Tukker, 2004). Tangible properties include the "hand" of the fabric, which defines characteristics such as the softness, comfort to touch, flexibility to conform to the body, wearability and familiarity. These material qualities are particularly suited to applications in well-being and medical contexts such as rehabilitation (Black, 2007). Healthcare practitioners strongly emphasise the bodily and social abilities of their clients: for example, during physical rehabilitation exercises or medical examinations. According to traditional marketing literature, services are considered intangible and therefore "cannot be touched, tried on for size, or displayed on a shelf" (Shostack, 1977). However, the relations between providers and clients are based on the materiality and embodiment of their interfaces (Secomandi & Snelders, 2011).

The combination of these separate fields introduces a challenge for the stakeholders to merge the tangible characteristics of textiles and healthcare on one side, and the intangible nature of services on the other side. Within Embodied Smart Textile Services these elements are considered holistically. Meaning is created, manipulated and shared by the different stakeholders based on corporeal, social and contextual elements (Dourish, 2001). Therefore, to investigate how the participants make sense during the design process of the Service Interfaces I also take an embodied approach. I follow the notion that sense-making is not exclusively defined by individual cognitive mechanisms, but rather as a shared process grounded in ongoing embodied and situated interactions in a shared action space (De Jaegher & Di Paolo, 2007). This perspective has been explored in a design context by Hummels & Dijk (2015): in their approach they used embodied sense-making technology in order to elicit social coordination between participants.

This leads to the research question: "How do prototypes support embodied sense-making during the collaboration in a Smart Textile Services design process?" I will approach this question in two steps. Firstly, what is the role of the prototypes for stakeholders during moments of sense-making in design meetings? And secondly, how do the stakeholders use the prototypes for embodied sense-making when designing the tangible and intangible elements of the PSS?

Parts of this chapter are based on a compilation of previous papers presented during two Participatory Innovation Conferences (PIN-C 2013 in Lahti and PIN-C 2015 in The Hague). The analysis we conducted, and also parts of the text are therefore the result of a collaboration between a Conversation Analyst and myself (ten Bhömer et al., 2013; Brouwer & ten Bhömer, 2013; Brouwer et al., 2015).

Design Approach
Sense-making during the design of services is a topic gaining more and more interest in PSS research. Prototypes play an important role in these studies, either as the activity of collaborative prototyping during the PSS design process itself, or as a prototype of a service that can be used to evaluate and test a PSS experience. Within the fields of Participatory Design and Participatory Innovation the collaborative prototyping approach is often taken. For example, a study by Buur, Ankenbrand, & Mitchell (2013) explored how the process of business model innovation can be opened up to a larger group of participants. By using tangible objects to redefine business elements, or by letting people role-play a PSS scenario, they explore activities to help organisations in creating, delivering and capturing value. As an example of the second direction, Black, Åberg, & Holmlid (2012) pinpointed in their framework of perspectives for prototyping that the greatest challenges of prototyping a service are authenticity and validity. For these issues it is important to consider the larger context of implementation, use and location, as well as the use of real people; thus a holistic approach. Furthermore, they (Black et al., 2012) proposed the service walkthrough as one of the methods to address these issues, as it can show how different Service Interfaces work together, how information travels through the service, and the general experience of the service while keeping in mind authenticity and validity (a holistic approach).

Prototypes are tactile, preliminary and functional versions of a design. They offer possibilities for evaluating how a design will and will not work. One may see prototypes as resources that assist participants in the design process in envisioning in what ways a PSS may, could or should be used, and what could be improved, interactively with the other stakeholders. Envisioning a future PSS in use may be easier (and thus more fruitful) when a prototype can be touched, pointed at, held, or taken into use, since its functionality thereby can be tried out. Stakeholders that partake in a design session may relate their expert knowledge directly to whatever they experience from the prototype. The body can play as an important resource for design and sense-making of embodied interactions (Loke & Robertson, 2013). For example, the design movement approach aims to support and inspire designers to design for movement interactions by using the body as a creative material (Hummels, Overbeeke, & Klooster, 2007). In the discipline of somaesthetics the body is taken as the centre of our experiential existence to realise and understand interactions that cultivate ourselves (Lee, Lim, & Shusterman, 2014). For the design of services there have also been studies that investigated how these principles can provide better bodily experiences (Sundström et al., 2011).

Research Approach
Conversation Analysis (CA) is a research tradition which aims to investigate social interaction, studying the social organisation of conversation such as distribution of turns at talking, the collaborative production of particular actions, or problems of understanding (ten Have, 2007). The methodology is data-driven, in the sense that it offers insights into the details of the actual practices of people in interaction. By analysing sound and/or video recordings, Conversation Analysts pay detailed attention to the verbal and non-verbal way each utterance displays an interpretation of the previous utterance. Since this chapter investigates detailed explanations of how the stakeholders use the prototypes to discuss PSS elements and evaluate the PSS, I used this methodology for the analysis of design meetings. Together with a Conversation Analyst two design meetings were analysed in order to investigate how the prototypes, in combination with the body, can support a holistic sense-making approach during design meetings (ten Bhömer et al., 2013; Brouwer & ten Bhömer, 2013; Brouwer et al., 2015).

To answer the second part of the question (how are the prototypes used for embodied sense-making when designing tangible and intangible elements of the PSS?) special focus in analysis was given to how participants in the meetings come to assessments. One of the major tasks which participants in a design session face is to assess ideas, objects, mock-ups and the like, and to make sense of those assessments with each other so that they can reach agreement (or not). CA literature describes assessments as products of participation in social activities (Pomerantz, 1984). Assessments occur in everyday and institutional settings, and can be seen as a recurrent and recognisable phenomenon. According to Pomerantz (1984), assessments encompass ascribing value terms to a *referent*, which is the thing or property that is being referred to. Excerpt 5.1 and Excerpt 5.2 present some of the different ways this is being done.

01 (S1)	Ja *yes*
02	(0.4)
03 (S1)	Zoiets inderdaad [of een] trektouwtje:: eh trektouwtje is niet ideaal *Something like that indeed or a pulling cord eh* *pulling cord is not ideal*

Excerpt 5.1: Example of an assessment and referent in the same sentence.

01 (S3)	Verschrikkelijke muziek. *Terrible music*

Excerpt 5.2: Example of an assessment.

It is an interactional task for the participants to establish the referent that they are making an assessment about. This can be done by naming the referent in the same turn at talk, as in Excerpt 5.1, where 'pulling cord' is the referent, and 'not ideal' the value term; and in Excerpt 5.2, the referent being 'music' and the value term 'terrible'. In both cases, the referent and the assessment are produced through talk by the same speaker. However, establishing the referent may be done by one participant, while another participant makes the assessment about it as in Excerpt 5.3. Here the Design Researcher (S1) establishes the referent through talk, the making of pleats in the cardigan, while the eldercare organisation Manager (S5) asserts the value term 'good'.

01 (S1)	Der is veel rekening gehouden met eh (0.4) *A lot of consideration was made with eh*
02 (S5)	(hhh)
03 (S1)	extra plooien der in te brengen om de lichaamsvo(h)rmen (h)e(h)e *placing extra pleats in order to make the body form*
04	wat eh makkelijker [te maken er] in te passen *fit in a better way*
05 (S5)	[nou wat goed] *wow how great*

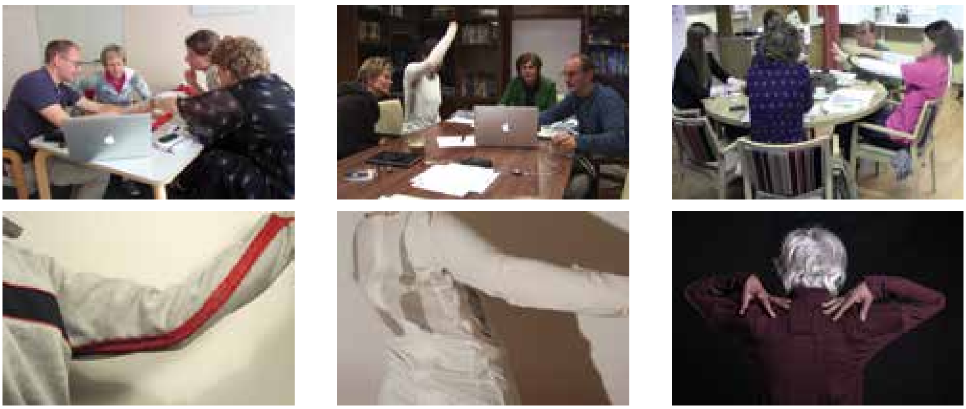
Excerpt 5.3: Example of an assessment and referent not by the same person.

Structure of the chapter

The *Data Selection* section will show which design meetings are used to investigate the research question. In the *Data Documentation* section these two meetings are further described in order to provide background information about the dataset. The analysis in this chapter is divided into two steps. Firstly, the *Data Codification* section introduces an analysis which was used to come to a codification to describe the bodily interactions in design meetings. Described in the *Data Analysis* section, this codification was applied in the second analysis to answer the second part of the research questions: how do these bodily interactions with prototypes play a role in the embodied sense-making process to assess PSS? In the *Findings* section the techniques that participants use to assess the different parts of the PSS are further developed into four categories. In the *Conclusions* section I will reflect on the implications based on the earlier introduced theory about sense-making and prototypes.

5.2 Data Selection

To answer the research question as explained in the previous section, this chapter will focus on the Vigour PSS. During the development of Vigour, the prototypes had an interesting role because the main Service Interface of the PSS was a wearable garment. This brought about challenges in the evaluation process, since it was harder to test the prototype during the meetings. In contrast, the pillow from Tactile Dialogues PSS was an object that could more easily touched and moved around while demonstrating. The Vigour PSS (as earlier explained in Chapter 2) is a smart cardigan for people with dementia that motivates the people to move more using sound. Although intangible components played an important role, the actual service is actualised through a Service Interface (in this case, a cardigan) that is available for bodily perception. To realise this application, connections between the whole vertical textile chain were needed (shown in Chapter 3). This approach required the involvement of a wide group of stakeholders to collaborate in a participatory innovation process. This analysis will focus primarily on meetings with the stakeholders from the eldercare service provider. There were many aspects of the Service Interfaces that had to be evaluated with these stakeholders, since the PSS had to be eventually deployed together with them. Another reason for choosing the meetings with these stakeholders is that they were involved in each iteration of the PSS, making it a very complete dataset for the sake of this analysis. Figure 5.1 shows the three main prototype iterations of the Vigour PSS, and the corresponding meetings with the stakeholders from the eldercare organisation (Me7, Me16 and Me21). Me16 and Me21 will be used for the Conversation Analysis; Me7 will not be discussed because this meeting has only been recorded in audio format (no video).



a) Stretch shirt concept being discussed

b) Evaluating Vigour prototype

c) Evaluating new Vigour and iPad application

Figure 5.1: Three prototypes of Vigour PSS, and the meetings with the eldercare stakeholders.

5.3 Data Documentation

The set-up of both selected meetings is based on a co-reflection structure, which consists of an exploration, an ideation, and a confrontation phase (the set-up of the meetings is more elaborately explained in the section about sense-making in Chapter 1). The goal of these phases is that, through reflecting on different ideas, people will be confronted with different viewpoints, which can change the frame of reference of both the design researcher and stakeholders.

Me16: Evaluation Vigour v1

The stakeholders present during the meeting were the two physiotherapists (S3 and S16), a care manager specialised in dementia care (S5), and myself (S1) to discuss the prototypes of Vigour v1 Interface (P13) and Vigour v1 (P14). On the one hand, this meeting aimed to reflect on the current state of the PSS, to envision new possibilities and decide on next steps. On the other hand, analysing meetings like these, that happen in a real project, with real stakeholders, can help find out more about the development process of PSS's, and in particular the role of prototypes. The group of people who took part in the meetings have met regularly during the course of the project to take important design decisions together. The meeting consisted of four steps: reflecting on the origin of the design decisions; reflecting on positive and negative aspects of the current prototype; generating ideal future service elements; and generating concrete next steps. In each step the participants filled in their findings on different forms and discussed their findings together. The participants spoke Dutch in this session. They mostly sat around a table during the session. Importantly, only one participant, S5, was introduced to the prototype in this session. Two participants saw and to some extent tried the shirt out before the session. The session thus to a certain degree concerned their earlier experiences with the shirt.

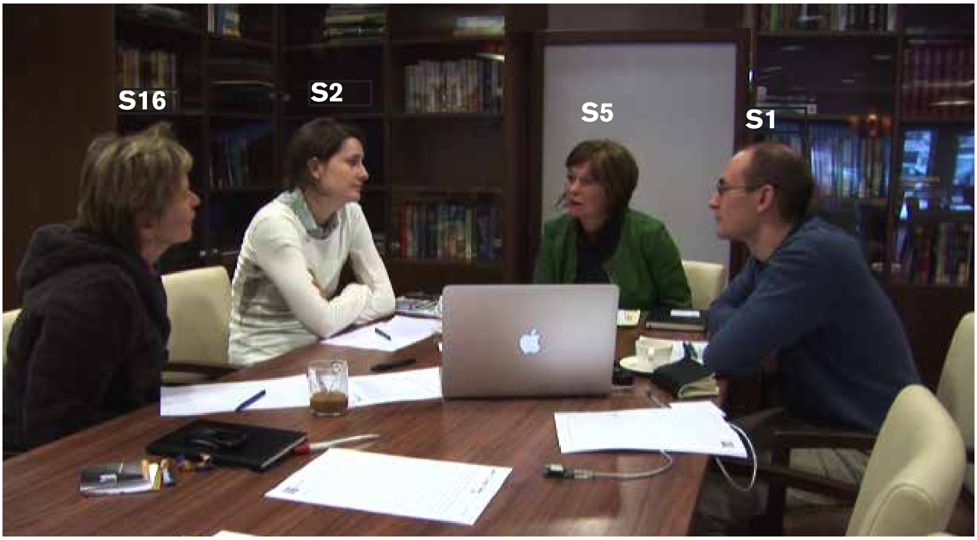


Figure 5.2: Sitting arrangement around the table.

To give an idea about what kind of insights were elicited during the meeting by the prototype, I will discuss some of the outcomes of the meeting. Having a prototype that could be touched, worn and interacted with helped to make the requirements of the stakeholders very clear. The shirt needed to be fashionable and have a good fit, and the sensors needed to be located on the right positions to provide accurate sensor data. Discussing the prototype also helped to open the discussion about the next things to consider when the PSS needs to be implemented.

Figure 5.3: Picture of Vigour v1 (P14) with sensor areas on specific parts of the body that can be used to measure movement of the arms and lower back.

Figure 5.4: The interactive application Vigour v1 Interface (P13), that the therapist saw on the computer. The red parts on the shirt indicate which sensors are currently being stretched. With the bars on the right side, the therapists could change the sensitivity of the sensors.

The stakeholders came up with a multitude of different scenarios in which the shirt could be applied. For example: for individual use, for group use, with family of the client or without, to measure daily activities, to be used in rehabilitation exercises. Finally, the meeting helped the design researcher and the stakeholders to create together a list of prioritised next steps that should be taken for the shirt to have value in the larger PSS. These were very concrete aspects such as: making the sensors more sensitive, choosing the target group for first tests, and deciding on how many people to test the shirt with.

Me21: Evaluation Vigour v2

During the development of this prototype the main focus was on improving the aesthetic and material qualities, and particularly in realising a less stigmatising medical appearance. The goal of meeting Me21 was: 1) to evaluate the current prototype (Vigour v2, P25 and the Vigour v2 iPad Application, P21); 2) to understand the participants' positive and negative associations with the iteration of the Smart Textile Service; 3) to brainstorm about the ideal future Smart Textile Service; and 4) to establish mutual agreement about the next steps to take. This could include, for example, who to involve, how to set up a test with the clients of the eldercare organisation, or how to design the sounds that reacted to body movement. The participants of the meeting (Figure 5.5) were the following: two physiotherapists (S2 and S3) from the eldercare organisation, a dementia expertise centre manager of the same eldercare organisation (S5), an Interaction Designer (S13) who was responsible for the design and development of the iPad application and myself, design researcher responsible for the integration of the elements in the prototype (S1). The duration of the meeting was 2 hours and 54 minutes.

