The (New) Roles of Prototypes During the Co-Development of Digital Product Service Systems

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This paper investigates different roles that prototypes play during the development of digital Product Service Systems (PSSs). A literature review reveals that prototyping supports designers during the design process, as well as during knowledge sharing processes with stakeholders. To create a better understanding of these two co-existing roles of prototyping, we executed a research-through-design project in the healthcare domain. This design project was centred around the development of four different prototypes that the designer sequentially developed. A major input into the design process was co-reflection sessions between the designer and different stakeholders. We analysed the prototyping process and the co-reflection sessions. Moreover, we executed a conversational analysis to understand the actual knowledge sharing processes between the designer and the different stakeholders. The results present a detailed overview of the different (co-existing) roles of the prototypes. We distinguished two new types of prototypes which were both related to the development of the intangible aspects of the digital PSS: (1) *service interface prototrial* aimed at exploring several options for detailing the different intangible aspects of the digital PSS, and (2) *service provotype* to stimulate collaborative creation of the intangible aspects of the digital PSS in an early stage.

***Keywords* –** Prototyping, Collaborative Design Tools, Product Service Systems, Healthcare.

***Relevance to Design Practice* –** This paper provides examples, guidelines and a framework that will support designers to prototype effectively during the co-development of digital PSS.

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Introduction

Designers are becoming more and more involved in the creation of digital Product Service Systems (PSSs) (see e.g., Carreira, Patrício, Jorge, & Magee, 2013; Trevisan & Brissaud, 2017; Tukker & Tischner, 2006; Valencia, Mugge, Schoormans, & Schifferstein, 2015). This paper focuses on IoT enabled digital PSSs that collect and interchange data among networked devices such as sensors and electronic devices. This form of connectedness is called ubiquitous connectedness (Lerch & Gotsch, 2015; Zeng, Lin, Chen, & Xu, 2018). Ubiquitous connected digital PSSs converge technical and social factors into a system (Morelli, 2006). Moreover, digital PSSs are embedded in our everyday physical and social spaces (Lytinnen & Yoo, 2002). The heterogeneous combination of sociotechnical elements and their embedding in our everyday environment suggest that designers could play in important role in the creation of digital PSSs (Morelli, 2006).

Within these digital PSS, design objects are discussed as means for supporting collaboration between people (Sangiorgi, 2011). One of the main tasks of designers is to develop the materiality and embodiment of their interfaces, which result in exchange relations between the stakeholders. Exchange relations are the sociotechnical resources that establish the context for attributing particular roles to the stakeholders involved in service co-production (Secomandi & Snelders, 2011). This interaction between the service and the end-users (provider and client) is often characterized as an exchange mediated by a material artefact, being also known as the *service interface* (Secomandi & Snelders, 2011). A service interface focuses on the sociotechnical resources immediately associated with exchanges between providers and clients. Besides this product/service-oriented role, designers take on a more process-oriented role that relates to facilitating knowledge sharing processes between all stakeholders involved (see e.g., Bohemia, 2002; Kleinsmann, Deken, Dong, & Lauche, 2012; Valencia, Person, & Snelders, 2013).

Prototyping is a promising means to support the designer in fulfilling both product/service and process-oriented roles. Literature on prototyping shows that they could support both the design process (see e.g., Faithfull, Ball, & Jones, 2011) as well as knowledge sharing processes (see e.g., Boer & Donovan, 2012). However, the prototyping literature is developed for a product-focused design process and not for designing services or digital PSSs. The design of digital PSSs is different because it also focuses on service-related aspects (Morelli, 2006). It is therefore

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unknown how these co-existing roles of prototypes can support the designer in the development of digital PSSs. It is particularly unknown how prototyping could support designing different intangible elements of a digital PSS. Consequently, the aim of the paper is to explain how prototyping techniques could support the development of a digital PSS and what types of prototypes support this process. We also look for possible new forms of prototyping that relate to the service-related aspects of digital PSSs.

To this end, we executed and analyzed a design project within the healthcare domain. We selected the healthcare domain because digital PSSs in healthcare involve multiple users with different desires and demands (e.g., unobtrusive tools for health improvement for the patient versus. tools for increasing the quality of the care process for the caregiver). Moreover, digital PSSs in healthcare consist of multiple physical forms. These aspects allow us to explore both roles of prototyping, making the healthcare context appropriate for the aim of the study. This design project was part of a larger project called the Smart Textile Services project (STS project), which aimed to integrate the knowledge from the separate domains of textiles, technology and services through design. Designers involved in the project developed design concepts in collaboration with a heterogeneous network of small and medium-sized enterprises (SMEs) and larger organizations. The specific design project presented in this paper centered on the sequential development of four prototypes. A major input for the design process was co-reflection sessions between the designer and project stakeholders. One could say that the prototypes functioned as rapid (collaborative) learning cycles (Jensen, Elverum, & Steinert, 2017), co-reflections on each prototype forming the input for a new, further developed prototype. In this way, the prototypes supported both the development of the concept and knowledge sharing between the designer and stakeholders (Bogers & Horst, 2014).

To provide an overview of the different sorts of prototypes, the paper starts with a review of literature on the two roles of prototyping. It then describes the research methods of the empirical study that resulted in a detailed and integrated overview and reflections on the different roles of the prototypes created throughout the design process. The results also reveal two new types of prototypes (1) *service interface prototrial* aimed at exploring several options for detailing the different intangible aspects of the digital PSS and (2) *service provotype* to stimulate collaborative creation of the intangible aspects of the digital PSS in an early stage. The paper ends with conclusions and discussion about the diverse roles of prototyping during the development of a digital PSS.

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The Role of Prototyping while Designing a Digital PSS

Prototypes as Supporters of the Design Process

Prototypes are early embodiments of a design concept that can have multiple physical forms (see e.g., Faithfull et al., 2001). Design researchers have classified prototypes in different ways. Houde and Hill (1997), for example, focus on the *purpose of the prototype*. They propose the following triangle of possible purposes: role (usability), implementation (function) and look and feel (form). Prototypes focusing on the role aim to investigate and demonstrate questions concerning what the design can do for a user. Prototypes focusing on implementation try to answer technical questions about how a future design might actually work to demonstrate technical feasibility. These prototypes are also called *functional prototypes* (see e.g., Campbell et al., 2007). Prototypes focusing on look and feel explore options for the concrete future experience of a design.

