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Challenges in the Design of Smart Product-Service Systems (PSSs): Experiences from Practitioners

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Smart Product-Service Systems (Smart PSSs) are market offerings that integrate products and services into one single solution through the implementation of IC technology. Smart PSSs allow organizations to develop relationships with consumers in new ways and have a growing presence in the marketplace. As designers' involvement in the design of these offerings is likely to increase, the understanding of the challenges emerging from the integration of product and service is of increasing relevance for the effective management of the design process.

To identify the challenges in the design of Smart PSSs, interviews with ten practitioners from various companies with experience in the design of Smart PSSs were conducted. Based on the findings, we outline seven challenges: defining the value proposition, maintaining the value proposition over time, creating high-quality interactions, creating coherence in the Smart PSS, stakeholder management, the clear communication of goals, and the selection of means and tools in the design process. Furthermore, we outline five ways in which designers can contribute to the design process through the use of their capacities: designers as foreseers of future scenarios, as guardians of experiences, as integrators of stakeholders' needs, as problem solvers, and as visualizers of goals.

***Keywords**: Smart, Product-Service System, challenge, design, process.*

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Introduction

A practice with growing attention from the design community is the design of Product-Service Systems (PSSs). PSSs integrate products and services to offer an overall value proposition to consumers (Baines, et al., 2007). While the majority of products contain service elements (e.g., after-sale services, warranties) and vice-versa, in PSSs both the product and the service play a central role for the *value-creation-in-use* for the consumer (Baines et al., 2007; Tan, Matzen, McAloone, & Evans, 2010). For example, when visiting launderettes, an example of a traditional PSS found in the literature (e.g., Mont & Plepys, 2007), consumers' opinions of the launderette may be influenced by the way the washing machines work, but also by aspects of the service, such as employee friendliness and the quality of the end-result (Bitner, 1992). PSSs have gained considerable attention among the sustainable production and sustainable design communities, who acknowledged its potential to reduce the environmental footprint of products; for example, by reducing the relevance placed on product ownership, thereby maximizing the lifespan of products. However, literature in this area often centres on business-to-business cases, and describes business models/frameworks that can influence the implementation of these types of offering (e.g., Baines, et al., 2007; Tan et al., 2010; Tukker, 2004). Although these insights are pivotal for the implementation of PSSs, they provide limited insight for designers on the distinctive aspects of the design process and its management. This paper addresses this need by reporting the challenges faced by experienced designers in the design of PSSs. In particular, our efforts are focused on a specific type of PSSs, which we call *Smart PSSs*.

Smart PSSs integrate smart products and e-services into one single solution through the implementation of information and communication technology (ICT)(Valencia, Mugge, Schoormans, Schifferstein, 2014). The ICT in the smart product is central to the concept of Smart PSSs because it guides the development of e-services and innovative interactions for the consumer. For instance, Laundry View (http://www.laundryview.com) can be considered the smart version of the traditional launderette explained above. Laundry View connects the washing machines to the Internet, allowing consumers to check and be notified about the availability of the machines in the laundry room (remotely). Hence, the ICT in the machines

facilitates the generation of relevant information, which can help consumers make more informed decisions about their laundry activities (Valencia et al., 2014). Moreover, through the e-service, consumers can report incidents or give comments/suggestions, facilitating the communication between service provider and individual consumers. Thus, the integration of smart product and e-service opens up an array of opportunities for designers, who can implement new touchpoints and interactions, enabling organizations to develop relationships with consumers in new ways.

Smart PSSs are a type of offering with growing relevance in the design field. Due to advances in technologies (e.g., ICT, connectivity of objects), and consumers' advancing attitudes towards online transactions, the number of Smart PSSs in the market place has increased over the years. Companies, such as Philips, Oral B and Nike have all attached e-services to their connected products. And as the knowledge economy continues to unfold, we expect more companies seeking to provide individual experiences to consumers (e.g., information, feedback; Johannessen & Olsen, 2010; Valencia et al., 2014) to make the move towards Smart PSSs.