Figure 5.5: Sitting arrangement around the table.

Figure 5.6: Picture of Vigour v2 (P24). In this meeting a fitting model (Vigour v2 Fitting Model, P24) was used, in which the electronics were not yet integrated.

Figure 5.7: Picture of the interactive sample of Vigour v2 (P22) that was used to connect to the iPad application, and enabled us to demonstrate the application.

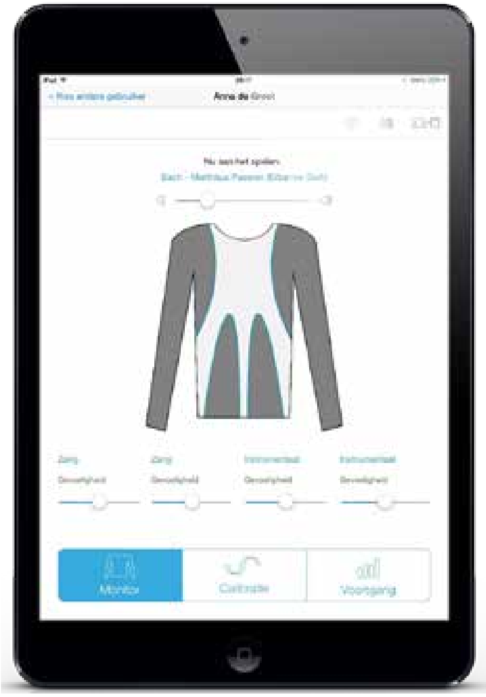


Figure 5.8: Interface for iPad (P21) that was developed by the Interaction Designer (S31), this screen shows the overview of the four sensors, and the instruments that can be connected.

5.4 Data Codification

Apart from the prototype, however, participants in a design session may, as they do in most contexts where social actions are accomplished, make use of their own bodies: for example, by gestures and gaze, and talk. Handling the prototype in itself may or may not be meaningful, but it is typically done in and through carefully concerted complex actions that encompass gaze, body movements, gesture, artefact handling, and talk. Moreover, although typically only one person has a turn at talk at a time (Sacks, Schegloff, & Jefferson, 1974), other participants may simultaneously make use of gaze, gesture, and bodily movements. In this section a codification is introduced that will help to define how participants handle the prototype in the design meeting, and how that handling, together with talk, body movements and gaze, is used in order to establish intersubjective meaning. This codification emerged from the analysis of the interactions that took place when evaluating prototype Vigour v1 (during meeting Me16).

Gazing with pointing, touching and/or manipulating
In Excerpt 5.4 the design researcher (S1) can be understood to instruct the participants to take the prototype into account (line 3), by asking a question of how the feature is expressed ('terugkomen': come back). The design researcher (S1) encourages linking the insight to the prototype not only verbally, but also by his gaze, and his spread hand addresses the prototype as central.

Figure 5.9: Hand spread towards prototype (line 3 in Excerpt 5.4).

01	0.3	
02 (S16)	[eh::]	
03 (S1)	[(en)] fashionable hoe zie {je {dat eh::m *and fashionable how do you see that ehm*	
	gaze S1	{>prototype
	hand S1	{spread point towards prototype
04 (S1)	eh terugkomen [in et eh *eh come back in the eh*	
	gaze S1	> S2
	hand S1 retreat folded back to body	
05 (S16)	[dat et een {shirt is wat = *that it is a shirt that*	
	gaze S16 > S1-------------------------{>prototype--	
06 (S16)	={iemand echt {e::h zonder problemen aan= someone really eh without problems can put	
	gaze S16 --prototype------{>S1-------------------------- hand S16 open palm up over table----------------------	
07 (S16)	=kan trekken en wat {ook best {mooi is. *=on and that is actually quite nice.*	
	gaze S16------S1------------------{>prototype hand S16-----open palm-----------{beat over prototype with back	
08 (S1)	ja (.) ja *yes yes*	

Excerpt 5.4.

This has some effects, since the physiotherapist (S16) (A) now specifically mentions the shirt (line 14), directs her gaze to it briefly in line 14 and again in line 15, and has a kind of vague pointer to it with the back of her hand (line 15). However, the physiotherapist (S16) does not specifically answer the design researcher's (S1) question as to which aspects of the prototype make it fashionable, but rather rephrases what she means by fashionable ('best mooi': quite nice). Just a little later in the interaction (the fragment shown in Excerpt 5.5), the design researcher (S1) further pursues a response that points to specific aspects of the prototype, an answer that to a greater degree exploits the prototype as an artefact.

01 (S1)	enne: e:h (0.4) *and eh*	
02 (S1)	waar zie je dat nu dan {terugkomen in:: *where do you see this coming back in*	
	hand S1	{>spread point towards prototype
03	(0.6)	

04 (S16)	e[::h]
05 (S1)	[ja] t is een beetje die herkomstvraag= *yes it is kind of this question about origin*
06 (S16)	=zeg ma[ar] dus ehm *you could say so ehm*
07 (S1)	**[ja]** *yes*

Excerpt 5.5.

Again, the design researcher (S1) encourages the participants to exploit the prototype as an artefact to explicate their insights. After some more quite abstract talk, the other physiotherapist (S2), explicates how the shirt is fashionable by taking the shirt, turning it around, and showing some fashionable feature. Hereby the physiotherapist (S2) exploits the prototype as an artefact to explicate the design feature 'fashionable'.

01 (S2)		ja (.) *yes*		
	hands S2	stretches>top of shirt and grabs		
02 (S2)		*en ook dat t boordje bevoorbeeld nie eh (.)* *yes and also that the collar for example not eh*		
	gaze S2 > gaze S26 > gaze S1 > hands S2	hands/prototype prototype prototype flips top of shirt over -- lies in front of S2		
03 (S2)		tot hier {zit *reaches here*		
	gaze S2 > gaze S16 > gaze S1 { >	S1 S2 S1	>	S16

Excerpt 5.6.

The previous analysis shows that the mere presence of a prototype does not necessarily mean that participants will exploit it in their talk about the design. It also shows that the design researcher (S1) implicitly encourages the participants to do so. Furthermore, Excerpt 5.6 shows a technique for exploiting the prototype by manipulating it directly. This manipulation can be seen as a display of one specific property of it to others that explicates the characteristic of 'fashionable'. In the example above, the physiotherapist (S2) deliberately reaches for the prototype in order to show it to the other participants, not to examine it in order to get insights. In this way, the physiotherapist (S2) seems to use the prototype to support an opinion she had beforehand, or to present it as such.

Figure 5.10: Arranging the prototype (line 2 in Excerpt 5.6).

More generally, manipulating the prototype in this way, as is the case with pointing, is treated by the other participants as an invitation to establish joint attention to the prototype or specific parts of it, or, in Goodwin's words: 'attempting to establish a particular space as a shared focus for the organisation of cognition and action' (Goodwin, 2003). The two other participants have their gaze on the part of the prototype as the physiotherapist (S2) is flipping it over and it remains there. In line 3 the physiotherapist (S2) has withdrawn her gaze and hands from the prototype and seeks the design researcher's (S1) and the other physiotherapist's (S16) gazes by looking at them in order to direct their gazes at her instead of the prototype. A speaker may thus, by demonstrably directing gaze and hands towards objects or contrarily withdrawing gaze and hands, guide the recipients' gaze towards the relevant persons or objects for the talk. Bodily orientations such as gaze, pointing and/or manipulating and talk are juxtaposed – they are produced and understood as a package (Goodwin, 2003). Such direction of attention to the prototype can be understood as an act of reference. Some utterances, specifically those that include deictic expressions (this, that, there, him, etc) can only be understood properly by ensuring participants' attention to the entity the expression is supposed to refer to, typically before that expression is made (Hindmarsh & Heath, 2000). This is the case in Excerpt 5.7. Touching, pointing at, moving and other manipulative (i.e. using the hands) actions with the prototype seem to establish the referent, in this excerpt 'deze twee sensoren' these two sensors, line 4. Afterwards, assertions are made about that referent (lines 9-12). Note that the speaker actually starts out with making an assertion about the referent (line 1), but then changes her speech to first establish exactly what she is talking about.

01 (S2)		ehm wat ik al {merkte/{is dat eh wanneer je:: *ehm what I already noticed is that eh when you*
	hands S2	{>laying out armpit section------------------
	gaze S2	{>armpit section------------------------------
	gaze S16	{>S2------------------{>armpit section------
	gaze S1	{>S2----------------- {>armpit section------
02		(0.5)
	hands S2	on armpit section---
	gaze S2	>armpit section
	gaze S16	>armpit section
	gaze S1	>armpit section
03 (S2)		ik had toen bevoorbeeld= *I did then for example*
	hands S2	stretches armpit section---
	gaze S2	>armpit section
	gazeS16	>armpit section
	gaze S1	>armpit section
04 (S2)		=deze twee sensoren aangeklikt? *click these two sensors?*
	hands S2	holds armpit section---
	gaze S2	>armpit section
	gazeS16	>armpit section
	gaze S1	>armpit section
05		(0.2)
	gaze S2	>S1
	gaze S1	>S2
06 (S1)		mhm
07 (S2)		met een geluid= *with a sound*
08 (S1)		=ja *yes*
09 (S2)		en je moet echt een {flinke *and you really have a big*
	Lhand	S2 {moves up over head
	gaze S17	> S2 {follows S2s hand
	gazeS1	> S2
10 (S2)		anteflexie {maken? *antiflex to make*
	Lhand S2	stays up over head
	gaze S16	> S2s hand
	gaze S1	> S2
11		(0.5)
12 (S2)		wil dat geluidje {afspelen *if the sound has to play*

Excerpt 5.7.

Figure 5.10: Holding the prototype (lines 2-4 in Excerpt 5.7).

Demonstration with the prototype

Pointing, touching, holding and moving the prototype is one thing, but participants may also take the prototype into use, the way it is supposed to be taken into use. In the design meeting (Me16), we thus see that, at some point, the physiotherapist (S2) is asked to put on the shirt in order to demonstrate its functions to the newly arrived fourth participant, the eldercare manager (S5). In the fragment presented in Excerpt 5.8, the prototype is represented by two artefacts: the shirt itself (P14) and the computer (P13), by which the sound feedback is given. The physiotherapist (S2) is demonstrating the prototype by fixing her gaze on the computer and by her verbal 'kijk' look, can be understood as establishing the computer as the relevant focus (line 1). The demonstrating physiotherapists' (S2) gaze is on the computer throughout the excerpt, and apart from glances from the eldercare manager (S5) (line 2 and line 6) as well as the other physiotherapist (S16) (line 2) towards the demonstrating physiotherapist (S2), gazes are on the computer screen. The participants thus mainly focus on what the computer does in relation to the movements that the demonstrating physiotherapist (S2) makes.

01 (S2)	*n ki{jk *nd look*	
	Rarm S2 gazeall	{moves stretched up >computer
02	(1.2)	
	Rarm S2 gaze S2 gaze S16 gaze S1 gaze S5	stretches up over head/short stretch beyond shoulder >armpit section >computer>S2sarm >computer >computer >S2sarm >computer

03 (S2)	want *because*	
	Rarm S2 gazeall	moves down >computer
04	(0.3)	
	Rarm S2 hands S2 gazeall	moves down - rest on table holds armpit section--- >computer
05	(0.7)	
	Larm S2 gazeall	moves up stretch to about eye level >computer
06	(0.8) ((total elapsed time 1.8))	
	Larm S2 Rhand S2 gaze S2, S16, S1 gaze S5	lowers sli{ghtly {touches upper left arm >computer >computer> S2
07 (S2)	hij moet dus *it ought to*	
	Rhand S2 S2, S16, S1 gaze S5	moves tiwards wrist of stretched left arm gaze >computer >S2 > computer
08	(0.9)	
	Rarm S2 gazeall	stretches parallell to stretched left arm >computer
09 (S2)	rood worden toch *become red right*	
	Rhand S2 gazeall	moves toward elbow of left arm >computer
10	(0.4)	
	gazeall	>computer
11 (S16)	ah ja *ah yes*	

Excerpt 5.8.

In making her movements, the physiotherapist (S2) demonstrates here that the sensors of the shirt may not be sensitive enough. This is an insight that the physiotherapist (S2) bases on earlier experience with the shirt, a point that she has made earlier in the session (Excerpt 5.7). In Excerpt 5.7, however, her manipulation with the prototype (touching the sensors at the armpit and stretching them) only illustrates her assertion. Other participants have to take for granted that a large stretch has to be made in order for the sensors to register the movement. In Excerpt 5.8, the assertion is substantiated with a demonstration through which the other participants get direct experience which provides convincing evidence for the assertion. In that sense, the version of the assertion in Excerpt 5.7 was a claim, while in Excerpt 5.8 it was done as a demonstration (Sacks, 1992). Demonstrating the prototype, and thereby providing evidence for design issues, can be seen as making the insight recognisable for other participants through experiences that they did not necessarily have beforehand.

Figure 5.11: Demonstrating the prototype (line 2 in Excerpt 5.8).

Demonstration by imitating use

Depending on what kind of object a prototype is, and what it does, it can be employed in different ways and thereby show specific issues to others. The physiotherapist (S2) could only illustrate (specifying the sensors) what she was talking about when making her point in Excerpt 5.7, while she could demonstrate her point in Excerpt 5.8. The difference was having the shirt lying on the table, or having it on her body. Initially one could claim that wearing the shirt would give the participants better opportunities for proving their points. This does, however, depend on what kind of assertion is being made, and to what extent different participants have access to those features of the prototype which are in focus. In the following Excerpt 5.9, the physiotherapist (S16) makes a remark about the sensors in the back that should be placed lower.

01 (S16)		en wat hadden we daar nou *and what did we again*	
	gaze S16	> S5-------------------------------	
02 (S16)		we hebben het daar wel es over ge{had hè *we did talk about this one time right*	
	gaze S16 torso S16	>S2--------------------------	{S2sback {leans back
03 (S16)		wat hadden we daar nou voor (.) bedacht?.ff *what did we come up with for that again?*	

	gaze S16	>S2s back
	arm S16	lifts over back of chairs
04 (S16)	dat ie eh *that it eh*	
	gaze S16	>S2s back
05	(1.7)	
	gaze S16	>S2s back
06 (S16)	dat *that*	
	gaze S16	>S2s back
07	(0.4)	
	gazeS16	>S2s back
08 (S16)	dat dat shirt eh *that that shirt eh*	
	gaze S16	>S2s back
	gaze S5	>S16
09 (S16)	dat {die sensoren *that those sensors*	
	gaze S16	>S2s back
	Lhand S16	moves over S2s back downwards
	head S5 lift	>S16 Lhand
	gaze S5	follows S16 Lhand
	torso S5	moving back in order to see S16 Lhand
10 (S16)	.mff	
11 (S16)	eigenlijk lager moesten be{ginnen he *actually should start lower right*	
	gaze S16	>S2s back------------------{>S1
	Lhand S16	rests on S2s lower back
	gaze S5	S16 Lhand
12 (S1)	ja (.) klopt *yes that's right*	

Excerpt 5.9.

The physiotherapist (S16) indicates the location of the sensors she is talking about by stroking her hand over them (line 8). But since the other physiotherapist (S2) is still wearing the shirt, the physiotherapist (S16) has to rearrange her body towards her, in order to actually see and touch the right place. The eldercare manager (S5), sitting in a 45-degree angle to the two physiotherapists (S2 and S16), also adjusts her body in order to follow the physiotherapist's (S16) hand and view the sensors (lines 9-11). Again, we see that when a speaker directs her gaze and hands towards the prototype, other participants will gaze in the same direction.
The other two participants, however, do not gaze at the sensors. The design researcher (S1), who sits in front of the physiotherapist (S2), would have to stand

up and walk to the other side of the table in order to see, and the physiotherapist (S2) wearing the shirt would have to take it off. The physiotherapist's (S16) hand movements are out of her sight, and her hand does not seem to directly touch the shirt, so the physiotherapist (S2) does not feel her gestures either. Hence, in this case, the participants do not have a mutual gaze on the features talked about. We see thus that, while taking a prototype into use may give stronger evidence for points made, in this case it also has limitations: since the prototype is 'in use', it can only be manipulated as an attribute to the physiotherapist's (S2) body, which makes it less flexible, even though there may also be advantages to have it on someone's body. The prototype on the table was to a higher degree accessible for manipulation and gaze by all participants.