Houde and Hill (1997) explain that a prototype can have multiple purposes at once. Ullman (2002) focuses on the *stage in the design process* in which the prototype is used and created. He distinguishes four classes of prototypes relating to: (1) proof of concept (initial stages of design); (2) proof of product (physical embodiment); (3) proof of process (production methods and materials for the desired product); and (4) proof of production (effective manufacturing). Throughout the design process, designers create multiple prototypes. They use these series of prototypes as means to organically and evolutionarily learn, discover, generate and refine their designs (Lim, Stolterman, & Tenenberg, 2008). Designers determine which aspects must be considered in the exploration and refinement of the design, such as materials, resolution and scope. To emphasize the sequential nature of prototypes, Sommerville (1995) distinguishes (1) throwaway prototypes (early stage prototypes that help in clarifying requirements), (2) evolutionary prototypes (iterative stages of building and evaluation) and (3) incremental prototypes (modifications of existing products).

Besides these classifications, research explains the role or function of prototypes in the design process. For example, research has shown that prototypes are an effective means for *comparing alternatives* (evaluation) and *speeding up* the design process (Houde & Hill, 1997; Ward, Liker, Cristiano, & Sobek, 1995). Virtual prototypes (see e.g., Colombo & Cugini, 2005) and rapid prototyping methods (see e.g., Campbell, 1996) are especially often used for speeding up the design process. Another advantage of prototypes described in the literature is their scope to *simulate* parts of the product's usability, function and/or look and feel (Houde & Hill, 1997) without the risks of production (Ward et al., 1995). Prototypes are inherently incomplete (they only simulate parts). Therefore, they also function as a *filter*. Filtering means that certain aspects of a design idea that a designer seeks to represent can be emphasized (Lim et al., 2008). Designers thus *select* what focus a prototype should have. Selecting is the art of identifying the most important open design questions. Designers use the prototype to ask questions such as: (1) What role will the artefact play in a user's life? (2) How should it look and feel? (3) How should it be implemented? (Houde & Hill 1997). Designers also use filters to reduce the complexity of the design problem at hand. Filters support the designer in controlling the design process (Gerber 2009; Gerber & Carroll, 2012).

The described roles of prototypes in the design process all refer to the conscious process of exploring and evaluating *known unknowns* (Ramasesh & Browning, 2014). Prototypes, however, also *surprise* designers by revealing *unknown unknowns*; the issues and details whose existence and relevance is unknown to the designer. Surprises lead to reflections, which in turn may lead to new design directions. To emphasize the explorative and surprising nature of prototypes, Jensen et al. (2017) coined the term *prototrials,* which are high-functional prototypes used in the very early stages of the concept development process, yet having low fidelity compared to the final product.

Prototypes as Supporters of Knowledge Sharing between Stakeholders

Creating a digital PSS requires drawing on the knowledge and skills of stakeholders with different backgrounds that often come from different organizations. These stakeholders have to create a shared understanding about the goal of the project and what the project involves. Prototypes that support scoping are called *provotypes* (Mogensen, 1992). Provotypes are low-fidelity prototypes that can function as a primary generator (Darke, 1979) to open up discussions. Designers create provotypes particularly with a view to expose taken-for-granted aspects of users' values and practices, which can provide design directions. Moreover, provotypes can serve as a platform for collaborative analysis and exploration of a design space (Boer & Donovan, 2012).

When creating a digital PSS with a network of diverse stakeholders, it is important for the quality of the digital PSS that the different roles of the digital PSS are well integrated into a coherent whole (Dong, 2005). Research shows that when stakeholders have diverse backgrounds, it is hard to establish 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; Carlile, 2002; Dougherty, 1992; Kleinsmann & Valkenburg, 2008; Kleinsmann, Buijs, & Valkenburg, 2010). Prototypes are important means to overcome these difficulties, as they make things explicit. At the same time, they make sense for each stakeholder from their own perspective. The term that is often used in the literature to describe this knowledge-brokering role of prototypes is *boundary objects* (Star & Griesemer, 1989). Boundary objects are prototypes that "inhabit several intersecting social worlds" (Star & Griesemer, 1989, p. 393). This means that the prototype accommodates different meanings for the various stakeholders involved in the process, yet robust enough to maintain a common identity across all social contexts. The term boundary refers to a shared space and allows people to work together without consensus (Star, 2010). Boundary objects exists in different shapes and forms and they can be concrete or abstract depending on their purpose. The different purposes of a boundary object depend on the use and interpretation of the object because its materiality derives from action (Star, 2010). Start and Griesemer (1989) distinguished four types of boundary objects: (1) repositories (e.g., indexed objects in a standardized fashion to overcome differences in unit of analysis), (2) ideal types (e.g., abstracted objects to delete local contingencies which have the advantage of adaptability), (3) coincident boundaries (e.g., objects that have the same boundaries but different internal contents), (4) standardized forms (e.g., methods of common communication). Designers and their collaborators mostly use ideal types (e.g., abstract prototypes used to explore design directions) and coincident boundaries (e.g., the shape of an artefact).

A specific type of prototype that supports knowledge integration is called an *experience prototype*. The aim of experience prototypes is to understand, explore or communicate what it might be like to engage with the product, space, or systems we are designing (Buchenau & Suri, 2000). Experience prototypes are intended 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 the design process in three key ways. Firstly, they facilitate developing an understanding about the essential factors of an existing experience. Secondly, they are useful in exploring and evaluating ideas to provide inspiration and confirmation or to reject these ideas. Thirdly, they are used to communicate issues and ideas to establish a shared point of view.

An additional challenge that diverse networks face is that stakeholders speak different languages due to their disciplinary differences. This hampers the communication between them. For example, in a specific design project, all the stakeholders might be able to talk English with each other, perhaps with different accents or dialects. However, all disciplines also use language fixed in their own so-called object world; worlds where specific scientific/instrumental paradigms fix meaning (Bucciarelli, 2002). Within object worlds, ordinary language is spoken in a specialized way, as if a stakeholder were speaking a different language. For example, textile developers use the English word report to indicate the specific configuration of the needles in the circular knitting machine used to knit a specific pattern. Within our object world as a designer, *report* has a different meaning, indicating mainly a textual overview of a certain process. Prototypes are effective means to overcome linguistic barriers. Specific prototypes that aim to overcome linguistic barriers are called *conscription devices* (Henderson, 1991). Conscription devices are prototypes and/or drawings whose function is to elicit group participation and communication during the creation process. Conscription devices allow stakeholders to actively edit and modify the object during a meeting. Moreover, conscription devices support the creation of the link between the meaning of the object and the coordination of the knowledge network around the object that is needed to produce the object (Hölttä, 2013). This means that prototypes have, besides their clarifying role, a role in the coordination of the design project. They also provide assistance for reasoning, reflection and the linking of items in new ways to facilitate new discoveries from the shared insights.

The literature review has shed light on the various purposes and different possible representations of a prototype in the design process. It shows the product-focus of current prototyping approaches. It did not, however, provide an answer to the question of *how* prototypes support the designer in developing a digital PSS with a network of diverse stakeholders and if the existing types of prototypes support the design of all elements of a digital PSS or if new types are needed. The remainder of the paper will give an answer to this question.