As designers' involvement in the design of Smart PSSs is likely to increase, so is the need to enlarge the knowledge related to the process of designing Smart PSSs. The creation of Smart PSSs may pose new challenges for designers. Designers are accustomed to creating products and services separately. However, the product and service in a (Smart) PSS are so deeply intertwined that a distinction between the two may no longer be possible. Despite this apparent complexity, there is limited existing knowledge that can help designers anticipate the possible challenges emerging from the creation of Smart PSSs (e.g., Isaksson, Larsson, & Rönnbäck, 2009). This information can help designers to fine-tune their best practices to the integrative design of product and service, and to manage the design process of Smart PSSs more effectively.

The design of (Smart) PSSs

The design of PSSs is defined as the process of integrating business models, products and services to create innovative solutions with added value for customers (Vasantha, Roy, Lelah, & Brissaud, 2012). Generally speaking, PSSs are developed when manufacturing companies add service components to their offerings (i.e., servitization), service companies add products to their service offerings (productization) (Baines et al., 2007, Tischner & Vezzoli, 2009), or when a new company forms its market proposition based on both. Thus, the design of a PSS often requires that a

specialized company moves to new domains where it has little or no experience (Morelli, 2002), and entails considerable organizational and intellectual efforts from those that are involved in its development (Tischner & Vezzoli, 2009; Isaksson, et al., 2009).

Organizational efforts may derive from larger transdisciplinary design teams (Issaksson et al. 2009), where the involvement of stakeholders (i.e., co-creation with suppliers, public organizations, users, etc.) is key to reaching innovation and added value (De Bont & Smulders, 2013). However, different stakeholders may differ in their views and interests towards the PSS (Dougherty, 1992), which can lead to efforts in managing their interactions. Furthermore, companies making the shift from manufacturing to service provision (and vice versa) may require a shift in organizational culture, and to rethink their ways of working and communicating (Mont, 2002; Issaksson et al. 2009; Martinez, Bastl, Kingston, & Evans, 2010).

Intellectual efforts may derive from having to consider multiple touchpoints (or service interfaces; Sangiorgi, 2009) in order support the relation-based value creation characteristic of PSSs (Martinez et al., 2010). Thus, while designing PSSs, designers need to think holistically at a system level, but should also be able to shift easily to details, for example, when discussing the specifics of product or service elements (Vasantha et al., 2011). Thinking at a system level (i.e., covering all touchpoints, product and service elements) is important because it can influence the creation of coherent experiences for customers (Sangiorgi, 2009).

Finally, on a more general level, the appropriate specification of the development context (e.g., business-to-business vs. business-to-consumer) can play an important role in PSS development. Different contexts may lead to the definition of different value propositions (Morelli, 2002), and consequently, to the identification of different capacities (i.e., stakeholders) (Vasantha et al., 2011) and methodologies (Mont & Tukker, 2006) needed in the design of the PSS. These traits may lead to efforts to achieving a thorough understanding of the context, but also to reaching a shared view among stakeholders of the value to be delivered through the PSS.

When not managed appropriately, the above instances can become challenges in the design of PSSs. The design of Smart PSSs may evoke similar challenges, as we suspect they are transferrable across development contexts. However, little is known about the design of Smart PSSs. The characteristics of Smart PSSs (Valencia et al., 2014) may bring about distinctive challenges, which may influence the effectiveness of the design process. With this study we set out to identify the challenges that

experienced designers face in the design of Smart PSSs. Our insights aim at broadening the existing literature by (1) studying the challenges in the design of PSSs with a particular set of characteristics (i.e., Smart PSSs), and (2) by exploring the design of (Smart) PSSs developed for the consumer market. Furthermore, we aim at supporting the activities of design managers by identifying the specific capacities of designers that can contribute to an effective design process.