Figure 5.10: 'those sensors' (line 8 in Excerpt 5.9).

Figure 5.11: Actually lower (line 10 in Excerpt 5.9).

Participants, as noted above, have techniques for establishing joint attention to some object or person. In a design meeting, this is not always the prototype. We saw already in Excerpt 5.8 that the participants mostly looked at the computer, but also had some glances at the physiotherapist (S2) wearing the prototype. In addition, in Excerpt 5.6, the physiotherapist (S2) went from manipulating the prototype to making a gesture at her throat, while, just before and during, she sought the gaze of the other participants. And in excerpt 5.7, the physiotherapist (S2) shifts from having her hands on the prototype to making a movement with her body in order to exemplify the movement a user will have to make in order for the sensor of the shirt to react. In both cases, her recipients move their gaze from the prototype towards what the physiotherapist (S2) is doing with her movements. Interestingly, the movement in Excerpt 5.7, lines 9-11, is understandable as a meaningful movement only in relation to the physiotherapist (S2) having the shirt on. In order to make sense of the movement, recipients need to take the prototype and its functions into account – one could say that in a sense they have to imagine or map the prototype onto the physiotherapist's (S2) body in order to understand how it is meaningful. This is of course also supported by her talk. Significantly, the physiotherapist (S2) is drawing on her having had an earlier experience with the shirt — having the shirt on. This way of exploiting the prototype, manipulating or using it as if it was there, is reminiscent of Streeck's description of gestures that mimic manipulations of materials. As he asserts: 'As onlookers or interlocutors we apprehend these gestures as mimetic representations, turning, pulling, pushing things that are implicitly there' (Streeck, 2002, p. 25) Using these types of gestures and movements means that the prototype can be exploited in the way that fits the participants best, even if it is in the wrong place for the purpose at hand. So, although the prototype is on the table, the physiotherapist (S2) shows how it works on the body. Now, as we have shown in Excerpt 5.9, having the prototype on someone's body is not always the optimal position. In this case, establishing joint attention to the referent was not possible. In the next fragment, a little later than Excerpt 5.9, still talking about the sensors on the back, the physiotherapist (S16) communicates how the fabric of the prototype needs to stretch when you make a specific movement. In order to communicate this, the physiotherapist (S16) has a double problem: the shirt is not directly available for manipulation with her hands, and it is also not available for her to demonstrate it 'in use' since it is on the physiotherapist's (S2) body. The physiotherapist (S16) solves the problem like this: firstly, the physiotherapist (S16) makes a gesture, as if she is manipulating the fabric of the shirt on the back, holds her hand at the stretching position as shown in Figure 5.12.

01 (S16)	dus eigenlijk moet die sensor *so actually this sensor*	
	gaze S16	> S1------------------------------
	gaze S1	>S16------------------------------
	gaze S5	> S16------------------------------
	gaze S2	> paper on table
02 (S16)	zo laag mogelijk beginnen *should start as low as possible*	
	gaze S16	> S1------------------------------
	gaze S1	> S16-------------------------------
	gaze S5	> S16-------------------------------
	gaze S2	> paper on table

03	(0.8)	
	hands S16	brings in a position in front of her body
04	*(0.4) ((total elapsed time 1.2))*	
	Rhand S16 starts stroking motion, palm out, upwards	
05 (S16)	het stuk daarboven (.) *the piece above that*	
	Rhand S16	continues stroking motion, following a round curve ending with palm downward at about eye level
06 (S16)	als je beweegt= *when you move*	
	Rhand S16 torso S16	keeps in position at about eye level forward movement
07 (S16)	=dat dat pu-{dat het uitge (.) rekt wordt *that that po- that this is being stretched*	
	torso S16 Rhand S16	backward movement {stretching gesture

Excerpt 5.11.

Figure 5.12: Manipulating the prototype as if it was there (lines 4-5 in Excerpt 5.11).

Figure 5.13: 'When you move' (line 6 in Excerpt 5.11).

Right after line 5 the physiotherapist (S16) mimics the movement you'd have to make for the shirt to stretch like this by moving her torso back and forth, while keeping the hand in position, and finishing off with repeating the stretching motion (shown in Figure 5.13). In a way, therefore, the physiotherapist (S16) is simulating two imagined prototypes at the same time: one in her hands which she manipulates, and one on her body which she takes 'in use'. All the while, the physiotherapist (S2) is wearing the shirt. By gesture and movement the physiotherapist (S16) invokes the prototype and what you can do with it. The prototype can be understood as being invoked by way of the situational and chronological context in which the prototype also has been exploited manually and been demonstrated — in Streeck's words: 'the indexical, tactile grounds of the gestures figuration are available from the recent interaction' (Streeck, 2002. p. 37). Thus, the physiotherapist (S16) manages to both manipulate and demonstrate the prototype in order to talk about design issues — and she does it in a space where all participants have good possibilities to direct their gaze.

Codification

Based on the analysis of the previously analysed meeting Me16, a language emerged to describe the specific bodily interactions with prototypes. To be able to answer the second research question (how do the prototypes play a role in the embodied sense-making of the tangible and intangible elements of the PSS?), this language will be extended with a layer to clarify the context of the interactions. This codification is shown in Table 5.2. The first variable (column 1) was derived from the previous explained findings about bodily interactions with prototypes in design meetings. The second and third variables (respectively, columns 2 and 3) emerged during the analysis of the next design meeting (Me21).

Bodily Interaction	**Referring to**	**Reason**
1.1 Gazing and Pointing	2.1 Vigour Fitting Model (P24)	3.1 Assessing Existing Prototype
1.2 Gazing and Touching	2.2 Vigour iPad Application (P21)	3.2 Assessing Future Features
1.3 Gazing and Manipulation	2.3 Vigour v2 Sample (P22)	3.3 Introducing Prototype
1.4 Demonstration with the Prototype	2.4 Diagram of Service Interfaces	3.4 Explaining Features
1.5 Demonstration with the Body		

Table 5.2: Overview of the coding that will be used to analyse meeting Me21.

The first variable describes the different bodily interactions that were found in previous analyses. Codes 1.1, 1,2 and 1.3 can be used to refer to the different ways that gazing is compared with bodily interactions, as described in the Gazing with pointing, touching and/or manipulating section. Code 1.4 refers to taking the prototype physically in use, as described in the Demonstration with the prototype section. Code 1.5 can be used to refer to the case that a participant is imitating the demonstration of the prototype, as described in the Demonstration by imitating use section. The second variable can be used to indicate which prototype the participants are referring to. For example, code 2.1 refers to the prototype of the Vigour v2 Fitting Model (P24); code 2.2 refers to the iPad application (P21); code 2.3 refers to a sample of Vigour v2 (P22) which already had the working sensors integrated; and finally code 2.4 refers to a paper with a diagram of the Service Interfaces which was used during the design meeting. The third variable is used to indicate the reason why the participant was referring to a certain object. Codes 3.1 and 3.2 deal with assessments, respectively, for assessing existing features of the prototype or features not yet implemented. Code 3.3 indicates that the prototype was introduced: for example, during the first introduction to the people who have not seen it yet. Code 3.4 was used to refer to instances where a participant used the prototype to explain features using the prototype.

The next section will present the analysis where this codification is applied in order to investigate how specific PSS elements are assessed during a design meeting.

5.5 Data Analysis

The previous section showed that certain bodily interactions play a role in design meetings, mainly gazing in combination with pointing, touching and/or manipulation with the prototype, but also in demonstrations of the prototype in use and even demonstrations by simulating the use of the prototype on the body. In order to answer the second research question (how do these bodily interactions with prototypes play a role in the embodied sense-making process to assess PSS?), this analysis will focus on the relation between these bodily interactions and the specific tangible and intangible aspects of the Smart Textile Services being evaluated. To substantiate the findings of the analysis, fragments of excerpts from meeting Me21 and still frames from the video recordings of the meeting are presented.

Initial Codification

To give direction to the analysis, I codified the 102-minute-long video recording of the design meeting using the codification explained in previous section (Table 5.2). Every bodily interaction in combination with a spoken utterance was coded with a combination of the three codes. For example, a sentence could be coded with the combination of 1.4, 2.1, 3.1, meaning that the Vigour fitting model was demonstrated in order to assess the existing prototype. I counted all the occurrences of the coding during sense-making moments in the meeting, and this resulted in the overview presented in Table 5.3.

Bodily Interaction	Count	Referring to	Count	Reason	Count
1.1 Gazing and Pointing	38	2.1 Vigour Fitting Model (P24)	82	3.1 Assessing Existing Prototype	24
1.2 Gazing and Touching	32	2.2 Vigour iPad Application (P21)	43	3.2 Assessing Future Features	64
1.3 Gazing and Manipulation	34	2.3 Vigour v2 Sample (P22)	31	3.3 Introducing Prototype	27
1.4 Demonstration with the Prototype	16	2.4 Diagram of Service Interfaces	14	3.4 Explaining Features	50
1.5 Demonstration with the Body	72				

Table 5.3: Overview of the coding in combination with the number of occurrences in the design meeting Me21.

Based on the codification of the design meeting, three interesting findings came forward:

– The physiotherapist (S3) who had used the cardigan for tests preceding the meeting used her body to evaluate past experiences.
– The body is used to evaluate the dynamic qualities of the interaction: for example, the physiotherapist (S2) explaining how the instruments should react to the body movement and how the interaction with the iPad application should work.
– The body and the prototype were used to simulate how the therapy session could relate to the service: for example, that values can be stored in a database, and how the cardigan is used to help a patient progress over time.

These initial points of interest were discussed together with the Conversation Analyst and used as input for the analysis phase. We decided to focus primarily on the occurrences of sense-making in different contexts: for example, sense-making of past experiences, of intangible features such as dynamic qualities, and of future features such as the use of data in the services. In ethnomethodological Conversation Analysis these are also known as moments in which ‘assessments’ take place.

Assessments

The analysis focusses specifically on a type of interaction known as assessments in CA. As exemplified in the Research Approach section of this chapter, participants use assessments to assign value terms to a referent (‘terrible music’). As pointed out by Fasulo & Monzoni (2009), assessments within evaluative activities, such as a design session, can be seen as central features of the overall activity. The assessments in this meeting are to some extent systematically solicited in planned activity because of the structure of the co-reflection meeting. The objective seems to be to achieve agreement, in order to make decisions about the next step of the design process. Central for such evaluative activity may be, therefore, that the assessments are validated or substantiated (Isaksen & Brouwer, 2015), in the course of working towards agreement. One such validation is seen in the fragment shown in Excerpt 5.14.

01 (S1)	Ja *yes*
02	(0.4)
03 (S1)	Zoiets inderdaad [of een] trektouwtje:: eh trektouwtje is niet ideaal omdat het *Something like that indeed or a pulling cord eh* *pulling cord is not ideal because it*
04 (S13)	[ja] *yes*
05	(0.8)
06 (S1)	ja het moeilijk was eh om het er in te brengen *yes it was hard to eh to get it in*

Excerpt 5.14.

In this excerpt, the participants are discussing how best to get the cardigan fitting at the lower edge. A belt is considered and then design researcher (S1) in line 1 considers a pulling cord. Just after, however, the design researcher (S1) assesses the pulling cord as not being an ideal solution. This is then followed by the reason why this is not ideal, which can be heard as an account for such an assessment being acceptable for other participants as well. Such validation is seen throughout the data: participants systematically provide reasons for their assessments being acceptable, and validated assessments tend to be reacted to with agreement from the other participants. In the next sections specific types of assessments found in the design meeting will be discussed further.

By Means of a Tangible Object

Validation of an assessment (the account of why a positive or negative assessment was made) may be made by pointing at, touching or demonstrating it with the tangible object that is the referent of the assessment, rather than by solely explicating this with talk. In Excerpt 5.15 the design researcher (S1) is gazing and touching (code 1.2) the physical prototype of Vigour on the table (code 2.1), while making an assessment about the existing use of a certain feature (code 3.1). The design researcher (S1) is making a negative assessment in lines 1-3. In lines 4 and 5 he produces a validation of this assessment by reference through talk to parts of the prototype while explicating it further by gazing at, and tapping (code 1.2), the part of the prototype (code 2.1) he is talking about. His bodily actions can be seen to produce evidence for his point, which then again can be seen as a move towards agreement on this assessment on the part of the other participants.

01 (S1)	Ehm dan als negatief daar aan gelinkt (.) *ehm then as a negative linked to this*	
02	dat (.) de integrat=van de stof nog niet (.) *that the integration of the fabric is not yet*	
03	optimaal is. = *optimal*	
04	=Dr zijn nog wat harde onderdelen in de casings die misschien niet heel *There are still some hard parts in the casings which probably might not be*	
	S1 gaze S1 righthand	from paper up > prototype------------------------ reaches out and touches prototype taps three types hearably on hard parts
05	comfortabel kunnen zijn. *quite comfortable*	

Excerpt 5.15.

Figure 5.12: The design researcher (S1) tapping the prototype (line 4 in Excerpt 5.15).

By Means of an Imagined Tangible Object

As shown in the analysis to come to the codification, participants may make use of earlier handling of a tangible object when making a point about a design. This is achieved by mimicking the handling in their gesture, and grounding an assessment of that object based on their earlier handling. In such cases, the participants' bodies act with an imagined object when assessing it — and this may even be done when the object is in the immediate surroundings of the participants. It is not only the tangibility of a design object (prototype, mock-up, etc.) per se which affords for explicating design insights, but the interaction of participants' bodies with tangible objects. These tangible objects may be physically present, but when not handled directly may also be ‘imagined’ on the basis of earlier bodily interaction with the object or similar objects. In other words, participants use their bodily knowledge of tangibility of the object in order to make their assessments about the design, and validate their assessment, simultaneously making the assessment both understandable and acceptable for other participants. In Excerpt 5.16 the manager of the eldercare organisation (S5) is demonstrating a function with her body (code 1.5): this movement is referring to the physical prototype of Vigour v2 (P24) lying on the table (code 2.1), and she is doing this to explain her opinion about a feature of the prototype (code 3.4). The more or less positive assessment of the collar is followed by first presenting a general validation for this being seen as positive (‘you have done this to make it broader’) but then followed by the manager’s (S5) actual validation of seeing it as positive. First, therefore, it becomes clear that the manager (S5) moves towards agreement on seeing the collar as a positive point based on her reasoning, rather than others’ reasoning.

Figure 5.13: The manager (S5) mimicking how the collar would be placed with her hands (line 1 in Excerpt 5.16).

01 (S5)	De rits zit er heel mooi in en ik vind die kraag op zich [ook wel hè](.) *The zipper is placed beautifully and I also think the colar as such is also, right*
S5 hands	[mimics colar on body]
02	Dat heb je eh natuurlijk gedaan om t brejer te maken >maar< *You did that of course in order to make it broader but*
03	.hh [voor veel mensen is het wel] oude mensen is het prettig= *for many people it is, old people, it is nice*
04 (S1)	[e:::h ja: :::]
05 (S5)	=als ze een kraag hebben. *to have a collar*
06 (S1)	Okay.

Excerpt 5.16

When the manager's (S5) bodily movement is studied in more detail, it becomes clear that she does not point at the collar of the prototype, which she could have done, since it is in front of her. Instead she mimics with her hand how the collar would be placed at her neck if she had it on (code 1.3) Thereby the manager (S5) accomplishes the gestalt of the positive feature of a collar when wearing the cardigan, thus underlining her positive assessment being made from the perspective of the user wearing the cardigan, rather than it being positive for technical-design reasons. Note in contrast how the design research (S1) may be moving to demonstrating this technical-design reason by validating it by use of the prototype itself which he reaches for in line 4.

By Means of an Imagined Future Object

Furthermore, design meetings sometimes evolve around aspects of a product that neither is present nor has been — for example, when discussing ideas for functions that have not (yet) been incorporated in a prototype. In these cases participants rely on their experience with tangible objects that have not yet played a role in the design process: for example, by gestural handling of imagined objects which they have experiences with from their daily lives. In Excerpt 5.17 the manager of the eldercare organisation (S5) is demonstrating a function (the addition of a belt to the cardigan) with her body (code 1.3). This is a function that refers to the Vigour prototype on the table (code 2.1); however, the function is not yet implemented, but for future use (code 3.2). An assessment (easier) is made about a referent (belt). The manager (S5) gestures the placement of a belt, much in the same fashion as she gestured the collar in the previously shown example.