Research Setting

The research setting was a design project in which a designer created, in close collaboration with a diverse stakeholder network, a smart textile service for people who suffer from dementia. The designer is one of the authors of the paper. He has an industrial design background with a focus on product and smart textile design. For this study, we selected the field of smart textile services, since it is an interdisciplinary field (see e.g., De Couvreur, Dejonghe, Detand, & Goossens, 2013; Joseph, Smitheram, Cleveland, Stephens, & Fisher, 2017) in which designers have a product/service and process-oriented roles. The stakeholder network involved in this design project included: an Elderly Care Organization (service provider), an Electronics Producer (responsible for the smart technologies in the Textiles), a Textile Producer (responsible for the knitting and the yarn selection) and a Fashion Designer (responsible for the form giving of the concept).

In collaboration with these stakeholders, the designer created a concept called Tactile Dialogues, a textile artefact in the form of a pillow with integrated vibration elements that react to touch (Schelle, Naranjo, ten Bhömer, Tomico, & Wensveen, 2015) and supports as such a dialogue between a person with severe dementia and a family member or (other) caregiver (see Figure 1). The design of Tactile Dialogues follows a phenomenological and humanistic design philosophy, rather than focusing on purely medicalization and quantification (Høiseth & Keitsch, 2015; Møller & Kettley, 2017). Consequently, the Elderly Care Organization *coaches* the users to adapt Tactile Dialogues to their specific needs (e.g., people can use the vibration for subtle massage or more intricate communication patterns).

Figure 1. Interacting with Tactile Dialogues
(photo: Bart van Overbeeke).

Methods

Data Gathering

During the design process for Tactile Dialogues, the designer created four main prototypes (P2, P4, P5 and P6 in Figure 2). He used them to progress the design process and to co-reflect with other stakeholders. These prototypes, first-hand reflections of the designer on the prototyping process and the co-reflections, form the data of this study. The co-reflections took place during seven meetings between the designer and a stakeholder. During these meetings, the stakeholders evaluated each prototype with the use of a co-reflection methodology (Tomico & Garcia, 2011). Figure 2 shows the moment in the design process in which the selected meetings took place. It also shows the prototypes that were evaluated during the meetings (P2, P4, P5, P6). The designer also created P1, P3 and P7 to progress his own design process. These prototypes were not used during co-reflection meetings with the stakeholders and are therefore not part of the data set (for a full overview of the prototypes created see Appendix A). Table 1 shows an overview of the stakeholders involved in each meeting.

Table 1. Overview of stakeholders in each meeting.

Meeting	Between designer and:
Me 1	Elderly Care Organization
Me 2	Elderly Care Organization
Me 3	Electronics Producer
Me 4	Textile Producer and Fashion Designer
Me 5	Elderly Care Organization
Me 6	Fashion Designer
Me 7	Electronics Producer

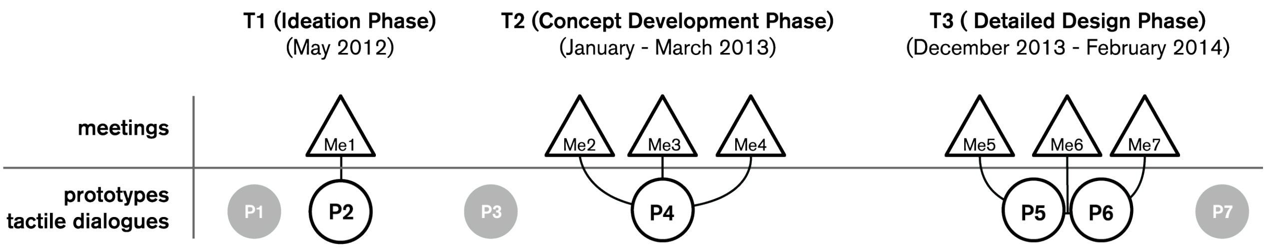


Figure 2. Overview of the selected design meetings.

Data Analysis

We applied the Research through Design (RtD) methodology (see e.g., Frayling, 1993; Zimmerman, Stolterman, & Forlizzi, 2010) to inquire the prototyping process and the intentions of the designer and his collaborators with those prototypes. We used RtD since it supports the active involvement of the designer and the stakeholders in gathering rich, first-hand insights into the prototyping process. In this study, knowledge is generated through and fed back into consequent cycles of designing, building and experimentally testing experiential prototypes in near-real-life settings (Hengeveld, 2011). To gain a better understanding of the actions of the designer and the functions of the prototypes, we applied an auto-ethnographic account methodology (see e.g., Chang, 2008). The auto-ethnographic accounts enabled the researchers get a first-person perspective on the prototyping process with the acknowledgement of all the bias it entails.

Secondly, the paper builds on the protocol-analysis tradition in design research to make sense of the co-reflection process between the designer and the stakeholders (see e.g., Badke-Schaub & Frankenberger, 1999; Cross, Christiaans, & Dorst, 1996; McDonnell & Lloyd, 2009). Within this tradition, this paper uses a specific methodology within protocol analysis called *verbal analysis*. Verbal analysis concentrates on investigating what the subject of research is actually doing, with the aim of modelling these actions and thereby leading to a more comprehensive understanding of the discourse (Chi, 1997; Hmelo-Silver & Barrows, 2008; Hogan, Nastasi, & Pressley, 1999). Previous studies show that this type of analysis can yield an understanding of conversational behaviour and shared information by examining the verbal interpersonal communication that occurs during design meetings (Deken, Kleinsmann, Aurisicchio, Lauche, & Bracewell, 2012; Luck & McDonnell, 2006).

We captured the conversations during the seven selected co-reflection meetings between the designer and a stakeholder with audio recordings, which we transcribed afterwards. We analysed the data with the use of two coding schemes: the *design activity* (why things were said; adopted from Deken, Kleinsmann, Aurisicchio, Bracewell, & Lauche, 2009; Deken et al., 2012) and the *design content* that was communicated (what was said). 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 the two coding schemes. See ten Bhömer [2016, p. 154 (design activity) and p. 156 (design content)] for an overview and definitions of the design content codes.

Both authors coded 50% of the data. During the analysis, we inductively further developed the coding scheme. Following Blessing and Chakrabarti (2009), we sought feedback from each other early in the process on a partial set of the codes and again later on to ensure continued alignment (see also Eisenbart & Kleinsmann, 2017). If we could not capture a segment with the existing codes, we either added a new category or refined an existing category. After adding a code, we checked all the data that we had already coded to see if the new code fitted better. The process that we followed to code the data is comparable to the six-step method of Deken et al. (2012). To show which prototype triggered what kind of design activities and what type of design content, we queried possible combinations of occurrence of design activity vs. design content codes. Inspired by recent research (see e.g., Deken et al., 2012; Stokmans & Snelders, 1994; Valencia et al., 2013), we used a descriptive statistical method called Correspondence Analysis to do this.

