Title:

Smart product-service systems design process for socially conscious digitalization

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Smart product-service systems design process for socially conscious digitalization

Abstract:

While digitalization has become a key driver for promoting value creation for customers and stakeholders, much attention is being paid to smart product-service systems (PSS) to meet their diversified needs. When designing smart PSS, there is a strong need to consider growing concerns about the social and ethical impacts of digital technologies. Numerous ethical guidelines for digital technologies, such as artificial intelligence, have been developed. However, a more practical methodology for designing smart PSS by taking into account both positive and negative impacts (including social and ethical impacts) of using digital technologies is anticipated. This paper aims to address this issue by integrating value sensitive design into the smart PSS design process. This design process combines participatory and systematic design approaches and integrates methods to extract values and develop the specifications of complex smart PSS in an iterative manner. To demonstrate its efficacy, this paper presents a case study of a monitoring service for seniors using a communication robot. The results demonstrate that the proposed design process can support design consideration for social and ethical values and lead designers and design participants to clarify design requirements and generate a socially conscious design solution.

Keywords: digitalization, smart product-service systems, value, ELSI, design process

1. Introduction

Digital technologies have become essential in our lives. Recent digital technologies such as artificial intelligence (AI), the Internet of Things (IoT), and social robotics are already being utilized in association with various services in our daily lives. As digital technology becomes more closely connected to people's lives, people of all ages, from children to seniors, will be greatly affected by how that technology is integrated into society. As a consequence, social and ethical concerns about digital technologies are growing (Winfield and Jirotka, 2018). While a variety of rules and principles for digital technologies such as AI have been proposed (Whittlestone et al., 2019; Morley et al., 2020), a concrete approach to developing better human-technology relationships is anticipated to realize sustainable futures (Vinuesa et al., 2020).

This study focuses on smart product-service system (smart PSS) concept to tackle this issue. Smart PSS emphasizes value co-creation among multiple stakeholders through smart technologies and services (Valencia et al., 2015; Zheng et al., 2018; Cong et al., 2020). Actually, many digital technologies do not work in isolation, but rather as a part of a larger system including people and organizations interacting mutually (Spohrer and Kwan, 2009; Zheng et al., 2018). Appropriate smart PSS design could contribute to cooperative relationships between humans and digital technology. Some studies on PSS/service systems have already focused on social and ethical perspectives (Paschou et al., 2020; Watanabe et al., 2020a; Cellary et al., 2021); however, there is still limited research on the concrete design methodology for designing smart PSS by taking into account social and ethical impacts of using digital technologies.

To address this challenge, we develop a design process of smart PSS based on value sensitive design (VSD) in order to extract customers' diversified values including social and ethical values and incorporate them into the specifications of smart PSS. Here, VSD refers to "a theoretically grounded approach to the design of technology that accounts for human values in a principled and comprehensive manner throughout the design process" (Friedman et al., 2013). To demonstrate the efficacy of the proposed design process, we conducted a case study of designing a monitoring service for seniors using a communication robot.

The remainder of this paper is structured as follows. In the following section, we overview recent research and discussions on digital technology and society and identify the research gap associated with smart PSS. We then present the concept and concrete steps of our design process for smart PSS. The proposed design process is demonstrated with a design case of a robot service to monitor the safety of seniors. We then discuss the effectiveness and limitations of the proposed process, and provide concluding remarks and future studies.

2. Research background

2.1 Social impact of digital technology: from principle to design

There has been a growing concern about the negative impact of digital technologies on society. Particularly in the field of AI, there is a growing awareness of the importance of addressing not only practical benefits but also ethical, legal, and social issues (ELSI) associated with the technology. One common issue relates to breaches of privacy (Stahl and Wright, 2018). Many digital services are based on data collected from IoT and human sensing, which can cause infringements of user privacy. The data bias issue in the application of machine learning is also a common concern.