01 (S5)	Maar ik denk ook dat een riem makkelijker is want anders heb je het nog niet (0.4) passend *But I also think a belt is easier since otherwise* *you will not have it (0.4) fitting*

Excerpt 5.17.

Figure 5.13: The manager (S5) gesturing a belt using her own body as a canvas (Excerpt 5.17).

However, in this case the belt is not a feature of the prototype and is only being talked about as a possible, future aspect of the design. Thus, in these cases participants use their bodily knowledge of objects that have not (yet) played a role in the design sessions in order to make their points about the design.

By Means of an Imagined Intangible Object
Finally, some functions of designs may be hard to make tangible: for example, the social interaction with caregivers, details of the software interface, or the interaction between a tangible part and software. In addition, in these cases the participants use their bodily knowledge of tangibility with existing parts of the design, and gesture accordingly in order to explain their assessments of those design functions. In Excerpt 5.18 one of the physiotherapists (S2) is using her body to demonstrate (code 1.3) an aspect part of the dynamic qualities of the interaction with the iPad application of Vigour (code 2.2), which is not yet implemented in the current prototype, but could be implemented in the future (code 3.2).

01 (S2)		En dan kan je [bijvoorbeeld met de] ene hand [z::ang doen?] And then one could for example with one hand do singing
	S2lefthand	[lifts up in the air]
02 (S3)		[ja:: (met de twee) huh] *yes with those two huh*
03		[En de andere] [dat- ie dus][dat mensen gaan zingen. *And the other that it thus that people will sing*
	S2 lefthand	[--rest on table] [rise up stroke, back in front of body]
	S2 righthand	[rise up in midair. stroke] [rest on table]
04 (S3)		[precies]
05 (S2)		Ah das grappig *Ah that is funny*
06 (S3)		ha(h)a
07 (S5)		m(h)m(h)m

Excerpt 5.18.

The validation of the assessment, consisting of a demonstration of the referent which the assessment is about, is presented before the assessment itself. The physiotherapist (S2) is talking about a possible function of the PSS, the possibility of incorporating singing in lines 1-3, initially moving towards making a contrast (indicating the singing sounds with left and right hand) but abandoning it and ending up only referring to gesturing the singing sound with only one hand. After this, she provides an assessment of this function in line 5 (‘that is funny’). Several observations can be made of her bodily movements: Firstly, her movement with her left hand in line 1 is understandable as mimicking a movement which a user of the prototype would make when using the system.

Figure 5.14: 'zang doen' (Line 1 in Excerpt 5.18).

Secondly, this movement is done at the exact moment when the physiotherapist (S2) describes the function (singing) that this movement would accomplish in the system. Thus, by producing talk and movement simultaneously, the physiotherapist (S2) creates a gestalt that is understandable as the function of singing combined with the user's movement while wearing the cardigan. In line 3, the physiotherapist (S2) starts to describe a function moving the other hand may do, but abandons this and repeats the earlier gestalt of singing combined with movement of the left hand — in both her talk and her movement. It is now this combination of a movement imagined to be worn by the physiotherapist (S2) in combination with her talk of a function (doing singing) that as a gestalt is being assessed by her in line 4.

The bodily knowledge of tangibility thus becomes a vehicle through which the participants work towards agreement on design decisions. The tangible objects do not have to be present in order for tangibility to be a central tool in design processes — they may work as vehicles to make the referents of assessments understandable for others by participants exploiting their bodily knowledge of the objects' tangibility. Moreover, functions that are hard to represent in a tangible object may be communicated by a similar exploitation of bodily knowledge of objects related to that function.

5.6 Findings

Even when considering an intangible aspect of the design, stakeholders in their interactions still rely on the prototype as a main principle for evaluating the design in a design meeting — either by manipulating or pointing at the prototype, or by using gesture or other bodily movements to mimic, explain or point out possible usage scenarios. These bodily interactions can be used for embodied sense-making of different aspects of PSS elements: for example, existing features, and interestingly also future features or even intangible features not directly tangible in the prototype.

Bodily Interactions with Prototypes
The first part of the analysis that was carried out focussed on how prototypes played a role in discussions about the PSS. Touching, pointing, holding, operating, employing, or even just gazing at a prototype while talking about the design are ways in which participants establish joint attention towards it. Thereby, assertions about the prototype may be substantiated. Furthermore, participants may get new insights about the prototype or ideas to develop it by viewing or handling it in a design session. In this way, prototypes may play a central role in design sessions. A codification was proposed in which three different techniques for using bodily interactions to explain design issues by involving the prototype were identified:

1. Pointing and manipulating with the prototype helped to make reflections concrete, made it easier to propose small design changes, and thereby helped the participants to reach common goals. In the development of a PSS this is particularly valuable because it can make certain problems transparent and concrete, and everybody has to agree that a solution needs to be found.
2. Demonstrating the prototype's function provided evidence for certain design issues (for example, the demonstration of the sensitivity of the sensors). It helped to make the insight recognisable through experiences that other participants had not necessarily had before. During PSS development the demonstrations can help to convince stakeholders of a problem that an individual notices, and can help to collaboratively find and try new solutions.
3. Imitating manipulation and/or demonstration of the prototype through body movement and gesture. In the last technique, the prototype is not handled directly, but is imagined in the gestural movement, or mapped onto the speaker's hands and/or body. Such gestural and bodily treatment of an imagined prototype may be even seen as more fruitful than actually taking it into use. It may, first of all, offer better opportunities for participants to have joint attention to some issue; secondly, it may convey complex issues in one package which would not have been possible with the actual artefact.

Assessing aspects of PSS
The codification from the analysis was applied to a second design meeting in order to find out how these bodily interactions helped to assess tangible and intangible elements of the PSS. This resulted in the following four bodily assessment techniques:

1. The body and the tangible object. The participants pointed, touched and manipulated the tangible object while gazing. For example, in Excerpt 5.15 the design researcher (S1) is talking about the existing use of the Vigour prototype on the table, and is indicating that certain parts in the prototype are too hard by gazing and tapping on the prototype.
2. The body and the imagined tangible object. The participants used their bodies to demonstrate certain aspects by "imagining" the object on the body using previous knowledge about the prototype: the bodily knowledge of tangibility of the object. In Excerpt 5.16 the manager (S5) makes a movement with her hands around the neck to indicate the collar is comfortably located for senior people.
3. The body and the imagined future object. The participants used their bodies to make gestures of handling an imagined object that is not implemented in the prototype, relying on bodily knowledge from other experiences. For example, in Excerpt 5.17 the manager (S5) makes the movement of adjusting a belt, which is immediately understood by the other participants.
4. The body and the imagined intangible object. The participants used their bodies to refer to design features that cannot be physically represented in the prototype. In these cases, bodily knowledge about comparable situations is used to explain their assessment. For example, in Excerpt 5.18 the physiotherapist (S2) uses her hand to indicate that the volume of the singer would increase when making a movement.

5.7 Conclusions

This chapter focussed on investigating how the prototypes of the Embodied Smart Textile Service could support the embodied sense-making process of the stakeholders in the design meeting. The analysis considered three aspects of embodiment: the corporal elements (how was the body used during the design meetings?), the social elements (how did the participants relate to each other and the prototypes during the design meetings?) and finally the situated aspects (how did techniques such as demonstration help the participants to assess the Service Interfaces?) The analysis concerns two design meetings that took place during the multistakeholder process to develop the Vigour Embodied Smart Textile Service. During these design meetings the current state of the development of the PSS is assessed by physiotherapists, a manager of the eldercare organisation, a design researcher, and an interaction designer. In the first meeting the analysis focusses on the role of the prototype in combination with the bodily interactions the stakeholders make. Three techniques for explicating design issues that exploit the prototype are identified: a) gazing simultaneously with pointing, touching and/or manipulating (moving, stretching, turning); b) demonstrating by taking the prototype into use the way it is supposed to be used; c) demonstrating by imitating the manipulation or use of the prototype through gesture — an 'imagined' dealing with the prototype. The analysis of the second design meeting uses this information to go more in depth into how the PSS is evaluated by means of 'assessments'. The main finding is that within the embodied sense-making process there are four types of assessments that come forward: assessments using the body and tangible objects; the body and imagined tangible objects; the body and imagined future tangible objects; and the body and imagined intangible objects. One of the findings is that bodily behaviour provides the basis for participants to agree on favourable/non-favourable tangible and intangible aspects of elements of the PSS Service Interfaces. In this section I will relate these findings to the two main theoretical foundations that this chapter aims to contribute to: the role of the prototype, and embodied sense-making.

Roles of the prototypes
From the findings a spectrum is emerging that shows the different assessments that are being made by means of interaction with the prototype and the body: from using the body with the tangible object to discuss properties of the PSS (1) on one side of the spectrum, to using the body to represent imagined and future parts of the PSS which are not yet present in the current prototype (4) on the other side of the spectrum. The tangibility of the design objects (such as the prototype of Vigour v2, P24) can be seen as central in the design process since this can be used as a trigger for bodily interaction. The tangible features of objects can be exploited to assess aspects of the design, even when an object is intangible or not at hand. This is very similar to the description of filters by Lim et al. (2008). In their study they argue that, by leaving open certain characteristics of the prototype, it can be used to evaluate these characteristics of the design. For example, by leaving open the exact ways that the Vigour v1 prototype (P14) could be used as a tool by the physiotherapist, I hoped to learn more about what they would actually use it for. This triggered the stakeholders during the meeting to focus on the value of Vigour as a tool to let the patients do their exercises more independently. For these new future and imagined elements, the stakeholders mainly used their bodies, in communication with the prototype, to communicate these elements: for example, by using their whole body to show what kind of exercises could be performed.

In the middle of this spectrum there are interesting instances where the participants could choose to use the tangible object, but instead used their bodies to demonstrate these imagined tangible objects (2) (such as demonstrating the imagined collar in Excerpt 5.16). Similarly, bodily demonstrations of future objects are used to assess future features of the design (such as the demonstration of the belt on the body in Excerpt 5.17), instead of relating them to current implementations on the tangible object itself (3). It seems that the expression through bodily gestures in combination with imagined objects enables the participants to demonstrate subtleties in the assessment, which cannot be easily expressed by talking or pointing to existing elements. The prototypes had the role as a trigger to come up with new functionalities, and then were used together with the body to explain these imagined properties. This could be an addition to methods in service design where hand gestures, role play and acting out are used as main methods to develop future tangible and intangible Service Interfaces. Thus we propose that tangible objects such as prototypes in relation to participants' bodily behaviour provide the basis for participants to assess both tangible and intangible aspects of a design.

Embodied Sense-making

One of the main reasons for me as a designer to have the design meetings with the stakeholders was to be able to bring the design of the Embodied Smart Textile Services forward. This could only be achieved if we shared and integrated knowledge in our collaborative design process. One of the critical factors in order to be able to integrate knowledge is that the stakeholders can make sense of each other and create meaning for the project. Embodied sense-making aims to use principles based on eliciting sensorimotor couplings in order to support social coordination between participants (Hummels & Dijk, 2015). Seven design principles have been brought forward in an approach to apply phenomenology-inspired embodied theory into sense-making practices:

1. Social situatedness: placing the interactions in the context which is valuable for the stakeholders.
2. Scaffolds: tools and props in the environment used to enable creative thought and solve problems.
3. Traces: physical traces of the interaction guide the way people interact with one another.
4. Interactive imagery: triggering imagination to stimulate ambiguity and openness.
5. Dialogical systems: acting face-to-face, coordinating with each other and co-adapting to each other.
6. First-person perspective: creating engagement and empathy through a first-person perspective.
7. Catalysing engagement: triggering bodily engagement through catalysers.

I will discuss per principle how they came about in the design meetings, based on the analysis described in the previous section.

1. Social situatedness: Based on the co-reflection approach, the design meetings with the stakeholders always took place in the context of the stakeholders. In the case of these two meetings, they were situated in the building of the eldercare organisation. The second design meeting (Me21) was actually located in the room next to the exercise gym of the physiotherapists.

2. Scaffolds: Scaffolds are tools and ad hoc recruited props that enable people to solve problems by relying less on only brain-internal processes. The prototypes could be considered as scaffolds, as they enabled the stakeholders to bring in a new layer to the meeting, which would have been difficult to do purely on a verbal basis: for example, in the moments they assessed tangible parts of the Service Interface by pointing and demonstrating. An interesting finding from the analysis is that the scaffolding could also be used for objects that were not there, by replacing the knowledge of the object with bodily gestures: for example, when a gesture was created by moving with the arms to indicate a change in the volume of the sound. It could be argued that, for example, a gesture is actually a scaffold being created by using the body.
3. Traces: Scaffolds can act as traces in the sense that they are a representation of a previous insight. In both analyses the physiotherapists had a priori experience of using the prototypes before the meeting. During the meeting in order to make their argument, they had to convey this previous experience to the other stakeholders. To do this, the physiotherapists used the prototype to demonstrate their previous experience. For example, during Me16 the physiotherapist (S2) demonstrated the stretch of the fabric and the sound it produced. It could be argued that in this case the trace was formed by the physiotherapist handling the prototype during the conversation, re-enacting the trace whenever it was necessary.
4. Interactive Imagery: By stimulating ambiguity, openness and confusion, people are triggered to use their imagination, although the prototypes were quite "closed", in the sense that some of the functionality of the Embodied Smart Textile Service was already defined before the design meeting. By closing the prototype the design space was limited to the features that needed to be designed, and actually triggered the participants to use their creativity in the space that was still open. Participants used their bodies to imagine new elements of the PSS which were not there yet, but still built on top of the existing design. For example, the belt that was imagined by the eldercare manager (S5) in meeting Me21.
5. Dialogical Systems: Based on the premise that dialogic conversations do not revolve around finding common ground or synthesis, but where curiosity sustains the cooperation and exchange of ideas, the starting point of the design meeting was that there was always something new to discuss. In the first meeting (Me16) it was the prototype of Vigour v1 (P14) and the application (P13); in the second meeting the Vigour v2 (P24) and iPad application (P21). These prototypes would trigger the curiosity, but also lead to a confrontation in which the stakeholders would critically assess the features that were changed in the new iteration. By pointing, touching and manipulating, for example, the stakeholders indicated the parts of the prototype that could be improved.
6. First-person Perspective: The co-reflection methodology introduced a certain flow in the design meeting, whereas in the beginning it was more about

eliciting the participants to bring in their first-person perspective: for example, by giving each participant the chance to voice their opinion. This was triggered by using the forms on which everybody wrote down their personal reflections, and a round-table discussion about these personal reflections. The last step of the co-reflection structure aimed to bring the personal reflections together, and come to a consensus about the next steps to take.

7. Catalysing Engagement: For example, open tools without a predefined goal that serve as a means to physically connect participants to enhance engagement, empathy and respect. In the design meetings we did not apply an open tool methodology. However, in the analysis we observed that the stakeholders who used the prototypes before the meeting would take a certain lead in demonstrating the prototype to the others. For example, the physiotherapist (S3) and Interaction Designer (S13) took the responsibility of showing the iPad application to the others. In reaction, these demonstrations with the prototypes triggered responses from the other participants.

6. Reflections

This thesis started based on the premise that technology is coming closer to the human body than ever before. However, current wearable products seem not yet fully able to provide a transformational role, unable to provide compelling experiences for most people that take an intimate and important role in their lives. This raised the question as to how to find out how close-to-the-body products and services can become truly meaningful to people's lives, and more closely connected to our bodily experiences than the current generation of wearable technology. The main research question that drove the preceding analyses was therefore: "How to design Embodied Smart Textile Services?"