Results

Classification Roles of Prototypes in the Design Process

This section describes the results of the RtD process and the reflections of the designer on how prototypes supported the design process. The design process could be characterized as iterative stages of building and evaluating mainly supported through prototyping. Since P2 was less developed than P6, we termed the set of prototypes as evolutionary prototypes (Sommerville, 1995).

Table 2 shows the reflections of the designer on the process related roles of the four prototypes. It shows that the designer created P2 (Touch Sleeve) because he wanted to explore design directions and he had questions about the purpose of the concept (testing the proof of concept as discussed by Ullman, 2002). The designer also used P2 to explore possible design directions with the elderly care institution. He explored several aspects to co-determine the purpose of the prototype (Houde & Hill, 1997). Together, they explored, for example, (1) the function in context (e.g., how would different smart textile products improve the life for people with dementia?), (2) the integration of the different parts (e.g., how can we practically integrate hard technology with soft textiles?) and (3) the possible interactions between user and product (e.g., how to implement interactive triggers such as sound, light and vibration?). This shows that P2 functioned also as a broad filter (Lim et al., 2008).

With P4, the designer intended to create an object that could stimulate people's senses. Yet, he did not know which senses to stimulate and how to do this. He therefore built P4 to function as a prototrial (Jensen et al., 2017) to explore the different stimuli. The designer explained afterwards that P4 changed the nature of the design process from concept to detailed design (proof of product Ullman, 2002). This is illustrated by the following reflection of the designer on the status of P4:

> 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 experienced. (translated from Dutch)

The designer developed P5 and P6 to further detail the design of the Tactile Dialogues (proof of process Ullman, 2002). P5 was a functional test to integrate the electronics, while P6 was a test to explore the aesthetics and tactility of the textiles combined with the electronics. The designer used P6 to further develop the intangible exchange relations of the service. Although the Elderly

Care Organization co-determined the main use of the product (providing an activity between a person with dementia and a family member), it was unclear if and what services the pillow could deliver (unknown unknowns). P6 supported the design of the service interfaces since it provided the insight that the pillow could support and train family members to communicate with people suffering from dementia. It became evident that therapists could use the data generated by the pillow during visits to provide continuous support. Moreover, they opted that a care facility could customize the product to match the needs of the facility (for example, the shape and colour of the pillow). This analysis of the use of P6 shows that the role of the prototype is similar to prototrials in the sense that it uses a highly functional prototype to target unknown unknowns. However, a key difference is that the fidelity of the prototype for the product-related aspects is very high, while the fidelity of the service interfaces is still very low. Another key difference is that the prototype is used in a late stage of the digital PSS development process, instead of an early stage. This shows that the service interfaces design process started after—and was supported by—the product design part of the PSS. Therefore, we termed this type of prototype a Service Interface Prototrial, which we defined as a tangible (high-fidelity) prototype that triggers the exploration and testing of exchange relations between the caregiver, client and relatives.

Classification of the Roles of Prototypes in the Knowledge Sharing Process

This section describes the results of the RtD process and the reflections of the designer on the role of prototypes during the knowledge sharing processes.

Table 3 shows that P2 provided the stakeholders from the *elderly care organization* with a better understanding of possible design directions. It also triggered critical reactions from them (e.g., about the qualities of the material, the form and purpose of the artefact). These reactions highly influenced the scoping of the project and one could say that P2 functioned as a provotype (Mogensen, 1992).

When giving feedback, the people from the *elderly care organization* often referred to the context of use while they were reflecting on P2. This provided the designer with a better understanding of the complex context of use. So, P2 also functioned as a boundary object (coincidental boundary) (Star & Griesemer, 1989).

The embodiment of P2 also triggered the people from the *elderly care organization* to generate solutions. P2 activated their imagination and they started thinking about possible *service interfaces*. They explored possible service interfaces by using their disciplinary skills and their knowledge about the context

Table 2. Overview of the process related roles of the prototypes over time.

TT	Prototype	Description of the prototype	Process related goal of the designer	Classification
T1	P2: Touch Sleeve 	P2 is a knitted textile with lines of conductive yarn in the shape of a sleeve; when the sleeve is worn around the arm, the prototype reacts to touches on the arm through changes in a visualization that is displayed on a screen.	Touch Sleeve was the designer's first experiment in developing a new fabric completely from scratch based on custom specification. 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 people with dementia during (group) activities.	Proof of concept (Ullman, 2002) Broad filter (Lim et al., 2008)
T2	P4: Blanket 	P4 is a textile object that reacts to touch with different stimuli, such as light, sound and vibration. Integrates six capacitive touch sensors, six vibration motors, two LEDs and one speaker. When one side of Blanket is touched, Blanket reacts with vibration both on the side where it was touched and on the other side where the other person has their hands. When touching for a duration of three seconds, the intensity of the vibration increases, the lights start blinking and the speaker makes a small sound.	The designer created Blanket to explore how different stimuli, triggered by touching the fabric, could activate hand movements of people with dementia. He therefore integrated actuators such as light, sound and vibration in the fabric. He also added an interactive element that is based on the principles of reciprocity, coordination and resonant interaction. This element translates the touch of the hand on one side of Blanket to a reaction on exactly the other side of the fabric.	Proof of product (Ullman, 2002): Prototrial (Jensen et al., 2017)
T3	P5: Tactile Dialogues v1 	P5 is a 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.	The designer developed P5 mainly because he was curious how to scale up the production of the fabric. He also aimed to explore how the different conductive yarns, with two different functionalities (conducting power and measuring touch), could be directly integrated into the fabric during the production process.	Proof of process (Ullman, 2002);
T3	P6: Tactile Dialogues v2 	P6 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 triggers plucking movements and ridges in the fabric 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 can be squeezed and an arrow-shaped casing that points in a certain direction.	The designer's goal of P6 was to create an aesthetic combination of the electronics and tactile structure of the textile. The designer used the tangible elements of P5 and P6 to explore and test possible service exchange relations (intangible elements of the service) between the client, his/her relatives and the care taker.	Service Interface Prototrial (NEW)

of use. Consequently, during the meetings with the *elderly care organization*, some exchange relations were designed before there was a definite embodiment. The tangible prototype functioned as a primary generator for the intangible aspects of the service to be developed and provided the designer with initial design directions for the intangible parts of the service. For example, P2 triggered the experts in the *elderly care organization* to give suggestions about how new therapy services could be developed based on the smart textiles that could sense touch. Subsequently, the designer used these insights and ideas as input for the further development of the digital PSS. Similar to *provotypes*[1], this prototype enabled the stakeholders in the process to open-up discussion and exposed taken-for-granted aspects of users' values and practices. However, a key difference was that the prototype challenged the stakeholders to reconsider their views about the service interfaces, instead or in addition to the actual tangible embodiment. Consequently, we coined this new type of prototype a *service provotype*.