To address these concerns, various design and application principles of digital technology have been proposed. For example, the Future of Life Institute (n.d.) proposed the Asilomar AI principles to ensure that the development of AI will benefit humans and enrich their lives on a long-term basis. Ethically aligned design (IEEE, n.d.) is another example that aims to dispel fears and unrealistic expectations of autonomous and intelligent systems by outlining core design theories and concepts. In addition, national governments (e.g., the UK, France, Japan) and international organizations (e.g., OECD) have also proposed such principles

(Whittlestone et al., 2019; Morley et al., 2020). Ethics by Design, which intends to implement ethical behavior in digital technologies, is anticipated to be more popular in the future of design (Bourgais and Ibnouhsein, 2021).

There are several arguments on how to implement these principles in actual research and development processes. For example, Whittlestone et al. (2019) identified that it is difficult to apply existing principles directly to technology development and integration. Mittelstadt (2019) also stated that AI development lacks “proven methods to translate principles into practice." To this end, Morley et al. (2020) developed a typology for practitioners to apply ethics in the development of machine learning applications, for example.

Among technology ethicists, VSD is attracting more attention (Stahl and Wright, 2018; Dignum, 2017). VSD is an approach for developing information systems while respecting human values throughout the design process (Friedman and Kahn, 2003; Friedman et al., 2013). In VSD, value is defined as "what people consider important in their lives," which covers a broader range of values than the economic concept of value (Friedman et al., 2013). The authors of this approach also provide three types of investigation methods to take various values into consideration for information system design: conceptual, empirical, and technical investigation. Conceptual investigation specifies stakeholders and their values affected by the design concept. Empirical investigation focuses on values in “the human context in which the technical artifact is situated” (Friedman et al., 2013). Technical investigation clarifies actual impact of technologies to human values. VSD is generic and applicable to a variety of system applications.

2.2 Smart PSS and its design process

Focusing on digitalization and associated value creation, smart PSS attracts more attention. Smart PSS, the term of which was coined firstly by Valencia et al. (2015), refers to “an IT-driven value co-creation business strategy consisting of various stakeholders as the players, intelligent systems as the infrastructure, smart, connected products as the media and tools, and their generated e-services as the key values delivered that continuously strives to meet individual customer needs in a sustainable manner” (Zheng et al., 2018). Current digital technologies are often not used as a single product, but rather as part of integrated systems that collect various data and provide valuable information and interventions for users. In particular, smart PSS usually includes multiple stakeholders and their interactions (Cong et al., 2020), and thus digital technologies may cause unintended impacts on these integrated systems (Cellary et al., 2021), which has not been addressed in the traditional product or system design. Hence, an appropriate design process for smart PSS is essential to create better applications of digital technologies from a social and ethical perspective.

Existing smart PSS design processes are characterized with the adoption of technology-oriented design methods for managing its complexity (Pirola et al., 2020; Cong et al., 2020). Specifically, the utilization of digital twin as "virtual and computerized counterpart of a physical system" (Grieves, 2014) is a major research trend of smart PSS design. Digital twin has been adopted as an effective approach to assess and optimize the layout and operation of workplaces (Leng et al., 2019; Leng et al., 2021). Zheng et al. (2018) proposed the digital twin-enabled service innovation and its design process utilizing data collected from smart, connected products. Lützenberger et al. (2016) introduce a method to utilize product usage information for improving PSS. The modelling method of smart PSS is also an important research topic (Cong et al., 2020; Halstenberg et al., 2021). Li et al. (2020) utilize knowledge graph constructed from open source data to support conceptual design of smart PSS. Poeppelbuss and Durst (2019) propose a representation scheme to structure elements of smart PSS including value, customer and ecosystem. In addition, data-driven approaches for requirement elicitation (Wang et al., 2019) and design management (Zheng et al., 2019) of smart PSS have been proposed.