The previous chapters aimed to generate knowledge about how the design process of Embodied Smart Textile Services would have an impact on different scales. A crucial insight is that, in order to understand the subtle characteristics of the personal experiences of Embodied Smart Textile Services, the approach is becoming more personal and subjective. By bringing technology closer to the body, the interactions with the Embodied Smart Textile Service itself are changing and becoming more personalised (Chapter 2, Scale of the PSS). In order to develop personalised Embodied Interactions, the design process itself is also changing into a bottom-up infrastructuring approach where the personal perspective is taken into account (Chapter 3, Scale of the Project). To allow the different perspectives from the various disciplines to be integrated into the Embodied Smart Textile design process, the collaborative design process will also change (Chapter 4, The scale of the Community). And finally, these new embodied collaborations have implications for the sense-making process between the stakeholders in which a first-person perspective is crucial to assess design solutions (Chapter 5, The Scale of the Stakeholders).

In this chapter I will reflect and speculate further about the findings by looking specifically at the personal and subjective nature of designing Embodied Smart Textile Services. I will approach this reflection from the perspective of the three communities that could benefit from this research: the entrepreneurial community who are developing Smart Textile Services and are interested in the impact of these new services and business models for the industry; members of the Service Design community interested in the multifaceted role of prototypes; and finally the Design Research community to discuss the value of research methods which combine my own first-person perspective, a second-person perspective from the stakeholders and a more objective third-person perspective based on the analysis of other experts.

6.1 Implications for Smart Textile entrepreneurs

Smart Textiles have existed for quite some time in university and research contexts. However, the actual Smart Textiles industry is still in its early stages and faces some serious challenges that need to be resolved before Smart Textiles can be adopted into the market. A community of entrepreneurs is currently exploring the Smart Textile space, experimenting with new business models and step by step solving the problems they meet. Smart Textile products and services are inherently complex due to the integration of various disciplines. One of the approaches of the current industry is to simplify the products up to the point that they just work. A disadvantage of this approach is that most of the subtlety and richness that belong to the personal and intimate experiences that they should offer is lost. In this section I will try to make some recommendations for this community, based on the previously introduced Embodied Smart Textile Services approach. This approach resulted in three Embodied Smart Textile Services: Tactile Dialogues, Vigour, and Vibe-ing. An analysis of the level of Embodiment in the Service Interfaces of these projects showed that they all use personalisation in order to achieve the link with the human body, context and social aspects. The personalisation of the Service Interfaces was driven by thee main elements: personalisation through the material properties, the look, fit and feel of the textile object, and the use of digital data in the interaction.

Next to the three novel Embodied Smart Textile Services, this approach also contributed in tackling issues that the Smart Textile industry is currently facing: a lack of existing market, no standard fitting, required support, and complicated maintenance. By developing the products as a service some of these main problematics can be overcome.

1. *From lack of existing market to co-development with service provider*: Because Smart Textiles are a new product type spanning multiple domains, there is no single specific market or distribution channel that can be used for these products. Some products might be sold to athletes, others for specialised medical purposes, and yet others aimed at high-fashion customers. The three Embodied Smart Textile Services were co-developed from the start with service providers, stakeholders and users. As a result, the three examples are all validated and accepted in their specific niche markets. For example, in the case of Tactile Dialogues the service providers themselves take an important role in distributing the PSS to the different users.
2. *From no standard fitting to tailor-made*: For Smart Textiles, and smart clothing specifically, new functionality is developed that has not existed in clothing before, such as sensors that measure physiological data. As a consequence there are more dimensions to consider in sizing and fitting because these sensors need to be mapped to specific locations on the body. An Embodied Smart Textile Service approach takes the phase before the actual production into consideration as part of the service. In the case of Vigour and Vibe-ing, for example, the body sizes are measured by the service provider and the medical sports store, respectively. This data is used to produce personalised clothing with the sensors at the right locations where the sensors are needed. In the case of Tactile Dialogues, the textile patterns could be produced in such a way as to match the hand movements and aesthetic preferences of the person with dementia and of the family.

3. *From requiring support to regular assistance*: Smart Textiles are a new type of product which require a new way of interacting with them. This implies that all stakeholders and users will have a steep learning curve ahead of them to understand how to integrate the products into their life. Next to this, the personal and contextual nature of Smart Textiles requires the products to be adapted to the user: for example, through calibration or set-up procedures. These aspects require the industry to educate their customers or provide assistance. Embodied Smart Textile Services are linked to already existing services provided by stakeholders. By integrating new Service Interfaces with existing ones, education and calibration can become an integral part of the service. For example, in the case of Vigour, the physiotherapists use the Vigour Embodied Smart Textile Service in their existing training programmes. The programming of the Tactile Dialogues' vibrotactile behaviour became part of the existing consultation between a motivational therapist and the family of a person with dementia.
4. *From complicated maintenance to lending systems*: Smart Textiles are prone to break: for example, because of the increased stress on internal electronic connections. In contrast to traditional textiles and consumer electronics, there are no existing locations where Smart Textiles can be repaired or recycled, which means that producers currently have to deal with these life cycle issues themselves. The previously introduced Embodied Smart Textile Service examples propose new business models as alternatives to direct product sales, such as closed loops in which the user or customer can lend or lease the products. All the Service Interfaces, from the first personalisation to recycling, become part of the service. For example, when the outside layer of Tactile Dialogues is cleaned, the pillow can simultaneously be checked for malfunctions and repaired.

6.2 Implications for Service Designers

For each of the three different scales that were explored in this thesis, the role of the prototype was taken as a starting point to frame the analysis. This resulted in three sets of findings: How do prototypes support the bottom-up infrastructuring approach (Chapter 3)? How do prototypes support the collaborative design process (Chapter 4)? and: How do prototypes support embodied sense-making (Chapter 5)? Since all the analyses of the different scales actually use the same set of prototypes to come to the conclusions, it would not be a surprise to find cross-links between the different scales. In this section I will try to make relations between the scales to complement the findings in order to come to a more complete overview of the roles of the prototype. The role of prototypes has been a lively discussion with the Service Design community, and I hope that the examples I'm about to introduce can contribute to this discussion. The mapping is not meant as a clear-cut categorisation of different relations, but rather a way to explain how the different scales can be combined. From the findings about the role of prototypes in the design of PSS I compiled three red threads based on findings of the previous chapters: the prototypes make it specific, and the prototypes keep it realistic, the prototypes make it valuable.

1. *Prototypes make the service specific:* Within product design, prototypes have an important role to develop the details of a product, which in the end is about making the product meaningful for the people who are going to use it. When designing services it is often necessary to develop a higher-level overview, and the focus is not always directly on the details. Throughout the analyses of the Embodied Smart Textile Services it became clear that by using prototypes throughout the process it is possible to work on the details and the larger picture in services as well. The prototypes increased the quality of the PSS (Chapter 3) by triggering a continuous process of refinement and striving for perfection. The prototypes focus discussion about the content (Chapter 4), while stakeholders could focus on in-depth details that could only be solved with their specific skills. The tangible prototype was used with the body (Chapter 5), and the stakeholders pointed, touched and manipulat-ed the prototype object while gazing. This helped to make reflections con-crete and made it easier to propose small design changes.
2. *Prototypes make the service realistic:* Throughout the process the prototypes helped to keep the project close to reality by developing a service that could be implemented by relying on the existing infrastructure and capabilities of the partners. Rather than promoting outside the box, brainstorming ideas that could never be implemented by the stakeholders, the prototypes helped to focus the design meetings on “inside-the-box thinking”. While ideating and thinking creatively about the new service, the feasibility was considered as well by staying close to the existing infrastructure and the stakeholders’ expertise. The prototypes assured the situatedness of the PSS (Chapter 3): by implementing the prototype in the actual context, confrontations were triggered between the context and the prototype. The prototypes embed the knowledge of the different stakeholders (Chapter 4), and all stakeholders bring a specific piece of the puzzle into the prototype, which triggers equal collaborations and support among the stakeholders. The imagined tangible prototype was used with the body (Chapter 5), and the participants used their bodies to demonstrate certain aspects and provide evidence for design decisions by “imagining” the prototype on the body based on their knowledge about the prototype.
3. *Prototypes make the service valuable:* In the process of developing the Embodied Smart Textile Service, most of the collaborations that are needed to bring it to the market are already created. Stakeholders adopted the new service, because they know where the process is going and it matches their interests and expertise. The role of the prototype is to help all the stakehold-ers to understand each other’s expertise and expectations, which gives the development a direction and can lead to deployment. The prototypes trig-gered horizontal collaborations in the PSS (Chapter 3), and the boundaries are blurred between disciplines which are normally quite separate. Prototypes

make the knowledge meaningful and applicable for others (Chapter 4), by supporting the stakeholders as they integrate their own knowledge, understanding the meaning of the expertise of the other, and in some cases even helping them to move to a transdisciplinary approach where stakeholders were able to apply knowledge of others in the design process. The imagined future prototype was used with the body (Chapter 5), and the stakeholders used their bodies to make gestures of handling an imagined object that is not implemented in the prototype yet, relying on bodily knowledge from other experiences.

6.3 Implications for Design Researchers

The previous reflections about the role of prototypes were aimed at contributing to practitioners in the Smart Textiles industry and Service Design community. To come to these findings, each scale was based on a theoretical starting point offered by a specific academic community. The scale of the project was based upon Participatory Design: for example, by using infrastructuring and the Growth Plan as an approach to design. The scale of the community started based on knowledge from the field of collaborative design, providing me with insights about knowledge sharing in multidisciplinary teams. The scale of the stakeholders was based on work that has been conducted around the topic of sense-making, providing me with principles that can be applied to trigger embodied sense-making. Besides the initial starting points, these different academic communities also led to a specific methodology to analyse the data for each scale. For example, Participatory Design led to the analysis based on autoethnographic accounts from me as a member of the community. For the analysis of the collaborative design process I combined verbal analysis methodology with descriptive statistics. And finally, for embodied sense-making I collaborated with an expert in the field of Conversation Analysis to take a detailed look at the interactions during specific moments in the meetings. One of the unique opportunities of a research-through-design process is that I was involved in the process as designer and researcher. Therefore, during the analyses I was able to triangulate between my own first-person perspective, a second-person perspective from the stakeholders and a more objective third-person perspective based on the analysis of other experts. In this reflection I will elaborate further on how in each analysis (as discussed in Chapters 3, 4 and 5), the interaction occurred between first-person, second-person and third-person perspectives.

1. *Third-person perspective on first-person reflections:* At the scale of the project (Chapter 3) I used autoethnographic accounts to understand how the project found direction. First-person reflections were the starting point for this analysis: I collected all my notes of design meetings and reflections on what had happened. Then, the visualisation into a factual timeline of what happened based on the documentation of all the Prototypes, Meetings, Tests and Stakeholders showed me the data from another perspective. This third-person

perspective was then used to give constraints and select the reflections that would be used to analyse how the Service Interfaces developed over time. The problem that this approach solved for me was that it made the selection procedure more explicit. It would have been very hard to choose the criteria to decide which reflections are relevant and which ones are not without seeing the larger picture. By combining all information into a third-person perspective it became possible to give meaning to each individual reflection in the context of the whole process.

2. *Combining first-person, second-person and third-person perspectives:* At the scale of the community (chapter 4) I used the second-person perspective of the different stakeholders to find out how multiple types of skills, a variety of knowledge and different viewpoints are incorporated into Embodied Smart Textile Services. I used three variables (Conversational Balance, Design Activity and Design Content) to codify eight design meetings that occurred within the design process. As a next step, the Correspondence Analysis method was used to visualise the data into biplots of the relations between the variables. Finally, I interpreted these biplots using my own first-person perspective and quotes from the stakeholders during the design meetings. The design research approach taken in this chapter, shows that there were many smaller loops between the different perspectives. Firstly, selecting the right variables for the codification was based on my first-person subjective understanding of the process. Secondly, choosing the right statistical method to visualise the second-person perspectives, was necessary to come to a third-person perspective representation of the process. And finally, by using my own first-person reflection on these graphs I was able to provide an interpretation of the data.
3. *First-person perspective to inform third-person interpretation:* At the scale of the stakeholders (chapter 5) I investigated how stakeholders made sense from the design and came to the next steps. This analysis was mainly driven by a study conducted by a Conversation Analyst. This was a completely different approach to look at the design meetings, since the insights came from another researcher. These insights triggered my first-person interpretation when I tried to relate them back to what it meant for me as a designer. One approach that I tried was to use the results from the first analysis (the language of bodily interactions) to create a codification. This codification included the bodily interactions, but also the specific design element that was discussed and the purpose of why it was discussed (for example, to talk about new features, or to evaluate existing functionality). The Conversation Analyst used this codification as a starting point for the second analysis to find the moments during the design meeting that were most valuable from a design point of view. This analysis led to the different types of assessments.

These different approaches show that by being involved simultaneously as designer and researcher it becomes possible to triangulate between different perspectives. By giving meaning based on a first-person perspective certain findings can be contextualised, rather than only relying on external accounts of a situation. Further, these different analyses show that there is no straightforward approach to follow. Finding the right process and methods to apply depends on the particular research question, the underlying theoretical foundations, and personal motivations. Finally, using multiple perspectives in the design research process can surely lead to a better informed result. However, this triangulation also adds a layer of complexity in the process. For example, it might not always be possible to distinguish between the different perspectives while being in the process itself.

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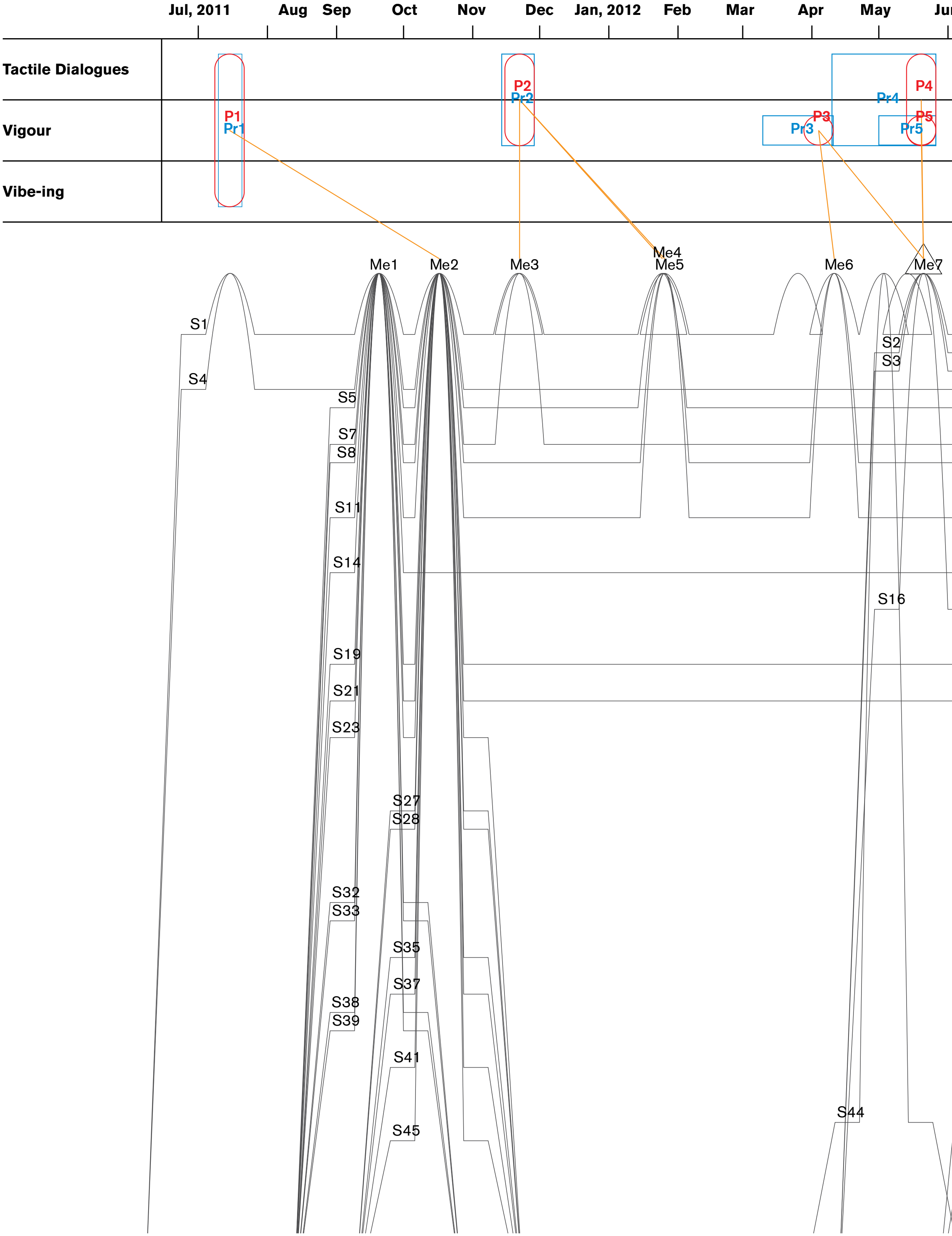
Appendix A: Process Overview