Table 3 also shows that reflections on P4 led to the surprising discovery that the sensors and actuators present in the prototype could be used for both sensing as well as for communication between people suffering from dementia and their relatives. In other words, P4 revealed that the social communication between the people who interacted with Blanket emerged as the most essential function of the digital PSS. This insight changed the design direction and provided the designer and the stakeholders with a shared view on design directions and next steps (e.g., the need for a Textile Designer). Consequently, we termed P4 as an experience prototype (Buchenau & Suri, 2000)

Reflections with the different stakeholders on P5 led to the development of a modular electronics toolset combined with knitted openings and padding. This finally led to a radically new way of constructing P6. The designer needed the input of several different stakeholders to come to this result and the stakeholders actively modified P6 during their reflections in order to optimize it. Therefore, this is an example of the prototype as a conscription device (Henderson, 1991).

P5 and P6 also supported the designer with the establishment of a bridge between disciplines. For example, the combination of a modular electronics toolset together with the knitted tunnels and padding created a totally new way of constructing Tactile Dialogues, which none of the individual disciplines could have realized alone. Therefore, P5 and P6 also functioned as boundary objects (ideal types) (Star & Griesemer, 1989).

Description of the Actual Design and Knowledge Sharing Processes

This section shows the analysis of the actual communication between the designer and the other stakeholders during the co-reflection meetings.

Table 3. Overview of the knowledge sharing roles of the prototypes over time.

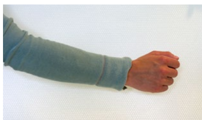
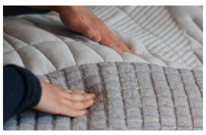
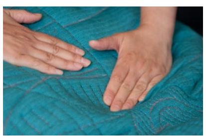
TT	Prototype	Knowledge sharing-related goal of the designer	Results co-reflection	Classification
T1	P2: Touch Sleeve 	The goal of the prototype was to scope the design project by showing a possible solution to The Elderly Care Organisation where physical touch was an important element, and which could be used to stimulate patients during group activities.	P2 triggered critical reactions from the people from the Elderly Care Organization (e.g., about the qualities of the material, the form and purpose of the artefact). P2 provided the stakeholders from the people from the Elderly Care Organization. It also triggered the people from the Elderly Care Organization to explain the context of use in detail. P2 triggered their imagination and they started thinking about the service by using their disciplinary skills and their knowledge about the context of use. P2 triggered the further exploration of possible exchange relations (before there was a definite embodiment of the prototype). This scoped the further development of exchange relations. (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.)	Provotype (Mogensen, 1992) Boundary object; coincidental boundary (Star & Griesemer, 1989) Service provotype (NEW)
T2	P4: Blanket 	The goal if the prototype was to test assumptions with the stakeholders. The designer wanted more specific knowledge from the stakeholders.	Reflections on P4 led to the surprising discovery that the sensors and actuators present in the prototype could be used not only for sensing, but also for communication between patients and relatives. The new direction created while reflecting on P4 trigged new collaborations; the Textile Designer was added to the team.	Experience Prototype (Buchenau & Suri, 2000).
T3	P5: Tactile Dialogues v1  P6: Tactile Dialogues v2 	The designer created these two prototypes to check design details with stakeholders and making plans for with them for service production and testing.	Reflections with the different stakeholders on P5 led to a radically new way of constructing the prototype, which the designer embodied in P6. The designer needed the input of multiple stakeholders to create the new construction. The prototypes P5 and P6 supported the communication.	Conscription Device (Henderson, 1991) Boundary object; ideal types (Star & Griesemer, 1989)

Table 4 presents an overview of the time spent on the different Design Activity categories. It shows that they spent more than half of the time (words spoken) on Solution Analysis (27.2%) and Solution Generation (24.8%). This means that the participants of the meeting actively evaluated the prototype (Solution Analysis) and that the prototypes triggered the creation of new solutions (Solution Generation).

Table 5 presents an overview of the time spent on the six different Design Content categories over time. It shows that the stakeholders with different disciplinary backgrounds focused on their own disciplinary content between 58.90% and 29.99% of the time (words spoken). Table 5 also shows that the stakeholders from the *elderly care organization* and the electronics producer discussed all six design content categories. During T2, the textile producer had discussions on four out of six design content categories and during T3 discussion on all six design content categories.

Table 6 presents part of the correspondence analysis (for a complete overview of the correspondence analysis see (ten Bhömer, 2016). The numbers in each cell of the table refer to the frequencies of co-occurrence between Design Activity codes (rows) and Design Content codes (columns). One can see that certain activities seem to be more related to specific design content than others. For example, there is a high co-occurrence between the words coded as *T1-Human* and *Solution Generation* (1536). This coincides with the designer's reflections on the communication process showing that in this phase he discussed and developed multiple potential concepts with stakeholders from the *elderly care organization.*

The second result of the correspondence analysis is that we found two dimensions (general tendencies) that together explained a rather high percentage of 63.1% of all relations between the Design Content variables (rows) and the Design Activity variables (columns). (Dimension 1 47.2% explains of the total inertia; Dimension 2 explains 15.9%.)

Table 4. Coding frequencies—Design activities.

	T1	T2	T3	% of the total
Problem Understanding	163	27	419	1.7%
Requirement Finding	125	283	913	3.7%
Past Design Discussion	0	427	137	1.6%
Solution Explanation	686	917	1903	9.9%
Solution Generation	2816	3042	2945	24.8%
Solution Analysis	2024	3588	4051	27.2%
Decision-Making	37	395	0	1.2%
Design Process	468	338	943	4.9%
Communication Process	0	662	477	3.2%
Organizational Information Sharing	0	446	699	3.2%
Team Coordination	0	48	452	1.4%
Solution-Testing Procedures	94	751	1372	6.2%
Disciplinary Information Sharing	128	290	329	2.1%
Off-topic	0	716	2404	8.8%

Table 5. Overview of the time spent on the six different Design Content categories over time.

Meeting	T1-Elderly Care Organization (Me1)	T2-Elderly Care Organization (Me2)	T2-Electronics Producer (Me3)	T2-Textile Producer and a Fashion Designer (Me4)	T3-Eldercare service provider (Me5)	T3-Electronics Producer (Me6)	T3-Fashion Designer (Me7)
Business	0.3%	3.5%	6.6%	0%	3.2%	4%	17.3%
Human	51%	47.1%	25.6%	3%	59%	18.9%	7.5%
Services	22.6%	17.4%	2.9%	2.6%	6.6%	14.6%	8.4%
Smart Textiles	15.8%	18.4%	26%	44.3%	16.2%	27%	48.1%
Technology	6%	3.3%	35.2%	0%	4.3%	30%	6.7%
Textiles	4.4%	10.3%	3.6%	50.1%	10.8%	5.5%	12%

Table 6. Contingency table.