Another characteristic of smart PSS design processes is its emphasis on value in design and value co-creation with users (Cong et al. 2020). Chang et al. (2019) focused on user experiences in their user centric smart PSS development scheme. Jia et al. (2021) also proposes a systematic requirement analysis process of smart PSS for rehabilitation. Liu et al. (2018) emphasizes the importance of user participation in the whole design process with the smart PSS co-creation process. Liu et al. (2019) also propose co-creative value propositions and the evaluation method for smart PSS. In this co-creative design process, iterative improvement has been expected even after the implementation (Liu et al., 2018; Watanabe et al., 2020b). Context-awareness of users (Cong et al., 2020, Wang et al. 2021) and personalized service based on user generated data (Chiu et al. 2021) are also actively investigated.

2.3 Research gap

Despite of the increasing concern on the social and ethical impacts of digital technologies, the research on smart PSS has not paid sufficient attention on this issue. Several studies on smart PSS design take multiple values of stakeholders into consideration (Liu et al., 2019; Jia et al., 2021), but social and ethical values are not the major concerns in the design process except for environmental sustainability. Considering the growing public concern on the social and ethical impact of digital technologies (Stahl and Wright, 2018; Whittlestone et al., 2019), the smart PSS design research needs to address this issue to contribute to sustainable development in a broader sense. In addition, most of the existing design processes of smart PSS include data feedback cycles or redesign cycles after implementation (Liu et al., 2018; Cong et al., 2020; Watanabe et al., 2020b), but do not explicitly contain iterative, exploratory processes to specify values and corresponding design requirements during the initial design phase. It is essential to explore values to be addressed before implementation for mitigating social and ethical impacts of digital technologies (Friedman et al., 2013).

Considering this research gap, we propose a new design process for smart PSS in a socially conscious manner.

3 Socially conscious design process for smart PSS

3.1 Concept

The basic concept of our design process is shown in Figure 1. In the design process, designers explore values with stakeholders and embody smart PSS according to the values, which infuses new values for the stakeholders. This stepwise, iterative process helps designers obtain in-depth understanding on potential impacts of smart PSS to be developed. The proposed process adopts the VSD approach for taking social and ethical values into account in smart PSS design. As mentioned above, values for stakeholders can be identified by different types of investigation approaches (Friedman et al., 2013). The proposed process involves these investigation approaches in its steps as shown in Figure 2. The detailed process will be introduced in the next section.

The smart PSS design process of this study uses systematic design methods to represent values and smart PSS specifications of both physical and cyber spaces. Meanwhile, user participation is also essential for designing smart PSS (Liu et al., 2018), especially when considering the values of stakeholders. Values are subjective and need to be extracted from actual or at least potential users. Hence, we adopt both participatory and systematic design approaches (Watanabe et al., 2013) and integrate two methods, a value typology for smart PSS design and an intermodel influence map to extract values and develop the specifications of complex smart PSS in an iterative manner.

3.2 Design procedure

The proposed design process has seven steps, which are categorized into two approaches: participatory and systematic phases. For the design steps taking a participatory approach (Step 1, 3, 5), smart PSS designers collaborate with actual or potential customers to identify their values, obtain the design requirements and receive feedback on the design solutions. For the design steps taking a systematic approach (Step 2, 4, 6), smart PSS designers solely work to determine the specifications of the smart PSS according to the results from the participatory design approach. By alternating between these design steps, the values and requirements of customers are incorporated into the specifications of the smart PSS.

The detailed design process is described as follows.

Step 0: Prior arrangement

During this step, a smart PSS designer first establishes a design problem, including its service domain, customers, and the core technological element. The designer conducts a preliminary study on related issues regarding the design problem and contacts representative customers to act as design participants. The designer plans the design procedure consisting of the following steps, with the design participants.