Method

To explore the design process of Smart PSSs, we interviewed ten professionals from six different companies (see Table 1). Participants fulfilled a set of criteria. First, we included companies with different characteristics to have a broad perspective on the employed design processes. Thus, large and small companies were contacted, as well as design consultants and in-house designers. Second, we selected professionals with experience in the design of Smart PSSs who could reflect on challenges they encountered while designing Smart PSSs. Participants included designers (e.g., product designers, service designers) and other professionals involved in the creation of Smart PSSs (e.g., problem owners). This varied group of participants, with ample experience in design, helped to bring the various perspectives that are characteristic for the design of PSSs. Furthermore, it permitted us to make use of multiple Smart PSSs cases related to business-to-consumer solutions.

Procedure

Semi-structured in-depth interviews were conducted with all participants. Designers were asked to choose a specific Smart PSS case that they had worked on to be discussed during the interview. Nevertheless, they were free to make use of other cases to reflect on the issues being discussed. An interview guide was developed to guide the interview while leaving room to address other, interesting topics. The interview guide was divided into four sections: First, a short introduction about the purpose and content of the interview was given to participants. Second, participants were asked to describe the Smart PSS they had chosen. The goal was to assure the common understanding of the Smart PSS being discussed, and to verify it could be categorized as a Smart PSS. All Smart PSSs discussed complied with our definition of Smart PSS. The third section was directed to understanding how the design of the Smart PSS was organized (e.g., in

terms of stakeholders) and which challenges were faced during the design process. This provided contextual information that facilitated the interpretation of the data during the analysis phase. The final section was directed to discussing the tools that were used during the design of Smart PSSs.

Table 1. Overview of participants. Note: Due to a request for confidentiality, the names of the companies are not disclosed.

Interviewee	**Role**	**Type of Company**
#1	Designer (facilitator)	Design consultancy 1
#2	Problem owner	Tools and technology for the taxi market
#3	Designer (manager/facilitator)	Tools and technology for the taxi market
#4	Designer (product)	Design consultancy 2
#5	Designer (product)	Design consultancy 2
#6	Problem owner	Tools and technology for the event industry
#7	Designer (service)	Tools and technology for the event industry
#8	Designer (service)	Design consultancy 3
#9	Designer (manager/facilitator)	Manufacturer of consumer products
#10	Designer (service)	Manufacturer of consumer products

Participants were visited at their place of work. The goal was to facilitate the use of readily available material related to the design of the Smart PSS, such as images or diagrams, whenever possible. This was a useful approach because many participants not only made use of past material, but they also made use of diagrams or information displayed in their offices to reflect on the issues that were discussed.

Interviews lasted between 50 and 80 minutes. Participants were open when talking about their experiences in designing Smart PSSs. Only one participant, who was an outsourced designer and bounded by a confidentiality agreement of his employer, had some restrictions to speak openly about his design expertise. Although he refrained from disclosing

sensitive information, he was still able to give his opinions in general terms. As a result, his input proved to be insightful and is included in this study.

Analysis

All interviews were recorded and fully transcribed. Interviews were analysed making use of the software Atlas.ti. The coding process was as follows. First, a set of five interviews was fully coded by the main researcher, generating an initial set of 135 codes. This initial set of codes was then discussed with the other researchers, taking into account quotes of different participants to assure the correct interpretation of the data. In this step, codes were refined and merged. Furthermore, an initial set of 5 themes describing the data was identified (e.g., challenges, stakeholders, tools), giving a first structure to the data.

Following, the remaining five interviews were coded, adding new codes to the list when applicable. Twenty-five new codes were added to the list, all belonging to any of the already identified themes. In a second session, all researchers reviewed the overall themes and codes again, trying to find subgroups within the themes, and connections between the different themes.

Results and Discussion

The findings from our interviews are presented in three sections. The first section reports the distinctive elements in the design of Smart PSSs, where we highlight general differences/similarities with traditional PSS design. Second, we outline the challenges participants faced during the design of the Smart PSS. Finally, we elaborate on how designers help to tackle the outlined challenges through the use of their capacities.