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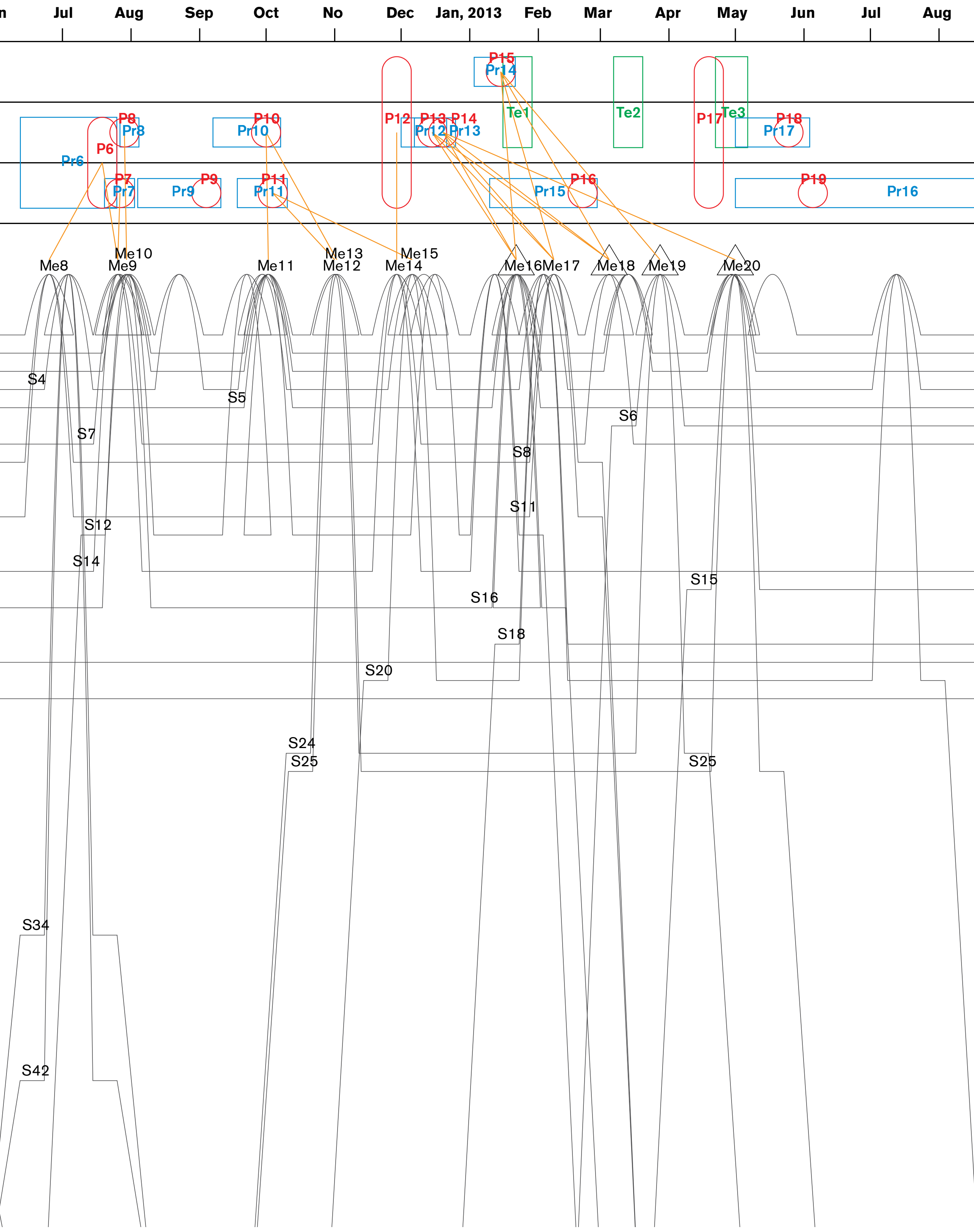
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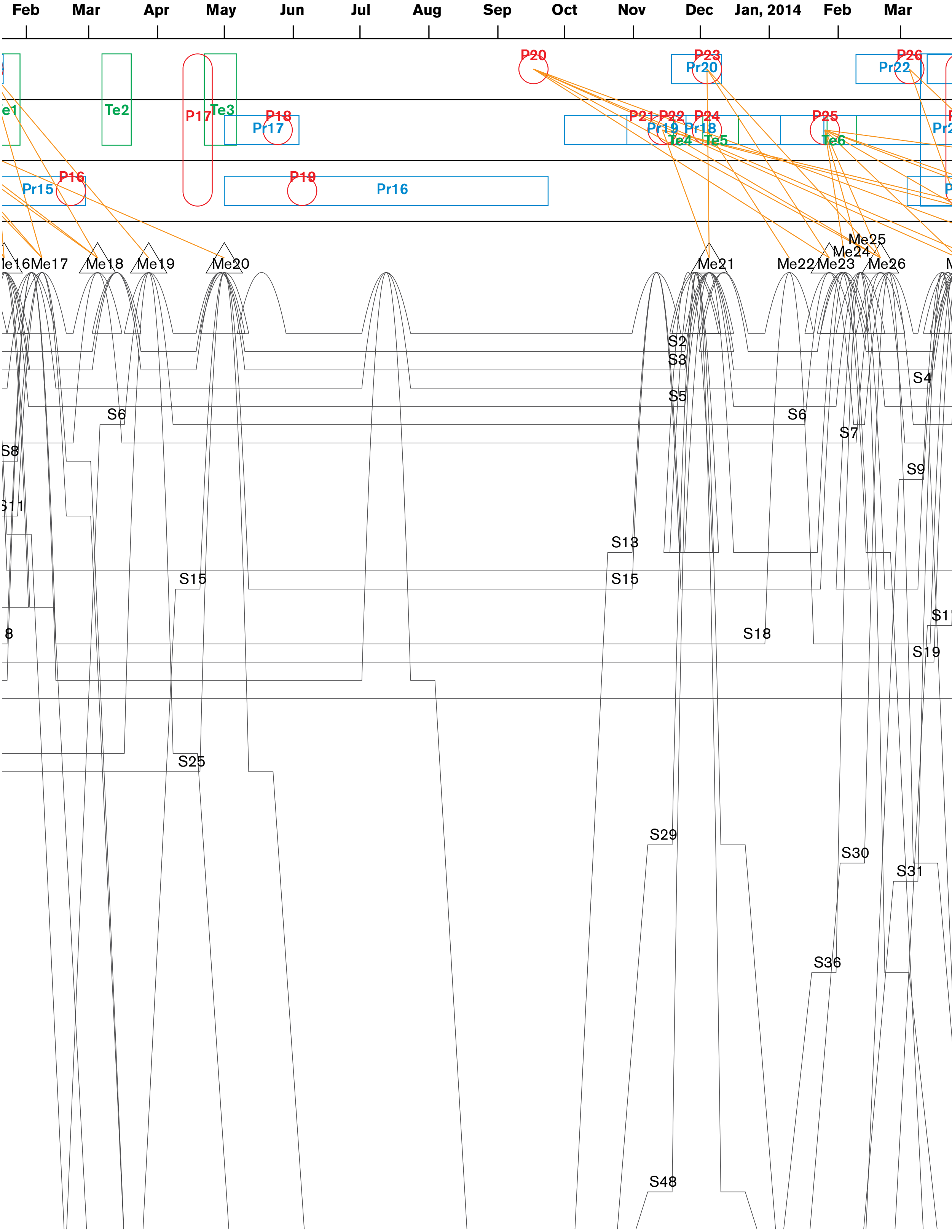
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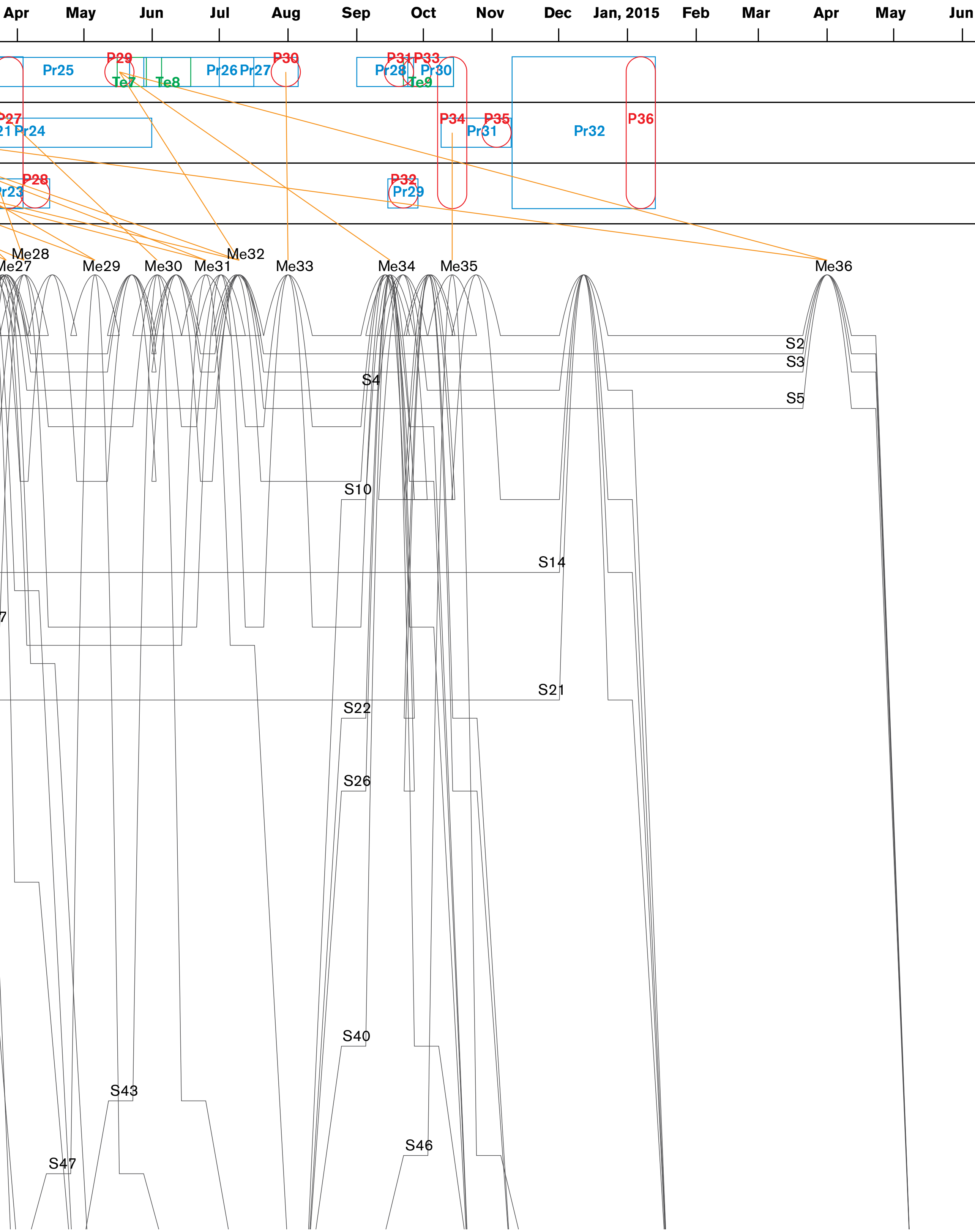

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Prototypes (P)

P	Object	Description
1	Feltball	Felted light emitting objects, reacting to movement
2	Music Fabric	Fabric with on it embroidered a pattern, when touched would change the musical composition on a phone
3	Stretch Sweater	Knitted stretch sensor attached to a sweater, when bending the arm sound could be recorded and played back
4	Touch Sleeve	Knitted textile with lines of conductive yarns in the shape of a sleeve, when worn around the arm touches on the arm would react in changes in a visualization
5	Knee Band	Knitted stretch sensor that could be attached around the knee, when detecting walking rhythms could give vibratory feedback if person with Parkinson freezes
6	Beta Textiles Fabric	Knitted textiles with conductive yarns, 1: when stretched resistance changed. 2: pockets for diffusing light, and at the same time react to touch
7	Light Electronics	Miniaturized version of the electronics required for the touch sensing and LED in the Beta Textiles fabric (P6)
8	Canvas Shirt	Garment made from white fabric to test the fit, and to use as canvas to draw the sensors locations
9	Tender PCB	Customized PCB with the electronics necessary to enable the LED and touch functions for Tender (P11)
10	Vigour v1 Fitting Model	Garment with the Beta Textiles fabric (P6), to test the fit of the measurements and sensor locations
11	Tender	Dress created with the Beta Textiles Fabric (P6), touch sensitive pockets emitted light when touched
12	CRISP modules v1	First set of electronics designed for the prototypes in the project, contained light, sound, heating modules
13	Vigour v1 Interface	Interface for computer to monitor the stretch sensors in Vigour v1 (P14), and add sounds to movements
14	Vigour v1	Garment made from the Beta Textiles fabric (P6), with stretch sensors that react to movement and is connected to the Vigour v1 Interface (P13), purpose is to stimulate geriatric rehabilitation exercises
15	Blanket	Blanket created from existing fabrics, tunnels and padding to integrate CRISP modules v1 (P12), conductive yarns react on capacitive touch with different stimuli, such as light, sound and vibration
16	Vibe-ing Fabric	Knitted textile from merino wool yarns with silver coated conductive yarns for connectivity. Knitted in panels that can be directly used in the garment
17	CRISP modules v2	Produced batch of 500 CRISP modules, the set contained motor, light, sound, heat and power modules
18	Vigour v1 Bluetooth	Proof of concept of Bluetooth connectivity module, in combination with mobile application
19	Vibe-ing	Dress created with the Vibe-ing fabric (P16), containing pockets with vibration motors reacting to capacitive touch, functioned as a self-care tool which invited the body to feel, move, and heal through vibration therapy

20	Tactile Dialogues v2 (No electronics)	Pillow created from circular knitted textiles which contained a graphical and tactile structure
21	Vigour iPad application	iPad application for Vigour with functions to change sound feedback, log the data from the garment and view movement history
22	Vigour v2 Sample	Demonstrator where the back part of Vigour v2 fabric was connected to the Bluetooth module
23	Tactile Dialogues v1	Pillow created from circular knitted fabric with conductive yarns, to sense capacitive touch and conduct power to the vibration motors
24	Vigour v2 Fitting Model	Cardigan created with flatbed knitted textile without electronics to test the shape and location of the sensors
25	Vigour v2	Cardigan based on the fitting model (P24), it included electronics, 3d printed casings and connectivity to iPad application (P21)
26	BB.Suit	Onesie based on circular knitted textiles with later integrated copper yarns for connecting Wifi and GPS technology in the garment
27	Textile Samples v1	Fabric samples with sensing and actuation capabilities, to show the functionalities of the CRISP modules (P17)
28	Well-be Fabric	Knitted textile based on the Vibe-ing fabric (P16), different colours and created in fully-fashioned panels for easier construction
29	Tactile Dialogues v2	Pillow based on P20, electronics are integrated in outer layer (vibration motors and felted pressure resistive fibres) and inner layer (CRISP modules and power)
30	BB.Suit Clean Air Prototypes	Prototypes made from different functional textiles to show possible concepts for the BB.Suit clean air
31	BB.Suit Clean Air	Garment from circular knitted textiles with integrated conductive yarns, to purifies polluted air and measure the air-quality around the body
32	Well-be	Collection of garments (male and female) based on Vibe-ing (P19) with integrated vibration motors and capacitive touch sensor
33	Tactile Dialogues v2 Behaviour	Programmed vibrotactile behaviours for the Tactile Dialogues v2 (P29) were developed, tailored to the specific requirements of the people with dementia and their family members
34	CRISP modules v3 Test	Prototype of the new flexible CRISP modules, sensors and actuators strongly coupled
35	Vigour v2 Sound Interaction	Sound samples designed for rehabilitation exercises triggered by movements by sensors in Vigour v2 (P25)
36	Textile Samples v2	Samples of smart textile materials and of the different prototypes developed during CRISP, powered by the CRISP modules (P17)