Step 1: Value extraction

This step explores the preliminary service concepts and associated values to be fulfilled by the service concepts. The designer and participants first ideate preliminary usage ideas of the core technology in the anticipated service domain. They then extract customer values that will be satisfied by the ideated usages. This process can be conducted in two ways: free ideation and forced ideation. The free ideation approach involves brainstorming potential values that satisfy the usage ideas without limitation. The forced ideation approach uses a value typology for smart PSS design, consisting of 22 value types, as shown in Table 1 to ideate concrete values under the fundamental values including both social and ethical values and conventional customer values. Research on value typology has a long history in the marketing research. For example, one of the most influential typologies was provided by Holbrook (1999). It consists of eight types of values: efficiency, excellence, play, esthetic, status, esteem, ethics, and spirituality. There have since been multiple variations based on this design (Gallarza et al., 2017). In this study, we adopted a set of values from the newer typology developed by Leroi-Werelds (2019) as a part of our typology. This typology reflects the recent advancement of digital technologies and contains several ethical values. However, it does not directly reflect some major values related to social and ethical impacts such as trust and fairness. Hence, we adopted a list of human values from the research on VSD and reorganized the typology to consider social and ethical impacts in smart PSS design (Friedman et al., 2013). This typology does not intend to encompass all types of values for all customers, but instead provides multiple views that may be useful for conceptual investigation.

Through this process, the design team can obtain several usages with associated values.

Step 2: Concept design

In this step, the designer structures collected values using a hierarchical value map (HVM). HVM represents the structure of values from the broad, general aspects to specific details (Reynolds and Gutman, 1988). Values are mutually connected by the means-end relations. Typically, more abstract fundamental values are fulfilled by more concrete values. The fundamental values in the value typology represent general, top-level values in the HVM. Smart PSS designers specify usages from Step 1 or develop new ones to fulfill these values. These are identified as the concepts of the smart PSS. These concepts are each described with a simple phrase.

Step 3: Usage scenario design

The usage scenarios of digital technologies are designed based on the concepts obtained in Step 2. Personas and scenarios, common design tools to represent a fictive person and their activity for design considerations (Homlid and Evenson, 2008) are developed with participants for this step. Smart PSS designers may develop tentative scenarios in advance. Even in this case, these scenarios are refined in collaboration with the participants. Through this refinement process, the persona and scenarios become more realistic and create virtual experiences for the participants, contributing to empirical investigation.

Step 4: Modelling of smart PSS

In this step, the designer creates smart PSS models based on the scenarios from Step 3. In addition to the HVMs as the representation of values, value network (VN) (Allee, 2008) and data flow diagram (DFD) (Li and Chen, 2009) are used to model the physical and cyber spaces of smart PSS. VN represents different types of interactions among actors in a physical space. DFD as the most common, universal model for data flow descriptions represents the cyber space in a smart PSS.

The smart PSS designer must also focus on the mutual influences among the models. In this study, we developed and adopted a design tool called the intermodel influence map to explore and represent influences between models, as shown in Table 2. First, the smart PSS designer puts the values to be fulfilled in the left column. Second, the potential service contents to fulfill the assigned value are listed in the middle column. Third, the side effects that the applied contents in the physical and cyber spaces may bring are described in the right column. Lastly, the side effect is copied to the left column again to consider different service contents as solutions to mitigate their impact. By taking these steps, the designer can gradually specify the smart PSS elements, clarifying the impact of the smart PSS on customers. The elements obtained in the map are then integrated into the smart PSS models.

Step 5: Prototyping

The developed models are prototyped in this step. Paper prototyping and digital mockups are effective methods here. The participants can roleplay using the prototype to serve as a prototype of the entire smart PSS. Through this experience, the participants can evaluate the current smart PSS design and its technological impact. More importantly, the experience through prototyping should provide the participants with additional opportunities to see the benefit and risks which may result from the actual implementation and dissemination of the current smart PSS. Hence, collected feedback after this step is essential for updating design ideas from the perspective of the social impact of smart PSS.

Step 6: Evaluation and re-design

The smart PSS designer reflects on the feedback from the participants provided in Step 5 and modifies the design ideas. The updated ideas may be tested again with the participants, or could even be tested on a larger scale. The smart PSS models are also updated and then utilized as design materials for the development of digital technologies and service operations.