Distinctive elements in the design of Smart PSSs

Some of the companies interviewed were traditionally manufacturing companies, while others were established since their beginning as a developer of Smart PSSs. Despite these differences, we found important similarities in their perceptions towards the process of designing Smart PSSs, which helped us come to generalizable findings across participants.

In general, the design of Smart PSSs was considered a new area of expertise that is yet to be developed. Participants generally worked on a trial and error basis, where the use of traditional product and service design tools (e.g., prototypes, illustrations, scenarios), was predominant. However,

participants indicated how these existing tools are being adapted and improved for the integrative design of products and services.

Organization-wise, the design of Smart PSSs was perceived as requiring the involvement of a large number of stakeholders in the design process, such as designers, manufacturing firms, problem owners, and consumers, who had a more or less prominent role depending on the stage of the design process. This view is consistent with traditional PSS design (e.g., Isaksson et al. 2009), where the identification of primary and secondary stakeholders is perceived as important to manage the design activity ("MePSS, Worksheet W03", n.d.).

Design-wise, Smart PSSs were considered to be complex market offerings. As in traditional PSSs, the integration of products and services implies the creation of multiple touchpoints (Martinez et al., 2010), which all need to be holistically considered in the design of Smart PSSs. However, the technology embedded in the Smart PSS, in combination with e-services, broadens the options designers have for implementing the interaction between the Smart PSS and the end-user, making decisions about the experience of the end-user more critical.

Furthermore, the design of Smart PSSs was seen as highly context dependent. Different than the reported literature (e.g., Tischner & Vezzoli, 2009; Vasantha et al., 2012), participant did not emphasize the relevance of context for stakeholders/actors identification. Rather, participants highlighted the importance of context (i.e., market, type of user, end goal, etc.) in defining a correct value proposition for the consumer. Participants considered the characteristics of each individual Smart PSS (Valencia et al., 2014) to be unique, not generalizable, dependent of the context for which the Smart PSS is developed, and the aimed experience for the end-user.

Moreover, participants declared that Smart PSSs are in constant evolution, typically through the e-service (Valencia et al., 2014). This is in accordance with Isaksson et al. (2009), who suggest developers of PSSs need to be prepared for 'life-long development issues' rather than regarding the development process as completed after product launch (p. 344).

To conclude, there are noted similarities between Smart PSSs design and traditional PSS design. However, there are important differences too, which are derived from the particular characteristics of Smart PSSs (e.g., ICT; Valencia et al., 2014). In the following section we outline the challenges related to the design of Smart PSSs, both in relation to the characteristics of Smart PSSs, and the distinctive elements of the design process discussed above.

Challenges in the design of Smart PSSs

Defining the value proposition

One of the most significant challenges mentioned by participants is the clear definition of the value proposition for consumers. Because companies providing Smart PSSs seek to create long-lasting interactions with end-users, a well-defined value proposition can be key in building relations that last.

Well-defined value propositions are a challenge for two reasons. First, technologies in Smart PSSs facilitate the generation of data related to end-users (e.g., measurements, content; Valencia et al., 2014). Furthermore, e-services facilitate the direct communication between companies and end-users, allowing companies to talk in a more direct and frequent manner to their clients (Rust & Kannan, 2003). Consequently, through Smart PSSs, consumers may be confronted with loads of data and information, much of which may be irrelevant to them. The challenge lies in determining the value users can derive from such data, and designing the service in a way that it can effectively support the transition from data to meaningful information. Consequently, designing Smart PSSs with perdurable value for consumers may be largely influenced by the thorough understanding of the use context, such as the end-user, his/her goals towards the system and expectations.

> *Any artefact doesn't empower anyone. The empowerment comes through how someone interprets that. What their goals are related to the data. #10*

Second, the nature and heritage of the company may influence the clear definition of the value proposition. Some companies have a heritage in the manufacturing of products, and may explore the possibilities offered by Smart PSSs starting from technological opportunities (i.e., servitizing; Tan et al., 2010). Such technology push may cloud the definition of a well-rounded value proposal, one that is coherent with the needs and goals of the context for which it is developed.