Design Content	Design Activity												
	Communication Process	Decision Making	Design Process	Organizational Information Sharing	Past Design Discussion	Problem Understanding	Requirement Finding	Solution Analysis	Solution Explanation	Solution Generation	Solution Testing Procedures	Team Coordination	**Totals**
T1-Business	0	0	0	0	0	0	0	19	0	0	0	0	19
T1-Human	0	0	149	0	0	131	125	1446	110	1536	55	0	3552
T1-Services	0	0	16	0	0	0	0	408	222	926	0	0	1572
T1-Smart Textiles	0	37	103	0	0	38	0	120	268	494	40	0	1100
T1-Technology	0	0	0	0	0	0	0	158	91	40	0	0	289
T1-Textiles	0	0	36	0	0	0	0	103	59	108	0	0	306
T2-Business	0	0	0	0	0	0	0	96	0	252	24	0	372
T2-Human	75	9	92	324	313	0	58	545	168	993	655	0	3232
T2-Services	0	72	0	0	30	27	0	238	49	692	0	0	1108
T2-Smart Textiles	91	150	0	0	0	0	145	1179	395	539	0	0	2499
T2-Technology	0	0	111	0	0	0	18	563	90	340	0	0	1122
T2-Textiles	42	164	33	94	79	0	0	635	187	184	0	0	1418
T3-Human	126	0	128	589	62	192	523	1162	380	759	1263	296	5480
T3-Services	0	0	0	0	0	0	121	482	159	462	0	0	1224
T3-Smart Textiles	42	0	166	0	31	156	181	848	903	959	33	0	3319
T3-Technology	11	0	100	0	0	0	0	814	127	430	0	0	1482
T3-Textiles	17	0	62	0	39	0	79	555	335	152	76	22	1337
Totals	404	432	996	1007	554	544	1250	9371	3543	8866	2146	318	29431

Figure 3 visualizes this two-dimensional space. It shows that all items from the Design Content coding scheme are positioned on the negative side of the x-axis (Human only for T1). It also shows that the Design Activity codes *Solution Generation, Solution Analysis and Solution Explanation* are all located on the negative side of the x-axis. The positive side of the x-axis mainly includes Design Activity codes that relate to the implementation of the digital PSS, such as Team Coordination, Requirement Finding, Organizational Information Sharing and Solution Testing Procedures. The only Design Content code that is positioned on the positive side of the x-axis is Human (for prototype T2 and T3). Based on these observations, we can describe Dimension 1 as ranging from activities focusing on the (technical) realization of the design to activities enabling the actual implementation and use of the design in its use context. Moreover, the negative side of the y-axis of Figure 3 (Dimension 2) contains Design Content codes such as *Smart Textiles, Textiles* and *Technology.* It also includes Design Activities codes such as *Decision-Making, Solution Analysis* and *Solution Explanation*. One can say that the Design Content Codes provide boundaries here and thus form a base for converging design activities. The positive side of the y-axis contains items related to a more diverging design process, such as *Solution Generation*. Design Content codes that support diverging are *Human, Business* and *Service*. Based on these inferences, we can describe the y-axis (Dimension 2) as an axis that ranges from a technically driven converging design process to a diverging design process that is driven by human aspects.

Based on the dimensions identified in this scatter plot, we can describe the roles of the prototypes in more detail. The prototype used in T1 (P2) mainly triggered discussions about topics coded as Services and Human, while discussing new solutions (part of *Solution Generation*). This matches with the role of the *service provotype* identified in previous section. This is illustrated by Excerpt 1, a Solution Generation episode taken from conversations held during Me2 with the *elderly care organization*. The excerpt starts just after the introduction of the Touch Sleeve prototype (P2). A Physiotherapist from the *elderly care organization* starts to discuss how the different stakeholders would relate to the concept presented. In the end, the discussion about these relations yielded the first ideas for Blanket (P4).

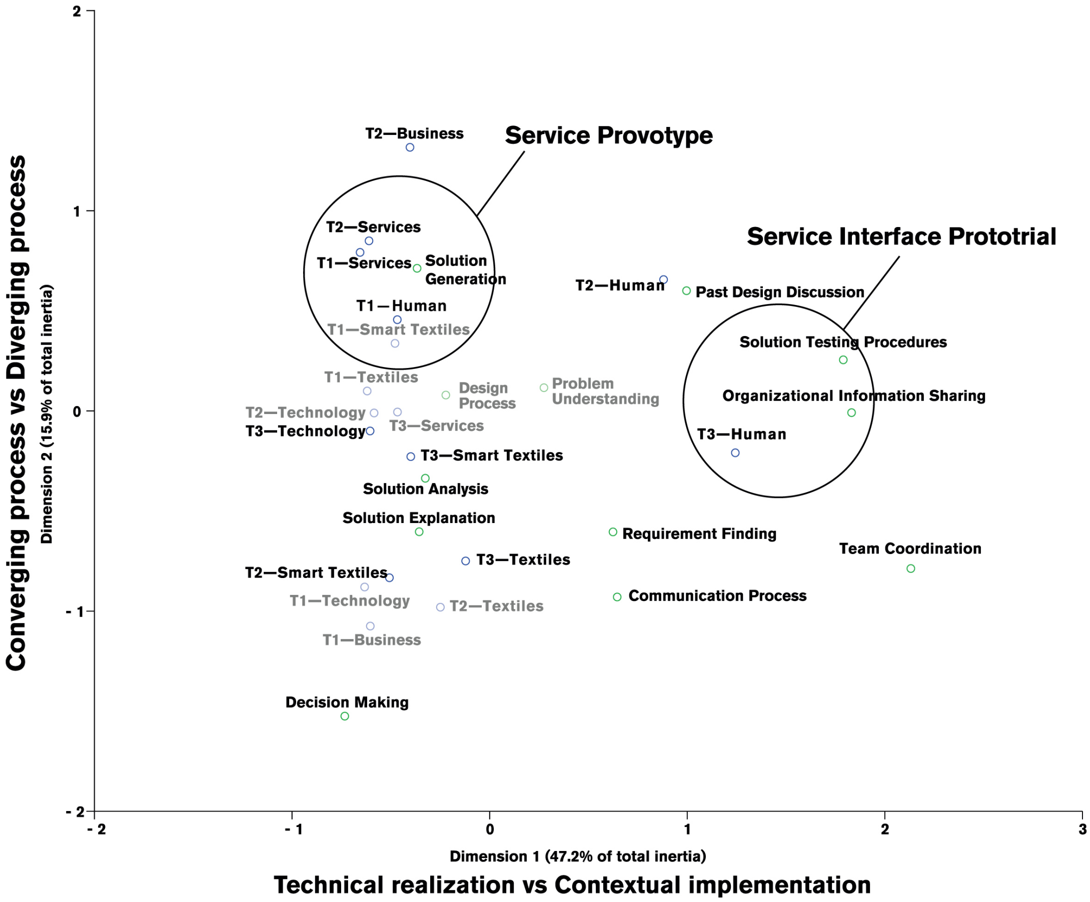


Figure 3. Two-dimensional scatter plot with additional interpretation of the two new types of prototypes identified (T1 and T3).