Stakeholders (S)

S	Role	Organization	Discipline
1	Researcher	TU/e	Interaction Design
2	Physiotherapist	De Wever	Physiotherapy
3	Physiotherapist	De Wever	Physiotherapy
4	Researcher	TU/e	Interaction Design
5	Manager	De Wever	Eldercare
6	Designer	ByBorre	Textile Design
7	Engineer	Metatronics	Technology
8	Business Developer	Unit040	Interaction Design
9	Student	TU/e	Interaction Design
10	Student	TU/e	Interaction Design
11	Designer	Studio Toer	Interaction Design
12	Student	SUMMA	Textile
13	Student	TU/e	Interaction Design
14	Researcher	TU/e	Interaction Design
15	Designer	Pauline van Dongen	Fashion Design
16	Physiotherapist	De Wever	Physiotherapy
17	Designer	Studio Eva de Laat	Textile Design
18	Textile Developer	TextielMuseum	Textiles
19	Researcher	TU Delft	Interaction Design
20	Researcher	TU/e	Interaction Design
21	Designer	Saxion	Smart Textiles
22	Researcher	TU/e	Interaction Design
23	Researcher	Saxion	Smart Textiles
24	Textile Developer	Optima Knit	Textiles
25	Textile Developer	Savo BV	Textiles
26	Student	TU/e	Interaction Design
27	Consultant	Alcon Advies	Textiles
28	Manager	De Wever	Eldercare
29	Student	SUMMA	Textiles
30	Designer	Vandaan	Graphic Design
31	Student	wdka	Textiles
32	Manager	TextielMuseum	Textiles

33	Researcher	TU/e	Interaction Design
34	Textile Developer	TextielMuseum	Textiles
35	Manager	Waag Society	Interaction Design
36	Photography	HammondImages	Photography
37	Textile Developer	Van den Acker	Textiles
38	Manager	Contactgroep Textiel	Textiles
39	Researcher	TU Delft	Interaction Design
40	Manager	De Wever	Eldercare
41	Textile Developer	Lantor	Textiles
42	Designer	Hatter & Hare	Smart Textiles
43	Manager	Metatronics	Technology
44	Student	Saxion	Textiles
45	Manager	V2	Technology
46	Engineer	Metatronics	Technology
47	Business Developer	TU/e	Technology
48	Student	HKU	Interaction Design

Meeting Activities (Me)

Me	Date	Goal	Result
1	9/20/2011	Exploring expertise, expectations and goals	Different clusters of topics and people
2	10/17/2011	Exploring directions to take with the project	Focus on eldercare and rehabilitation together with De Wever
3	11/22/2011	Exploring collaboration possibilities, showing my prototype	Insight in challenges and opportunities, interest in conductive textiles and curved surfaces
4	1/25/2012	Exploring collaboration possibilities	Agreement for regular co-design sessions with physiotherapists, placing the smart-textile technology in their context
5	1/26/2012	Exploring collaboration possibilities	Agreement to start with regular feedback moments, explained the difficulties of developing products and services in eldercare context
6	4/11/2012	Demonstration of stretch sweater, thinking about applications	Possibilities in other applications, for example using the sensing fabric in bed-sheet to prevent bed-sores
7	5/21/2012	Discussing and receiving input on further development concepts	Continuation with three directions, combining new input from physiotherapists
8	6/25/2012	Showing developed textiles, discussing continuation collaboration	Pivot from intelligent bed-sheet to measuring in sports garments
9	7/26/2012	Discussing manufaction of the PCB's	Plan to start new version of modules together before start new semester
10	7/30/2012	Progress update, input about placement sensors and fit of the garment	Decision on which prototypes to test with patients, feedback about wearability and sensor locations
11	10/2/2012	Progress update, deciding on the further development of the prototypes	Next steps for the preparation of the prototypes for tests and ethical committee guidelines
12	11/1/2012	Kick-starting the collaboration with Optima Knit	Jan did tests with their machines, new yarns are necessary
13	11/2/2012	Discussing the plan of producing textiles at Savo BV, talking about production possibilities	Martijn will bring the yarns at Savo, and Jan is going to do tests
14	11/29/2012	Evaluating PCB's and discussing next iteration	Next iteration with sensor inputs on all actuators, decisions about amount to produce and timeline
15	12/6/2012	Selecting yarns for knitting Vibe-ing and discussing prototype plan	Selection of soft merino wool in grey colour, paying attention to touch and sustainability
16	1/22/2013	Creating a concrete plan for the tests in February and testing the workshop set-up	Improving sensitivity of sensors, target group definition and test set-up
17	2/8/2013	Updating Unit040 about previous developments (prototypes and metatronics)	Plan to meet together with Admar, looking at business possibilities of shirt
18	3/5/2013	Evaluation of the use of the modules in the Vigour and Blanket prototypes, deciding on next steps	Discussed target applications such as golf, developing a CRISP Bluetooth module
19	3/28/2013	Introducing Borre to Jan from Optima Knit, comparing the different yarns, deciding on a plan of action	Explore the technical possibilities of the machine, combining aesthetic fabric pieces with technological

20	5/1/2013	Making a plan together for the production, Jos and Pauline show previous work and ideas for the project	Tests with the machines, design direction based on these explorations
21	12/5/2013	Evaluation about the prototype so far, make plans for next steps	The cardigan has to be tested, new partners can be involved, also introduce the garment in other organisations,
22	1/10/2014	Discussion about knitting new Vigour prototypes, in new colours and with adaptions to the sensors	Plan to produce Vigour in TextielMuseum, yarns have to be prepared
23	1/28/2014	Evaluating the integration of the electronics in the Tactile Dialogues pillow and deciding on next steps	Direct translation between graphic pattern and textiles, expand the approach to the textile industry at large
24	2/4/2014	Discuss the latest iteration and plan about next production step in TextielMuseum	Changing the location of the sensors, improve the belt to fix the garment on the body
25	2/11/2014	Discuss the set-up, story and filming plan of the movie	Full day with therapists and volunteers to show the usage of Vigour will be planned
26	2/20/2014	Discuss the final prototypes of Vigour and Tactile Dialogues	Develop the mechanics further (connectors, casings) with an engineering company
27	3/27/2014	Discussing the plans to organise the workshop for the UKON conference	Using the customer journey to build a service that fits their organisation
28	4/4/2014	Starting the project to develop a product dealing with air pollution	Plans are made to find students to join in the project
29	5/6/2014	Explorative meeting to discussing the commercial possibilities of the developed products	Together with Innovation Lab a patent study would be done to see if there is IP to protect
30	6/3/2014	Exploring the possibilities to collaborate on the wearable electronics platform	Plans were made to further stay in touch about the demonstrator that would be created for the E&A fair 2015
31	6/25/2014	Evaluate the development process from a knitting point of view	Finding new production combinations between partners, by giving the electronics more textile properties
32	7/10/2014	Evaluate the process, making plans for test set-up after summer	Involving the other people in the company more, for example the people from activity groups
33	8/1/2014	Presenting and discussing the directions set-out by the students	Decision to focus no the infographic and find an technological partner who can help with the air filtration
34	9/16/2014	Discussing the test plan of Tactile Dialogues with Marja in order to get approval	The test plan was approved, and the motivational therapists were asked to help to find clients who wanted to participate
35	10/14/2014	Metatronics showing the first version of the new modules	To create a more linked combination between sensor and actuator on the modules (i.e. speaker also includes microphone)
36	4/1/2015	Workshop to wrap-up the collaboration with De Wever	Shared the results from the last experiment, looking for further possibilities to continue projects from both sides

Prototyping Activities (Pr)

Pr	Start	End	Goal
1	7/10/2011	7/14/2011	Exploring the disciplines of each other
2	11/14/2011	11/22/2011	Exploring different textile production techniques in combination with a system and service approach
3	3/10/2012	4/4/2012	Exploring different knitting structures and techniques, experimenting with integrating conductive yarns
4	4/10/2012	5/20/2012	Exploring the possibilities of semi-automated knitting machines to create materials with conductive yarns
5	5/1/2012	5/20/2012	Creating a prototype of a band that would react with vibration to the movement a person made
6	6/12/2012	7/19/2012	Transferring flatbed knitting knowledge and gaining experience with integrating conductive materials
7	7/20/2012	7/27/2012	Creating a miniaturized version of the LiliPad with LED and touch sensing capability
8	7/27/2012	7/29/2012	Creating a shirt to test the pattern and fit to be able to discuss the details with the physiotherapists
9	8/4/2012	9/4/2012	Creating a small circuit board that could be inserted in the pockets of the Tender fabric and reacts to touch with a light fade
10	9/7/2012	10/1/2012	Creating a new pattern for the shirt, making sure that the stretch measurement fabric was placed on the right locations
11	9/18/2012	10/4/2012	Integrating the Tender PCB into the Tender Fabric, cutting and sewing the pattern pieces into the garment shape
12	12/1/2012	12/15/2012	Creating a computer interface for Vigour v1 using Processing
13	12/7/2012	12/19/2012	Creating a new pattern for the shirt, making sure that the stretch measurement fabric was placed on the right locations
14	1/3/2013	1/15/2013	Using tunnel structures and padding to integrate yarns and different actuators (light, sound, vibration) into a textile blanket
15	1/10/2013	2/21/2013	Development of a next iteration of Tender, creating fully fashioned patterns with pockets
16	5/1/2013	9/17/2013	Sewing the knitted textile panels and integrating the electronics into the fabric
17	5/1/2013	5/28/2013	First tests with creating a Bluetooth connection directly from the Vigour garment to an iPad application
18	10/1/2013	1/19/2014	Through several iterations the iPad application for Vigour was developed
19	10/29/2013	11/18/2013	Testing the connection between the new Vigour garment a sample knitted textile piece
20	11/18/2013	12/4/2013	Casings for the vibration motors were designed and integrated inside the outer layer of the pillow
21	1/6/2014	5/25/2014	Finishing all the Vigour garments, including all the electronics, 3d printed casings and iPad application

22	2/9/2014	3/4/2014	Creating the wifi-accesspoint and GPS functionality of the BB.Suit and integrating it into the garment
23	3/4/2014	4/9/2014	Knitting the new fabric based on explorations of the pressure points and new models for both male and female
24	3/10/2014	3/28/2014	With simple textile techniques basic sensing and actuator demonstrators were created
25	3/13/2014	5/15/2014	Integrating the vibration modules, together with the touch sensors in the fabric used to create Tactile Dialogues v2
26	5/28/2014	7/30/2014	A team of students created concepts, prototypes and the input for an infographic as pillars to develop the next BB.Suit
27	7/1/2014	7/10/2014	Making a second prototype of Tactile Dialogues based on the design of Tactile Dialogues v1
28	9/1/2014	9/20/2014	Circular knit development in China, integrating conductive yarns, sensors and air cleaning device
29	9/15/2014	9/22/2014	The CRISP motor modules were integrated into the new Well-be prototypes
30	9/24/2014	10/8/2014	During the tests the electronics of Tactile Dialogues were repaired and behaviours for the families were programmed
31	10/9/2014	11/3/2014	Developing sounds that could be used with Vigour to do exercises and improving connectors
32	11/10/2014	1/7/2015	Creating combinations of materials and actuators, placing them in frames

Testing Activities (Te)

Te	Start	End	Goal
1	1/16/2013	1/21/2013	The therapists tested the two prototypes for 1 week in advance to the meeting, to be able to have more insight to help with the evaluation
2	3/7/2013	3/7/2013	Pilot test to find out whether the set-up of the test and the prototypes needed to be changed, tested with two clients, one for each prototype
3	4/22/2013	4/30/2013	Testing Vigour v1 and Blanket, 5 clients for each project. Goal to find out whether the directions showed potential when testing in real situations,
4	11/19/2013	11/19/2013	Testing first iteration of the iPad application with a client and physiotherapist from De Wever
5	12/5/2013	12/5/2013	Testing the fit of the garment with one of the clients of De Wever
6	1/27/2014	1/27/2014	Testing with two clients the fit of the new Vigour and whether the sensor on the back of the garment work
7	5/16/2014	5/16/2014	Test the new iteration of electronics in Tactile Dialogues
8	6/5/2014	6/5/2014	Testing with the vibration elements in the pillow
9	9/22/2014	10/8/2014	The vibration patterns of Tactile Dialogues were tested with clients and their family members, 5 clients and their families participated

Publications from this thesis

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Exhibitions and presentations from this thesis

Start	End	Type	Name	Location	City	Country
1-Apr-16	*permanent*	Exhibition	The Future of the City	Technisches Museum Wien	Vienna	Austria
9-Feb-16	14-Feb-16	Exhibition	Wearable: la conférence sur la mode du futur	La Gaité Lyrique	Paris	France
10-Jan-16	15-Mar-16	Exhibition	West Bund Art Center Shanghai Art & Design Exhibition	Trans-Design Shanghai Art & Design	Shanghai	China
27-Nov-15	17-Apr-16	Exhibition	Please touch!	Museum of Design	Zurich	Switzerland
5-Nov-15	5-Nov-15	Presentation	Science Talk	OMsignal	Montreal	Canada
17-Oct-15	25-Oct-15	Exhibition	Hands Off: New Dutch Design at the Confluence of Technology & Craft	Veemgebouw	Eindhoven	Netherlands
17-Sep-15	20-Sep-15	Exhibition	Design Night Festival: Smart textiles - wearable services	Suka EKA	Tallinn	Estonia
3-Sep-15	3-Sep-15	Exhibition	Interlaced	Boiler House	London	UK
1-Sep-15	1-Sep-15	Presentation	Innovation Talks: Wearables	Zilveren Kruis Achmea	Utrecht	Netherlands
23-Jul-15	15-Aug-15	Exhibition	Smart Flexibility: Advanced Materials and Technologies	Design Research Institute	Melbourne	Australia
4-Jun-15	4-Jun-15	Exhibition	Dutch Technology Week: Tech Meets Design: Innovation Exchange	High Tech Campus	Eindhoven	Netherlands
2-Jun-15	2-Jun-15	Presentation	Electronics and Automation: Wearable Electronics – Smart Fashion	Jaarbeurs Utrecht	Utrecht	Netherlands
31-May-15	28-Jun-15	Exhibition	Cure & Care Exhibition	Maxima Medisch Centrum	Veldhoven	Netherlands
23-May-15	25-May-15	Exhibition	Openluchthotel 2015: Smart textiles - wearable	De Burcht	Leiden	Netherlands
19-May-15	19-May-15	Presentation	Participatory Innovation Conference	The Hague University	The Hague	Netherlands
18-May-15	18-May-15	Exhibition	3TU.Innovation & Technology Conference	World Trade Centre	Rotterdam	Netherlands
13-May-15	16-May-15	Exhibition	Leiden Textiel Festival	Scheltemagebouw	Leiden	Netherlands