> *In the case of some of the projects, I am not entirely convinced of certain directions, because I don't… I don't see an issue being solved. #9*

Maintaining the value proposition relevant over time

Smart PSSs are characterized for being ever-evolving and in constant growth (Valencia et al., 2014). The design of Smart PSSs is characterized by the continuous 'introduction' of new content or functionalities via the e-service. For example, a Smart PSS that sells games may periodically create new possibilities in specific games to keep users motivated and excited. This characteristic of Smart PSSs poses opportunities and challenges for the design process. The opportunity lies in the low risk associated with maintaining the value proposition relevant through the service. As companies involved in this study were traditionally manufacturing and start-ups, they perceived service design as demanding much shorter lead times than product design. Furthermore, this approach was seen as a means to test the Smart PSS with consumers, making it possible to react to changes in the market (e.g., new needs) rapidly.

We release product updates as often as possible and we try to have about a six-week product cycle or six week release cycle […]. We build it and we test it and make it available […] every six weeks we can say this is good but let us work on something completely different. #7

However, the challenge relates to having a clear vision, from the outset, for where the market is heading in the longer term. Having this vision can help anticipate required characteristics of the smart product (e.g., sensors), which may be needed to enable certain functionalities or features in the service.

You just have to kind of create enough degree of freedom [in the product] to be able to get what you want in the [service]... And here of course we have no degree of freedom... There is no freedom for the software to really change, or to do anything with the data. #4

Creating high-quality interactions

A challenge often mentioned by participant was that of creating meaningful, high-quality interactions, between the end-user and the Smart PSS. Creating high-quality interactions, as defined by participants, refers to the importance of understanding the human dimension in the Smart PSS; to being empathic about the emotions evoked through the Smart PSS and the overall experience that is created for the end-user. As previously discussed, Smart PSSs aim to create long-lasting relations with consumers. These interactions are of a recurrent nature, and may evolve together with the

system (Valencia et al., 2014). Thus, designers face a challenge in translating end-user needs and wishes into meaningful interactions that create value, and to maintain these relevant as the system and its user evolve. This can be achieved, for example, by implementing technology in such a manner that it results in a simple and intuitive process and by making use of an appropriate tone and language in the communication towards end-users.

> *It was challenging, but the reason we have won the market and killed our competitors is that they didn't understand the fundamental emotional aspect […] we really understand the emotional aspect of what makes it a success. #6*

An important side effect of creating high-quality interactions is the positive effect it can have on trust. The concept of trust and its relevance in online transactions have been studied before (see e.g. Harris and Goode, 2010). In the case of Smart PSSs, trust can be related to the technology being used (i.e., a new product's functioning), but also to the data that is being handled through the Smart PSS. As some Smart PSSs may generate data that is considered sensitive, interactions with the system should reassure consumers of the proper handling of data by the provider. Furthermore, trust may be influenced by the correct interpretation of the needs of consumers, and a challenge may surface in designing interactions that match the expectations of end-users. As exemplified by one participant:

> *A lot of parents also said to us, don't take over my intuition, I am the parent. So there is a delicate, delicate balance there, you know. I don't want, [a] machine or iPhone to tell me [what] I am, or what I should do as a parent. Just give me hints. #9*

Creating coherence in the Smart PSS

Achieving coherence was acknowledged as an important challenge in the design of Smart PSSs. Coherence is particularly important because of the multiple touchpoints that are part of the system (Martinez et al., 2010), which can influence consumers' experience with it (Sangiorgi, 2009; Shostack, 1982). Coherence was defined as relating to two aspects.

First, visual coherence was defined as the cohesiveness between the visual representations around the system, such as colours, shapes, images or written language (e.g., Van Rompay, De Vries, & Van Venrooij, 2010; Valencia, et al., 2011). Consequently, visual coherence can help consumers to associate different touchpoints with the Smart PSS.