Excerpt 1 (physiotherapist) in Me2 explains her ideas (translated from Dutch):

> But no, this could be something fun that the motivational therapist could use. Or the family could. Certainly, the family would find it useful in that phase when someone has severe dementia, like I just mentioned, 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 play with. But I can also imagine something with a light—they could do it together, even if it is for a short time, because they cannot keep using it for hours.

The discussions that occurred in phase T3 show an interesting division between the different roles of the prototype. On the *technical realization* side of the x-axis, the stakeholders mainly talked about *Technology, Smart Textiles* and *Textiles* while they were executing *Solution Explanation* and Solution Analysis activities. Excerpt 2, taken from conversations held during meeting Me6, shows how a Fashion Designer evaluated the vibration behaviour of P5 and P6, concluding that it lacked an element that would bring people together.

Excerpt 2 (a fashion designer) in Me6 discusses elements related to technology, such as how the vibration triggers the interaction (translated from Dutch):

> It's vibrating, but it does the same thing when you're alone. It doesn't bring people together yet. Because it does not bring people together, there is no playful element yet.

On the contextual implementation side of de x-axis, the prototype helped trigger discussions focused on the human-related content while focusing on activities such as *Organisational Information Sharing* and *Solution Testing Procedures*. This pattern fits within the definition of the *Service Interface Prototrial*, where it helped the designer and his collaborators to uncover unknown unknowns. Excerpt 3 is a good example, where the elderly care experts realized that the product could be rented out and that various coaching services also needed to be designed, such as the coaching session or the explanation movie.

Excerpt 3 (an elderly care expert) in Me5 talks about how the various services around the Tactile Dialogues pillow could be developed during (translated from Dutch):

> There can be some within the care facility or in the shop with the other supporting products. You could rent or buy the pillow, so that it can become a valuable part of the meeting. And then there can also be a coaching or explanation movie to make it clear for everybody how to use it.

Discussion and Conclusions

This paper has explained how prototyping enables the development of a digital PSS and what (new) types of prototypes support this process. We addressed this topic since there is only limited knowledge on how prototypes support the designer in their design process while at the same time supporting the diverse stakeholder network. The findings presented in the paper extend the current understanding of the role of prototypes in both theory and practice in three ways.

Firstly, our study provided an in-depth analysis of the role of prototypes during the design process of a digital PSS and co-reflection sessions with stakeholders. By showing how and when the different conceptions of prototypes, described in different literatures, co-exist, we desegregated the scattered literature on how the prototypes supported the design and knowledge sharing processes, for example, by showing that a prototype could function as a filter and a boundary object at the same time. This connects the two supportive roles of prototypes: 1) supporting the progress of the design process and 2) supporting design collaborations. Additionally, we found that prototypes used during different phases of the project trigger different modes of collaboration. For example, a prototype that we labelled as proof of concept triggered provocation and initial involvement, while a prototype that we labelled as proof of product was used to test the experience.

Secondly, we detected two new types of prototypes that were both related to the design of the exchange relations of a digital PSS; (1) *service provotype* and (2) *service interface prototrial*. The two new prototypes contribute to the literature on prototyping that originated from product design processes.

Thirdly, the correspondence analysis sheds light on the actual design and knowledge sharing process of the designer and the other stakeholders. It shows that there was co-reflection process going on that mainly focused on Solution Analysis and Solution Generation; only during T3 they also focused on Solution Testing Procedures. Moreover, we found that the designer and the other stakeholders spent 70.1% of their total time on designing and devoted the remaining 21.1% of their time to project management-related activities (see Table 3). The percentage of time that the stakeholders spend designing is high compared to regular design progress meetings. Olson, Olson, Carter and Storrosten (1992), for example, studied the topics in small-group design meetings, which showed that 20% of the design meetings they followed concerned planning and monitoring, 30% progress and 40% designing. This finding suggests that the prototypes triggered co-designing in making the embedded knowledge meaningful and applicable for others. The correspondence analysis also showed two dimensions that explain the nature of the co-reflection process. Dimension 1 explained that the co-reflection activities varied from the (technical) realization of the design to activities enabling the actual implementation and use of the design in its use context. Figure 3 shows that the designer moved from the left side to the right side of the x-axis (Dimension 1) over time. This reflects the general course of a design process.

Dimension 2 shows that the designer and the stakeholders engaged in a co-reflection process that ranged from a technically driven converging design process to a diverging design process driven by human aspects. Figure 3 shows that the designer started with a diverging process related to human aspects to scope the project and to explore with the Elderly Care Organization what services to design. He used a service provotype as a primary generator. In T2, the designer mainly aimed for a conformation of technical qualities in his meetings with the electronics producer, the textile producer and the fashion designer. In his meeting with the Elderly Care Organization, he explained with the prototype how the product part of the digital PSS could look like (experience prototype). This led to the new idea to use the sensors for communication purposes. In T3, the designer produced a high-fidelity prototype that covered the main technical aspects and product appearance. At the same time, it showed the further exploration of possible services interfaces based on the surprising insights in T2 (service interface prototrial).

Table 7 combines these three main insights. It shows the different roles of the four prototypes used during T1, T2 and T3 as well as the findings of the correspondence analysis. Table 7 combines insights in the prototyping process gained through the first-hand reflections of the designer (that provide a rationale of the prototyping process) with the correspondence analysis (that offers insights into the actual design and knowledge sharing processes).

Table 7 also shows that the designer mixed the development of product and service aspects during the process, since the different elements of a digital PSS were not developed at the same time or at the same speed. The production of the actual pillow (tangible elements) developed gradually over time, which is explained by the x-axis of Figure 3. Every prototype became more detailed. Yet the service-related aspects (exchange relations) were developed less gradually. The *service provotype* scoped the initial development of the exchange relations by putting the focus on hand movements. Yet, it took the designer until P5 and P6 to actually further detail the exchange relations. The explanation for this is that in-depth development of the exchange relation requires user involvement (as both supplier and user co-produce the service). This means that the prototype should be on the level at which co-production could be simulated. As the designer explained, this was only possible from P5 onwards, which explains why the prototype in T3 is positioned on the middle part of the y-axis in Figure 3; the product-related aspects converged, while the service-related aspect continued to diverge.