9-May-15	13-Sep-15	Exhibition	Hands Off: New Dutch Design at the Confluence of Technology & Craft	Museum of Craft and Design	San Francisco	United States
21-Jan-15	22-Feb-15	Exhibition	Smart textiles - wearable services	Textile Museum Tilburg	Tilburg	Netherlands
15-Jan-15	19-Jan-15	Exhibition	Tangible, Embedded and Embodied Interaction Conference	Stanford University	Stanford	United States
14-Jan-15	17-Jan-15	Exhibition	Heimtextil: Smart textile services samples	Messe Frankfurt	Frankfurt	Germany
23-Dec-14	8-Mar-15	Exhibition	Cure & Care Exhibition	Taiwan Design Museum	Taipei	Taiwan
18-Nov-14	20-Feb-15	Exhibition	ArcInTex: Shaping (un) common grounds	TIO³	Ronse	Belgium
4-Nov-14	4-Nov-14	Exhibition	Emerce eHealth Convention	Pakhuis De Zwijger	Amsterdam	Netherlands
22-Oct-14	22-Oct-14	Presentation	World Health & Design Forum 2014	Klokgebouw	Eindhoven	Netherlands
20-Oct-14	20-Oct-14	Presentation	ABN-AMRO “Smart Fabrics: from Fibre to Fashion”	Oude Rechtbank	Eindhoven	Netherlands
18-Oct-14	27-Oct-14	Exhibition	Dutch Design Week	Piet Hein Eek	Eindhoven	Netherlands
18-Oct-14	26-Oct-14	Exhibition	Dutch Design Week: Mind the Step	Klokgebouw	Eindhoven	Netherlands
16-Oct-14	16-Oct-14	Presentation	ArcInTex: Design Films	Zwarte Doos	Eindhoven	Netherlands
13-Oct-14	17-Oct-14	Exhibition	ArcInTex: Shaping (un) common grounds	Eindhoven University of Technology	Eindhoven	Netherlands
26-Sep-14	3-Oct-14	Exhibition	Beijing Design Week	Dashilar Area	Beijing	China
13-Sep-14	17-Sep-14	Exhibition	E-textiles 2013 Swatchbook	ISWC 2014	Seattle	USA
25-Jun-14	16-Nov-14	Exhibition	Smart Flexibility: Advanced Materials and Technologies	Design HUB Barcelona	Barcelona	Spain
13-Jun-14	13-Jun-14	Presentation	European Creative Business Cup	Amsterdam Economic Board	Amsterdam	Netherlands
10-Jun-14	10-Jun-15	Exhibition	E-textiles 2013 Swatchbook	MAK, the museum for applied art	Vienna	Austria
3-Jun-14	3-Jun-14	Presentation	Internet of Things Event	High Tech Campus	Eindhoven	Netherlands
21-May-14	21-May-14	Exhibition	Night of the Nerds	Klokgebouw	Eindhoven	Netherlands

7-May-14	21-Sep-14	Exhibition	Design Column #8: Beyond The Senses	Museum Boijmans Van Beuningen	Rotterdam	Netherlands
15-Apr-14	15-Apr-14	Presentation	UKON: Eldercare and movement	Radboud UMC	Nijmegen	Netherlands
7-Apr-14	27-Apr-14	Exhibition	ArcInTex: Shaping (un) common grounds	Auckland University of Technology	Auckland	New Zealand
29-Mar-14	30-Mar-14	Exhibition	Mini Maker Faire	Klokgebouw	Eindhoven	Netherlands
23-Mar-14	28-Sep-14	Exhibition	Tradition meets future	De Kantfabriek	Horst	Netherlands
17-Mar-14	17-Mar-14	Presentation	Mobile Life Seminar	Mobile Life Centre	Stockholm	Sweden
13-Mar-14	22-Mar-14	Exhibition	SXSW Interactive	South by Southwest	Austin	United States
12-Mar-14	12-Mar-14	Presentation	ArcInTex Symposium	Chalmers University of Technology	Gothenborg	Sweden
28-Jan-14	15-Mar-14	Exhibition	Co-created wearables	Baltan Laboratories	Eindhoven	Netherlands
22-Jan-14	31-Jan-14	Exhibition	ArcInTex Exhibition	Vilnius Academy of Art	Vilnius	Lithuania
6-Jan-14	8-Jan-14	Exhibition	ArcInTex Exhibition	Art Academy of Latvia	Riga	Latvia
17-Dec-13	17-Dec-13	Presentation	Waag Open Space: Careful Designs	Waag Society	Amsterdam	Netherlands
24-Oct-13	24-Oct-13	Presentation	CRISP Design Review Session	Dynamo	Eindhoven	Netherlands
22-Oct-13	22-Oct-13	Presentation	Baltan Open Lab: Wearable senses	Natlab	Eindhoven	Netherlands
19-Oct-13	27-Oct-13	Exhibition	Design changes	DDW: Design United	Eindhoven	Netherlands
17-Oct-13	17-Oct-13	Presentation	ArcInTex Symposium	TIO^3	Ronse	Belgium
14-Oct-13	18-Oct-13	Exhibition	ArcInTex Exhibition	TIO^3	Ronse	Belgium
26-Sep-13	3-Oct-13	Exhibition	Beijing Design Week	The Dutch Pavilion	Beijing	China
25-Sep-13	25-Sep-13	Presentation	Conference on Design and Semantics of Form and Movement	Wuxi Museum of Chinese Calligraphy and Paintings	Wuxi	China
22-Sep-13	25-Sep-13	Exhibition	Conference on Design and Semantics of Form and Movement	Wuxi Museum of Chinese Calligraphy and Paintings	Wuxi	China
20-Sep-13	20-Sep-13	Presentation	Company presentation	Coor Design	Ningbo	China
20-Sep-13	24-Dec-13	Exhibition	Designing Health	Designhuis	Eindhoven	Netherlands

2-Jul-13	5-Jul-13	Exhibition	Design 4 Health conference	Sheffield Hallam University	Sheffield	United Kingdom
18-Jun-13	18-Jun-13	Presentation	Participatory Innovation Conference	Lappeenranta University of Technology	Lahti	Finland
9-Jun-13	12-Jun-13	Exhibition	Nordic Design Research Conference Exhibition	School of Design	Copenhagen	Denmark
6-Jun-13	6-Jun-13	Exhibition	Smart Textiles Salon	Museum of Industrial Archaeology and Textiles	Ghent	Belgium
11-Apr-13	11-Apr-13	Presentation	Design Research Lab Talk	Universität der Künste Berlin	Berlin	Germany
10-Mar-13	10-Mar-13	Presentation	Close To The Body	Institute of Advanced Architecture of Catalunya	Barcelona	Spain
7-Nov-12	7-Nov-12	Presentation	Skills Tour #1	TIO^3	Ronse	Belgium
28-Oct-12	16-Dec-12	Exhibition	Pretty Smart Textiles	TIO^3	Ronse	Belgium
20-Oct-12	28-Oct-12	Exhibition	Wearable Senses exhibition	DDW: Videolab	Eindhoven	Netherlands
6-Oct-12	6-Oct-12	Exhibition	Night of the Nerds	NEMO science center	Amsterdam	Netherlands
29-Jun-12	29-Jun-12	Presentation	Beta-Textiles Workshop	Waag Society	Amsterdam	Netherlands
18-Jun-12	18-Jun-12	Presentation	International Symposium on Wearable Computers (ISWC)	Great North Museum	Newcastle	United Kingdom
20-Apr-12	22-Apr-12	Exhibition	Smart Textile Services	Milan Design Week: Design Academy Eindhoven	Milan	Italy
19-Apr-12	19-Apr-12	Presentation	CRISP Design Review Session	Lijm & Cultuur	Delft	Netherlands
9-Feb-12	9-Feb-12	Presentation	Service Design and Innovation conference (Serv.Des)	Laurea University of Applied Sciences	Helsinki	Finland
22-Oct-11	30-Oct-11	Exhibition	Dutch Design Week 2011	TU Eindhoven	Eindhoven	Netherlands
29-Aug-11	29-Aug-11	Presentation	Summer School in Services	Aalto University	Helsinki	Finland
15-Aug-11	15-Aug-11	Presentation	Summer School - Social shaping of innovation	University of Southern Denmark	Sønderborg	Denmark

Summary

Designing Embodied Smart Textile Services: The role of prototypes for project, community and stakeholders

The age of wearables has been a prophecy for decades, with visions such as the disappearing computer (Weiser & Brown, 1997) bringing technology everywhere around us. The miniaturisation of technology is reaching a point where it will become possible to finally evaluate the results that this vision has brought. Previously rigid and hard technology is being transformed and shaped to the body, for example in wristbands, activity trackers and glasses. This raises the question as to how close-to-the-body products and services can become truly meaningful to people's lives, and more closely connected to our bodily experiences than the current generation of wearable technology. Technological developments in textiles and technology make it possible to augment the existing qualities of textiles with sensing capability (for example, measuring touch, stretch, movement, light, and sound) and actuation capabilities (for example, changing heat, colour, light, and shape) (Schwarz, Van Langenhove, Guermonprez, & Deguillemont, 2010). By combining intangible properties from services (for example, the ability to measure and store data or change the functionality of a material over time), it becomes possible to tailor smart textiles to individual users. Smart Textile Services are a type of Product-service Systems (PSS's) where the value for the end-user is achieved by combining an interactive physical component (the smart textile) with intangible components, such as digital data or interpersonal relations. The influence of embodiment, emotions and the phenomenological significance of ways of expression on the service are aspects not widely recognised in service design because service research has always focussed on an information process approach. Both the design process and the result tend to be disembodied, because of limited awareness of the corporal, situated and social elements. The main objective of this doctoral work is to bring forward a new perspective on the design of Smart Textile Services for close-to-the-body applications. The central research question that drives this exploration is: "How to design Embodied Smart Textile Services?"

This thesis aims to generate knowledge about bringing technology closer to the body by investigating how Embodied Smart Textile Services have an impact on different scales. By bringing technology closer to the body, the interactions with the Embodied Smart Textile Service itself are changing and becoming more Embodied: the scale of the PSS. In order to develop these types of Embodied Interactions, the design process itself is also changing: the scale of the Project. An embodied design process also leads to changes in the collaborations between various disciplines: the scale of the Community. And finally, these new embodied collaborations have implications on the sense-making process between the stakeholders: the scale of the Stakeholders. The main way of approaching these different scales is by taking the multifaceted role of the prototype as the main point of departure.

Chapter 2 describes three Embodied Smart Textile Services that have been developed and function as the carrier of the research: the scale of the PSS. Tactile Dialogues is an Embodied Smart Textile Service which aims to enable a dialogue by triggering physical communication patterns between a person with severe dementia and a family member, spouse or caretaker. It consists of a textile object in the form of a pillow with integrated vibration elements that responds to activity and hand movement. Vigour is an Embodied Smart Textile Service that enables geriatric patients, physiotherapists and family to gain more insight into the exercises and progress of a rehabilitation process. It consists of a knitted, long-sleeved cardigan with integrated stretch sensors made of conductive yarn and an accompanying iPad application which monitors the movements of the upper body and can give sound feedback. Vibe-ing is a self-care tool for well-being in the form of a garment which invites the body to feel, move, and heal through vibration therapy. An analysis of the level of Embodiment in the Service Interfaces of these projects shows that they all use personalisation in order to achieve the link with the human body, context and social environment. The personalisation of the Service Interfaces was driven by three main elements:

- *Personalising the textile material properties.* The textile material can be personalised to the bodily behaviour of the user, leading to a strong relation between the material qualities and the interaction.
- *Personalising the look, fit and feel of the textile object.* The locations of sensors, overall fit of the garment and aesthetics can be tailored specifically to the person, leading to physical and emotional comfort, which increases the subjective well-being of the wearer.
- *Personalising the interaction with the digital data.* By personalising the relation between the data from the PSS and the user, the interaction can be more tuned towards the bodily senses and capabilities of the user.

Chapter 3 analyses in more detail the role of the prototypes in the design process of the Tactile Dialogues Embodied Smart Textile Service: the scale of the Project. One of the main challenges of designing Embodied Smart Textile Services is the difficulty to grasp what exactly is the object of design that is being developed. Instead of trying to pin down what the object of design exactly is for all the involved stakeholders, it is more interesting to ask the question how it can still move forward, even when it is such an ambiguous phenomenon. Participatory Design is used as a theoretical starting point within this scale to frame the research question: “How do prototypes support a bottom-up infrastructuring approach to design embodied Smart Textile Services?” Subjective autoethnographic accounts are used as a research methodology for this investigation, which led to three main conclusions:

- *Prototypes assure the situatedness of the PSS.* By implementing the prototype in the actual context, the PSS becomes real and confrontations are triggered between the context and the prototype: for example, by creating connections between the digital infrastructure of the organisation and the digital data of the Embodied Smart Textile Service.

- *Prototypes increase the quality of the PSS.* By experiencing the development of the prototype, stakeholders feel challenged to bring the quality of the PSS to a higher level of refinement and striving for perfection.
- *Prototypes trigger horizontal collaborations in the PSS.* By taking a prototyping approach, the boundaries are blurred between different fields: for example, by merging the textile and technology disciplines, but also by forming internal bridges within the PSS itself.

Chapter 4 focuses specifically on the collaboration between the stakeholders and zooms in to the scale of the Community. In order to develop Embodied Smart Textile Services many disciplines are needed: one designer is not able to integrate all the different viewpoints alone, but requires collaboration and participation of a range of other stakeholders during the design process. Knowledge sharing and knowledge integration are critical characteristics of a successful collaborative design project (Kleinsmann & Valkenburg, 2008). By looking to the field of collaborative design as a starting point, this chapter provides insight into the research question: "How do the prototypes support the collaborative design process within a community during critical transitions of the process?" Verbal analysis is used as a methodology in order to create an objective dataset from the transcripts of six critical design meetings. Guided by the patterns found by applying a descriptive statistical method (correspondence analysis), three main roles of the prototypes were identified:

- *Prototypes focus discussion about the content.* The prototypes support the stakeholders to focus on in-depth details that can only be solved with their specific skills. Furthermore, the prototypes trigger and frame discussions about existing issues.
- *Prototypes make the knowledge meaningful and applicable for others.* The prototypes support the stakeholders to understand the meaning of the expertise of the other, allowing them to communicate as equals with each other.
- *Prototypes embed the knowledge of the different stakeholders.* The direction of the project is defined based on the expertise and skills of the stakeholders. The designer does not need to have knowledge of all the elements of the Embodied Smart Textile Services.

Chapter 5 zooms further in on the critical design meetings and focusses on sense-making moments, presenting a detailed analysis of the scale of the Stakeholders. Combining the tangible characteristics of textiles and healthcare on one side, and the intangible nature of services on the other side introduces difficulties to make sense of and attach meaning to the different elements. This challenge leads to the central research question of this chapter: "How do prototypes support embodied sense-making during the collaboration in a

Smart Textile Services design process?" Conversation Analysis methodologies were applied in order to find patterns during the design meetings. These patterns showed that stakeholders use their bodies in combination with the prototypes to make assessments as part of the sense-making process. As a result, four different types of assessments were identified in which the prototype and the body play an important role:

- *The body and the tangible object.* The participants pointed, touched and manipulated the tangible object while gazing.
- *The body and the imagined tangible object.* The participants used their bodies to demonstrate certain aspects by "imagining" the object on the body using previous knowledge about the prototype.
- *The body and the imagined future object.* The participants used their bodies to make gestures of handling an imagined object that is not implemented in the prototype, relying on bodily knowledge from other experiences.
- *The body and the imagined intangible object.* The participants used their bodies to refer to design features that cannot be physically represented in the prototype.

Chapter 6 aims to bring the insights from the different scales described in the previous chapters together for the different audiences of this thesis. Firstly, reflections about the impact of Embodied Smart Textile Services for the Smart Textiles industry. Secondly, reflections on the different roles of prototypes for designers who are working in projects related to Product-service Systems. And finally, reflections on the different research methodologies for design researchers.

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DQI

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Wearable Senses theme

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Curriculum Vitae

Martijn ten Bhömer was born in Roermond, The Netherlands on the 4th of April, 1985. After obtaining his VWO-diploma in 2004 at Lyceum Schöndeln in Roermond, he studied Industrial Design at the Eindhoven University of Technology. He received his master's diploma cum laude in 2010. As part of his bachelor's course he studied at Southern Yangtze University in Wuxi, China. During his master's education he was a research intern at Microsoft Research in Cambridge, UK. After his master's education he worked as an Interaction Designer and focussed on designing Product-service Systems. He started with a PhD project in 2011 at Eindhoven University of Technology as part of the Creative Industry Scientific Programme (CRISP), the results of which are presented in this dissertation. During his doctoral work, Martijn was a lecturer and coach at the Wearable Senses educational theme of the Industrial Design Department and visiting researcher at the Design Research Lab in Berlin.

During the course of his doctoral work his collaborative work has won through to the national finals of the Creative Business Cup for the BB.Suit platform, he was awarded second prize in the Social Design Award for the Tactile Dialogues project, and he was nominated for the Index Award and the New Material Award with the BB.Suit Clean Air project. His work has been exhibited at national and international exhibitions, museums and conferences, such as South by Southwest in Austin, the Museum of Design in Zürich, the Tangible, Embedded and Embodied Interaction conference in Stanford, and multiple Design Weeks in Eindhoven and Beijing.

Photo by Bart van Overbeeke.

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