Second, coherence was perceived to be related to how the system behaves across different touchpoints (e.g., gestures in the system), and how end-users interact with it. Despite the changing character of the Smart PSS, the interaction of the system should remain consistent across touchpoints, minimizing the time invested by consumers learning how to interact with it.

> *The reason why [coherence] makes sense is to, on the one hand you create one experience for the user, but it is also [that] you help the user to use it more easily, you know. Like he doesn't have to relearn how to use the service. #3*

Stakeholder management

Because the design of Smart PSSs is typically transdisciplinary, multiple stakeholders are involved, who may have different perspectives on what the system should deliver, have different problem-solving approaches, or communicate differently (Dougherty, 1992; Martinez et al., 2010). For example, while an entrepreneur may have more daring attitudes towards product development and rely on fast product launches, investors and development partners may follow more cautious approaches, and aspire longer development cycles. This is particularly important for (Smart) PSSs because of the larger number of stakeholders with an interest in or influence on the system (Issaksson et al., 2009). Consequently, integrating the demands of stakeholders, getting to agreements on the approaches to be followed during the development process, and getting commitment from all parties involved, may be particularly challenging in the design of Smart PSSs.

> *It opens up a whole new world, a whole new box of stakeholders that need to be involved... And a lot of these stakeholders especially these product developers… are not used to being exposed to the methodologies that we use in for example digital methods. So we have technological people, business people, engineers, who aren't necessarily aware of the way we designers do things. #10*

Furthermore, due to the different degrees of involvement throughout the development process, the clear communication of the tasks/involvement among stakeholders may be particularly challenging:

> *What we learned in this process is that [the problem owner] would continue with another design company to get the app on the market.*

We learned that it was a company called [company name], nobody knew about them. We never had contact with them at all. #8

Finally, it is relevant to note that differences between stakeholders regarding the Smart PSS were defined to be desirable at times, as they were suggested to lead to better solutions. Thus, the challenge lies in managing the discussions around the Smart PSS, and clashes between stakeholders, so they do not exceed the limits of what is considered desirable.

We went through many iterations that were not quite right. And the people that helped create [the] iteration felt like it was right. I was the one that was pushing back. So [by] picking and having different people involved in different stages, but all during the design process [helped us] came up with this [solution]. #6

Clear communication of design goals

The communication of design goals among stakeholders is challenging for two reasons. First, the multiple elements making part of the system (i.e., products, e-services, other touchpoints) may complicate the visualization of the Smart PSS and the depiction of connections and relations between its elements. For example, some Smart PSSs have different use contexts, with different products and services in each of them. Thus, the information depicted through the service may vary considerable among contexts, complicating the visualization of the system as a whole. Because visual representations aid in the discussions around design goals (Valencia, Person, & Snelders, 2013), this challenge may hinder the effective communication among stakeholders in the design process. Second, while designing Smart PSSs, designers undergo cognitive shifts, jumping from abstract (i.e., system level) to specific (e.g., product level), while discussing the Smart PSS. However, these cognitive shifts may be more difficult to attain by some members of the design team than others. Discussions around the Smart PSS can be overwhelming, and affect the shared understanding of design goals.

Even in my mind, I had to cut out a whole part of it and cut it out even to the team; just have the team focus on one little piece. The product was being developed in the wrong direction. I had to say, forget all that and focus only on this […] you have to start very simple. #6

Selection of means and tools in the design process

The design of Smart PSSs is considered to be a new domain, where designers are learning by doing. All of our participants were experienced designers, however, none of them was particularly trained in the design of Smart PSSs. This 'newness' poses challenges for designers when selecting tools and methods to support the design process. Participants expressed uncertainty about the effectiveness of some tools, and a required change in mind-set when combining products and services.