4 Case study

4.1 Overview

We conducted a design case study to examine the effectiveness of the proposed methodology. The topic of the design case was a system for watching over seniors using a communication robot. All the authors of this paper acted as smart PSS designers, whereas four participants, two males and two females, joined as design participants. The participants were all researchers with an engineering background. They were middle-aged and had potential needs to care for their older parents, making the design case relevant to them.

In addition to the design works by the designers, design workshops were held with the participants three times (#1: August 6, 2020, #2: October 29, 2020, #3: December 14, 2020), which corresponded to Steps 1, 3, and 5. Each workshop lasted two hours. The participants joined all workshop sessions. Step 2, 4 and 6 followed these steps respectively.

In this study, we analyzed the collected data, including design documents and materials, videos, audio recordings, and memos. The audio clips were transcribed into text and used for both design practices and research analysis. Based on the collected data, we examined whether the proposed methodology sufficiently fulfilled the objectives of this study.

4.2 Design process

Step 0: Prior arrangement

As mentioned in the previous section, the design topic of the case was determined to be a monitoring service for seniors using a communication robot. Several previous studies have mentioned this service as an exemplary case requiring ethical consideration for involving topics such as a privacy issues (Čaić et al., 2018; Fosch-Villaronga, 2015), which is why we chose this as a design case.

In this design case, the smart PSS is expected to respond to emergency situations, such as when a senior has experienced an acute illness or an accident such as a fall. Thus, the senior and their family are the main customers of the smart PSS. The main digital technology is a communication robot. According to the above problem and situation settings, we invited the participants in the design process.

Step 1: Value extraction

Prior to the value extraction workshop, the smart PSS designers brainstormed multiple usage ideas for the communication robot as initial assumptions for value extraction. The smart PSS designers used a 2 × 2 scenario building matrix to create four potential use cases. The two axes applied were direct or indirect use of the collected information on seniors and whether seniors' approval would or would not be needed to collect the information. The developed use cases are as follows.

a) Calling device: *The family members of the senior make an audio or video call to their robot as if making a phone call, and the senior can respond to their family member by communicating* *through the robot. In this usage, the senior's family members talk through the robot and can view the video images provided by the robot to confirm their status.*

b) Incognito: *The family members of the senior can access the video and audio feeds provided by the robot at any time, and can watch over them without their knowing.*

c) Activity recording: *The family members of the senior can access their activity records that are periodically acquired by the robot, by requesting permission from the robot each time. The activity records reflect the senior's daily rhythms, such as the frequency of outings and interactions with the robot.*

d) Automatic problem detection: *In the same manner as in c), the robot collects the activity records of the senior and recognizes their daily behavioral patterns. The robot sends a notification to the family's smartphone when an irregular activity is detected as compared to the ordinary behavioral pattern.*

In the value extraction workshop, participants ideated values based on the above four usages. After instruction regarding the prepared use cases, the participants were first asked to individually freely ideate positive values and negative impacts to senior users and their families for each use case and write them down. The smart PSS designers collected the notes with ideas from the participants and organized them on a value classification table based on the value typology. Some of the results are presented in Table 3. In this workshop, the values related to "relational benefit," "safety," "privacy," "trust," and "sense of control" were the main values described by the participants. The participants further ideated values associated with the value typology upon seeing the classification table.

As a notable discussion in the workshop, one of the participants pointed out that the use cases with unilateral communication, in particular the Incognito approach, were simply against the value of "relational benefit":

> "The overall scenarios of this watching-over robot are not bidirectional. The family watches over or calls to the senior in a one-way manner...the value of relationship seems disregarded or even refused, considering that the family can see the senior whenever they want, irrespective of her or his thoughts."

The same participant also suggested that the design problem of a "monitoring service" needed to be redefined, which was agreed upon by the other participants.