Limitations and Future Research

In this project a RtD has been used as a driving mechanism. A strength of this approach is that design considerations could be followed and discussed in great detail, as the designer was also part of the research team. This approach has certain limitations as it creates a bias on the data that is considered. To be able to counter this effect, we used verbal analysis as a methodology to gather a more objective representation of the events during the development process. Table 7 also shows the result of this mixed method approach. It shows that the first-person perspective on the different roles of the prototypes is in line with the actual design and knowledge sharing processes.

Another limitation of our approach is that we only analysed one case in depth in this paper. Ten Bhömer (2016) showed that a comparable analysis of a second case within

Table 7. Combination of roles of the prototypes over time.

T	Classification prototype design process	Actual design process (correspondence analysis)	Classification prototype knowledge sharing process	Actual knowledge sharing process (correspondence analysis)
T1	Broad filter (Lim et al., 2008) Proof of concept (Ullman, 2002)	Diverging process Technical realization	Boundary object coincident boundaries (Star & Griesemer, 1989) Provoking prototypes (Mogensen, 1992) Service provotype (NEW)	Sharing own disciplinary knowledge and refer to other disciplines Collaborative solution analysis (Technology and Business) Collaborative solution generation (Service, Human and Smart textiles)
T2	Prototrial (Jensen et al., 2017) Proof of product (Ullman, 2002)		Experience Prototype (Buchenau & Suri, 2000)	Sharing own disciplinary knowledge and refer to other disciplines Collaborative solution analysis (Textiles and Smart Textiles) Collaborative solution generation (Service, Business)
T3	Service Interface Prototrial (NEW) Proof of process (Ullman, 2002)	Converging process Contextual Implementation	Conscription Device (Henderson, 1991) Boundary object ideal type (Star & Griesemer, 1989)	Sharing own disciplinary knowledge and refer to other disciplines Collaborative solution analysis (Human, Smart Textiles, Technology) Collaborative solution generation (Human, Smart Textiles) Testing procedures (Human)

the same context yielded similar results. Moreover, another designer within the STS project used a similar approach. She also managed to build a rich and diverse stakeholder network with the use of prototyping (see Kuusk, 2016). The concepts that Kuusk created were also successful and led to a commercially available product. Despite this additional evidence, we cannot claim that our findings will be representative for all design projects in which a network of diverse stakeholders have to create a digital PSS. However, we think that the existing case could support designers in the development of digital PSS, since it is the first study that explains in detail why and how the product-related aspects and the service-related aspects develop during the design and collaboration process. It also explains in detail what types of prototypes could serve which part of the design and collaboration process.

A subject for future research is to see how the digital PSS can be developed in such a way that there is an optimal alignment between its tangible and intangible elements (e.g., why is it optimal to design the product part first?) and how different forms of prototyping can play a role in creating this alignment. This requires an experimental setting. The current study can be inspirational while developing hypotheses for an optimal alignment.

In this paper, we have emphasized the role of prototyping during design collaborations within a network of stakeholders from different disciplines. We hope that our findings inspire other designers and design managers of diverse stakeholder networks to make use of prototyping during co-reflection sessions with stakeholders. These findings may support designers with empirical evidence that prototyping is a powerful means to progress a design and at the same time enhances collaboration.

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Endnote

1. Boer and Donovan (2012) refer to provotypes to support the design of products and services. However, their work only refers to product design and tangible embodiments. This paper shows how provotypes support the reconsideration of the service interfaces that exceeds the actual tangible embodiment. This has led to the introduction of *service provotypes.*

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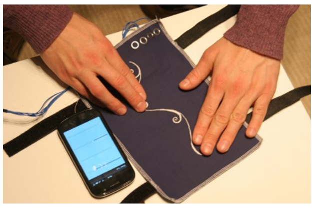
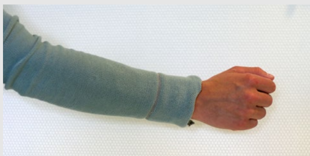
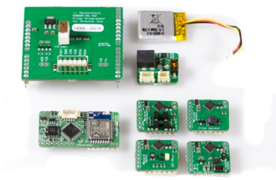
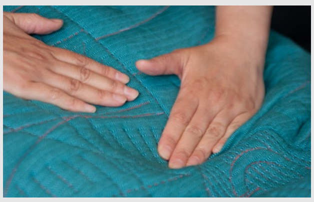
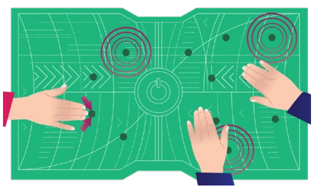
Appendix. Eight Different Prototypes That Led to Tactile Dialogues

Name	Description	Goal
Music Fabric (P1) 	Music Fabric is a piece of fabric with pressure sensors that control a mobile phone application playing music samples. Putting pressure on the different areas of the fabric increases the volume of certain instruments. For example, touching the top part lets the rhythm increase in volume.	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 the people who were skilled in textile engineering to become acquainted with textile techniques such as laminating and building pressure-sensitive surfaces.
Touch Sleeve (P2) 	Knitted textile with lines of conductive yarn in the shape of a sleeve; when the sleeve is worn around the arm, the prototype reacts to touches on the arm through changes in a visualization that is displayed on a screen.	Touch Sleeve was the first experiment in developing a new fabric completely from scratch based on custom specification. The goal of the prototype was to show an approach to rehabilitation where physical touch was an important element and which could be used to stimulate patients during group activities.
CRISP Modules (P3) 	Set of modular electronics with its 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.	The modules were initially developed to be able to create a specific functionality on the location of the body where it was needed, such as a touch sensor combined with a vibration motor on the shoulder. Furthermore, the goal was to bring sensing and actuation closer together by combining the two in one module.
Blanket (P4) 	Textile object that reacts to touch with different stimuli, such as light, sound, and vibration. Integrates six capacitive touch sensors, six vibration motors, two LEDs and one speaker. When one side of Blanket is touched, Blanket reacts with vibration both on the side where it was touched and on the other side where the other person has their hands. When touching for a duration of three seconds, the intensity of the vibration increases, the lights start blinking and the speaker makes a small sound.	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. This element translates 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 is to enable family members to trigger light, sound, or vibration, and thereby get a new type of activity to engage in with the person suffering from dementia.
Tactile Dialogues v1 (P5) 	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.	The development of Tactile Dialogues v1 was mainly triggered by curiosity about how to scale up the production of the fabric. 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.
Tactile Dialogues v2 (P6) 	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 triggers plucking movements, and ridges in the fabric 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 can be squeezed, and an arrow-shaped casing that points in a certain direction.	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.
Tactile Dialogues v2 Behaviour (P7) 	The interactive possibilities of Tactile Dialogues allow personalized design 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 mirroring; touch on one end of the pillow is mirrored with vibrations on the other end. We could adapt the program to design different behaviours for each person.	The aim of this prototype was to find out whether personalization of the vibrotactile stimuli is appreciated over a mirroring vibrotactile behaviour.