> *Not many people have experience with this. And specially getting kind of all these disciplines together, figuring it all out, trying to do the best for [the company], but nobody has really experience, that's a challenge in itself. #9*

The role of designers in the design of Smart PSSs

Our interviews revealed five ways in which designers can positively contribute to the design of Smart PSSs, which are consistent with previously discussed roles of designers in the existing literature:

Designers as foreseers of future scenarios

Designers can contribute to maintaining the value proposition relevant for consumers in the long run. To counter the challenge that Smart PSSs are continuous and fast changing, designers bring tools to the design process to help the team to keep an eye on the future. Scenario thinking was particularly acknowledged as an important tool in the design process because it helps foresee (changing) end-users preferences and technologies (Sanders & Stappers, 2008), or the roadmap needed (and actors involved) to reach a particular result (Morelli, 2009).

> *And then define in let's say the future, or the co-creation process that we will continue, if there is a co-creation process with the consumers, or the community or the local people, to actually determine what kind of games, or what things they found nicer to do in the interaction. #1*

Designers as guardians of experiences

Designers may face challenges in achieving coherence in the design of Smart PSS. Incoherence can lead to poor experiences for the end-user, and result in dissatisfaction with the Smart PSS. To counter this challenge, designers were acknowledged to play an important role in defining and guarding the experience around the Smart PSS (Valencia et al., 2013).

Designers have been trained to think in a user-centred manner, have been equipped with tools to understand the context of the end-user, and his/her needs towards the system. To this end, designers perform a series of activities traditional of their practices. For example, by prototyping the product and service, designers can evaluate and discuss the concept first hand with the end-user and other stakeholders (Blomkvist & Holmlid, 2010), and have a better understanding of its usability and perceived value. Furthermore, by using visualization tools, such as customer journeys, designers can achieve a clearer perspective of the current and desired user experience, and translate research insights into clear design specifications for the Smart PSS (Segelström & Holmlid, 2009).

> *Once we designed it only in kind of squares and points, we sit down with designers and talked about the feeling it should have and trust. They would start designing it around it, and those are really important. #2*

Designers as integrators of stakeholders' needs

To manage the different views and expectations of stakeholders, designers were perceived to have the capacity to listen to stakeholders and integrate their demands (Valencia et al., 2013). Moreover, participants highlighted the importance of the project champion, someone with an overall view of the system and a clear understanding of what the project should deliver. This project champion was associated with the problem owner (i.e., a design thinker), but also with designers themselves. Having an overall vision of the project eases the integration of demands, and contributes to the effective communication among stakeholders.

> *And what we notice often, that direct communication doesn't work. People who design the electronics think in a different way than the consumer does. So, basically we were some kind of translator between different worlds and different stakeholders, and keeping constantly all stakes. #5*

Furthermore, designers contributed to generating interesting discussions that lead to important solutions or decisions around the Smart PSS. Specifically, designers' role in asking questions during developing meetings, bringing forward solutions and listening to stakeholders' opinions was perceived to have a positive impact on the final solution. This contribution closely relates to the role of designers as 'facilitators' discussed by Sanders

and Stappers (2008), and the role of designers in helping organizations define the reason, focus and value of implementing innovation in the firm discussed by De Lille, Roscam Abbing and Kleinsmann (2012).

Designers as problem solvers

Reaching a clear communication of design goals during the design of Smart PSSs was outlined as an important challenge. In relation to this challenge, the problem solving capacities of designers were perceived to have a positive effect on the communication among different stakeholders. For example, designers are able to cope with abstract information, which makes them particularly suited for the design of complex systems (Sanders & Stappers, 2008).

> *If you're working with a lot of parties, you are working from abstract to concrete. So if you want to have something in a certain amount of time, you have to start freezing things on an abstract level, otherwise you never reach the kind of concrete level that you can actually produce something. #4*

Designers as visualizers of goals

Finally, the visualization skills of designers contributed to visualize project goals and communicate them to other stakeholders (e.g., Krucken & Meroni, 2006; De Lille et al., 2012; Valencia et al., 2013). Design tools typically used both in product and service design, such as storyboards, drawings, and prototypes, helped to attain a better visualization of the system. Furthermore, these visualizations contributed to a shared understanding of the project objectives among team members, for example, when used to discuss project goals during project meetings (Blomkvist & Holmlid, 2010).