Step 2: Concept design

The smart PSS designer structured the collected values using HVM. In addition to the values placed on the classification table, the smart PSS designers also extracted values from the voice-recorded discussions during the workshop. Based on the comments and discussions on the relationship from the first workshop, the smart PSS designers focused on the values of the relationship "feeling connected to the family / parent (senior)" as the main value provided to the senior and the family, and "respecting the will of the parent (senior)" as an additional value for the family.

By focusing on the relationship between the senior and the family, two types of relationships were found in the results of the workshop. The first is a close relationship characterized by direct communication through conversation. The other is a mutually caring, but less communicative relationship, which was described with the following comment in the workshop:

> "...for example, one can get to know about the weekly activities or the absence of the other...There is no need to check at all times."

Putting the communication at the forefront, rather than guardianship, the smart PSS designers set the design concept as "a communication service system to achieve natural communication that matches the relationship between seniors and their family." Based on the findings from the described relationships, the smart PSS designers decided to develop two types of scenarios with different personas.

1) A ‘conversation’ scenario: direct communication through conversation
2) A ‘thinking-about’ scenario: representing a less communicative, with technological support for indirect communication

Step 3: Usage scenario design

The smart PSS designer created the two types of personas and usage scenarios for the design of communication services tailored to the relationship between seniors and their families. Both scenarios described the daily situation wherein the senior and the family communicated through the robot as an avatar and an emergency situation, wherein the family needed to check the senior’s status.

The usage scenario design workshop was conducted using handouts for the personas and the usage scenarios created by the smart PSS designers. Due to time constraints, participants were divided into two groups, discussing the ‘conversation’ scenario and the ‘thinking-about’ scenario.

Participants were asked to read the handouts, and then the smart PSS designer organized discussions among the participants in each group. During the discussion, comments and feedback on the personas and usage scenarios were collected. Then, the smart PSS designers asked the participants about any points of discomfort or empathy they felt as a result of the scenario. The main comments were as follows:

- A keyword suitable to initiate conversation naturally and also to prevent accidental calls is needed.
- Seniors should have an option to stop sharing the video, for example by covering the camera.
- The robot may also facilitate the communication with other family members by sharing the space.

Step 4: Modelling of services

The designers developed smart PSS models based on the created usage scenarios and the feedback obtained in the usage scenario design workshop, examining the influence among the models. In the intermodel influence map shown in Table 4, the value for the family being "able to check on the parent's situation" (row #1) could be achieved with the technological feature "connecting a camera for monitoring " in both the physical and cyber spaces. However, this could cause the adverse effect for the senior in that they feel like they are being observed. This negative impact, shown in row #2, can be avoided by the physical feature of "covering the camera physically" in the physical space. This causes further challenges, such as potential unavailability of monitoring, which can be solved with the function of uncovering the camera after long-term unavailability (row #3).

The models were developed through this iterative review process. In response to the updated value model, VN and DFD were developed.

Step 5: Prototyping

After this step, the designers prototyped the designed smart PSS. Due to the time constraints of the workshop and the implementation cost of prototyping, only a smart PSS based on the conversation scenario was prototyped. The aim of this prototype was to allow the participants to communicate through the robot. To implement the prototype rapidly, the smart PSS designers combined the roleplay method with existing technologies. The roleplay scripts were prepared based on the usage scenario, demonstrating the conversation between a mother and a daughter in both daily and emergency situations. For the communication robot, the designers applied the communication robot TAPIA (MJI, n.d.), which was programmed to turn to the speaker's side and show the “on-call” signal on the screen. The actual voice conversation was transmitted through a tele-meeting application.

In the workshop, the participants were separated into two pairs for roleplay. One of the pairs acted as the mother and the other as the daughter. They moved to separate rooms and communicated with each other through the prototype system, following the roleplay script. Figure 3 shows a scene of the roleplay. After the roleplay by the two pairs, the smart PSS designers organized the discussion with the participants to obtain feedback on the experience. Feedback was collected for each phase of the script and the associated values.