> *If you have a product described on paper, people won't really understand it. With visuals they can create a storyboard and it can be just going from page to page, and then describing the story to the people, and they will understand, and [this] makes it come alive. #7*

Conclusion

In this study, we set out to research the challenges designers are likely to face in the design of Smart PSSs. In doing so, we contribute to the existing PSSs literature by deepening the knowledge related to the process of integrating products and services. Our focus was on the design of Smart

PSSs because we consider it to be an activity with increasing relevance for designers. Our study allowed us to attain a deeper understanding of the distinctive elements surrounding the design Smart PSSs, and to identify seven challenges and five contributions of designers that can help lessen the drawbacks likely to be encountered in this particular design context. The challenges and roles outlined in this paper relate to the design process (e.g., stakeholder management), but also to aspects with significant influence on the definition of the final solution (e.g., visualization of design goals). Consequently, our findings can help design managers to anticipate on design challenges, and to take action towards more effective design processes, leading to a more meaningful outcomes for companies and consumers (end-users).

We found undeniable similarities between Smart PSS design, traditional PSS design, and service design. In particular, the involvement of a large set of stakeholders seems to be a concurrent aspect between the three product development contexts. However, there were also important differences between them that evoke particular challenges in the design process of Smart PSSs. For example, the numerous options that Smart PSSs offer in terms of creating content and interactions for end-users can be an overwhelming factor for designers, with a negative effect on the value proposition brought to consumers. Furthermore, the continuous nature of Smart PSSs makes it particularly important to oversee aspects of the tangible product (e.g., technology) that could influence the implementation of important service interactions in the future.

Many of the discussed roles/contributions of designers are consistent with the broadening role of designers discussed in the existing literature (e.g., Sanders and Stappers, 2008). Particularly, the capacity of designers to solve problems, and consequently, to simplify complex information, can have a positive effect on how design goals are understood by stakeholders. In this regard, the capacity of designers to visualize project goals seems to be an important channel for effective communication during Smart PSS development. The user-centred mind-set of designers, and their toolset (e.g., prototyping, scenario thinking, customer journey maps, context mapping), can contribute to the creation of Smart PSSs whose value propositions matches the expectations of end-users. Furthermore, many of the identified challenges seem to emerge from the service design arena. Thus, there is much to be learned from service designers, and their involvement in the design process of Smart PSSs could be key.

Existing product and service design tools are predominantly being used in the design of Smart PSSs. Designers are adapting these tools to the design of Smart PSSs, and their use appears to be effective. Interestingly, we did not find evidence about the use of design tools generally associated with the design of PSSs. For example, system mapping ("MePSS, Worksheet W21", n.d.) could be an important tool to manage stakeholders and other important actors in the design of Smart PSSs. Moreover, the design of Smart PSSs may require the use of specific tools in the design of this type of offerings. Specifically, the challenges of defining the value proposition, having a shared understanding of such proposition among stakeholders, and keeping it in mind as the Smart PSS evolves, seem to be not sufficiently addressed by the tools being used. Thus, future research needs to explore these challenges further, and the extent to which current/new design tools contribute to lessen them.

Other limitations and opportunities for future research come out of this study. First, our findings are based on the experiences of design consultants, traditionally manufacturing companies, and providers or Smart PSSs. Our study did not include traditionally service companies moving into the manufacture of products, which could bring about different challenges. Second, our findings are based on the views designers (and design thinkers) have of their own work, and their contribution to the design process. Thus, future studies should broaden the scope and include other important actors in the development network (e.g., technology specialists), which can lead to the identification of new challenges and/or contributions of designers. Finally, our findings are a first step in identifying the differences between product, service, PSS and Smart PSS design. Future studies should deepen this knowledge, for example, by defining the critical phases in the design of Smart PSSs, where challenges are more likely to occur. Such research can lead to the identification (or development) of key design tools that can effectively support the design Smart PSSs.

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