Step 6: Evaluation and re-design

After the workshop, the feedback was collected to evaluate the designed smart PSS with the associated values. Figure 4 shows a part of the smart PSS models.

The major problem of the prototype was its presence as an avatar of the mother or daughter, which is associated with the value “able to feel the family’s presence”. Although the robot was programmed to show its attention to the speaker, its appearance was largely different from that of the original person, which hindered the experience of communication between the mother and daughter. Malfunctions in the ability of the robot to turn to the speaker, because of the limited capability of sound source detection, also affected the impression of human-robot communication. As a design solution, the robot’s appearance such the eyes could be modified to more closely approximate the actual speaker.

The other issue raised by the participants was the adjustability of the interaction protocol. The roleplay script and robot function requested the participants to use the key phrase

“Hi, mom” (in Japanese) to start the conversation. This was intended to serve as natural, smooth beginning of the conversation, but such a phrase actually depended on the relationship between the speakers. To address this issue, the keywords need to be modifiable.

5 Discussion

5.1 Consideration on values in design

The originality of the proposed design process is to extract customer values to be considered, with the participants involved, by integrating the concept of VSD into the smart PSS design process. We confirmed the usefulness of the design process based on the case study as follows.

In Step 1-2, initial values to be considered for the monitoring service of the elderly were clarified. The value typology (see Table 1) was useful to categorize the collected values during the workshop and further ideate within the typology scheme. The value list represented diverse values ("relational benefit," "safety," "privacy," "trust," and "sense of control") which encompassed both the conventional customer values (e.g., relational benefit) and social/ethical values (e.g., privacy, trust, and sense of control). The typology worked well as a tool to describe a variety of collected values which were not addressed in the existing smart PSS design studies (Liu et al., 2019; Jia et al., 2021). The smart PSS designers were able to discuss and extract values for specific value categories. The negative impact on the relational benefit was an example of this process. In addition, the proposed typology was useful in supporting the concept design step by conceiving possible scenarios not originally considered by the designers. The results of the case study do not guarantee the completeness of the typology but demonstrate the effectiveness of the extended value scheme.

In Step 3-4, more situation-oriented values were taken into account. The developed scenario and personas enabled the participants to discuss experiences of the personas and correlated values. The procedure to detect adversarial effects was meaningful, especially for integrating social and ethical values such as privacy in a more concrete setting.

In Step 5-6, the participants experienced technological investigation with the prototype. This brought a more nuanced image about the expected experience through the robot related to their value about the relationship with the parent. This is meaningful for clarifying the social acceptability of the developed smart PSS.

5.2 Iterative update of values and smart PSS specifications

The proposed design process is characterized by the integration of participatory and systematic design approaches. In the design step with the participants, easy-to-use representation schemes (e.g., value categorization tables) and methods (e.g., personas, scenarios, roleplays) were used. These worked effectively to obtain feedback on design ideas and assist in their revisions. The systematic modeling scheme was a combination of existing methods, but described the details of the smart PSS in a more structured manner. Combining the two different approaches with the suggested steps and the intermodel influence map, the iterative design update of the smart PSS among the three models worked effectively. New values of different stakeholders, related to privacy and sense of control were specified in the initial design phase, which is beneficial for design assessment and unique to the proposed design process. The modified design ideas were tested through the prototyping and evaluation phases, which were effective in obtaining direct feedback from potential users. The evaluation in this study was conducted by a multi-criteria, qualitative approach, which is effective to investigate diverse impacts of the design result. It will be also beneficial to combine the quantitative evaluation using a questionnaire study or collected data from adopted digital technologies, for example to clarify the degree of the impacts. The simulation-based design approach can be combined to assess the design solution before implementation and even the long-term impact of the designed smart PSS. These will be considered in the future study.

A key advantage of the proposed design process is that it facilitates the design cycles of generating various values (including social and ethical ones); developing possible scenarios, necessary services and functions to achieve the desired smart PSS; and gain insights and feedback through the prototyping and testing steps. This sequence will help researchers and practitioners design smart PSS in a more systematic manner.

5.3 Limitations

In this paper, we demonstrate how the values, including social and ethical values, are integrated in the smart PSS, but the output is still in its early phases. For the actual implementation of the smart PSS, the development process also needs to be further investigated. In addition, the participants of the case study were not very representative of ordinary citizens, although they did have the same needs regarding communication with their older parents. More case studies with a wider variety of users, including seniors, need to be considered in future research.

6. Conclusion

In this paper, we proposed a design process for smart PSS which takes social and ethical values into account. The proposed smart PSS design process is based on a combination of participatory and systematic design approaches and includes two methods: the value typology based on VSD and marketing research and the intermodel influence map for iterative design update. Based on the input and feedback from potential users as design participants, the structure of the smart PSS is systematically developed using the modeling scheme. The design process was tested in a case study on a monitoring service for seniors. The results of the case study demonstrate that social and ethical values were well integrated in the design considerations through the proposed design process. In addition, the design process properly led the designers and participants to collect the input to the smart PSS design and generate the concrete specification for a design solution in an iterative manner. The case study demonstrates that the proposed design process contributes to sustainable development in response to the concern to negative impact of digital technologies.

In future work, more case studies with relevant stakeholders need to be considered. In addition to the current design process, the development and implementation processes of a smart PSS also need to be studied. Moreover, the data-driven and simulation-based design approaches to assess both short-term and long-term influence of smart PSS need to be investigated in the future study.

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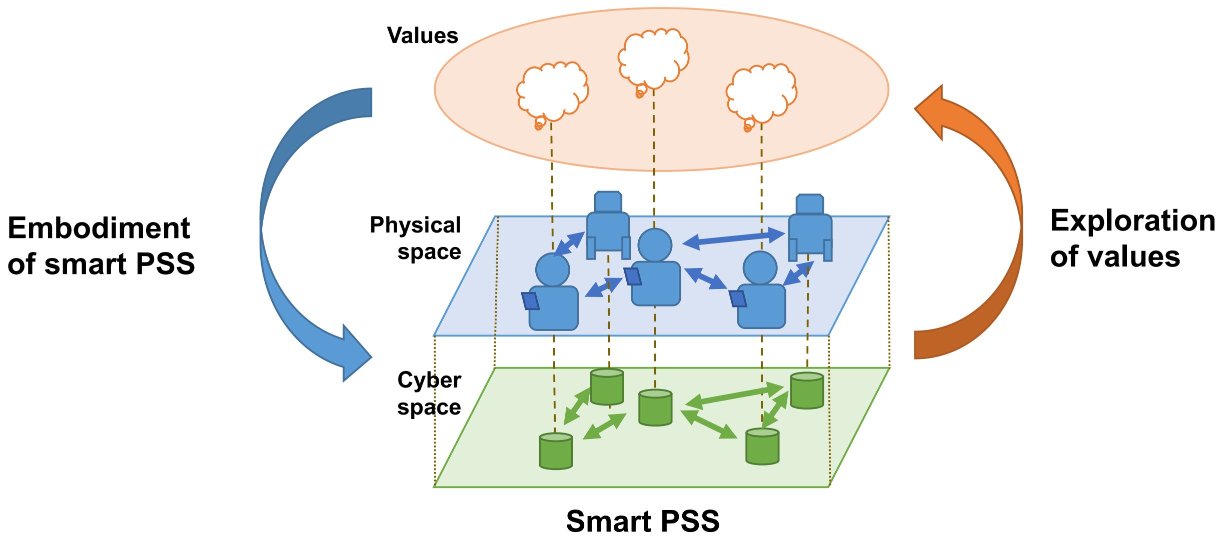

Figure 1 The basic concept of the design process

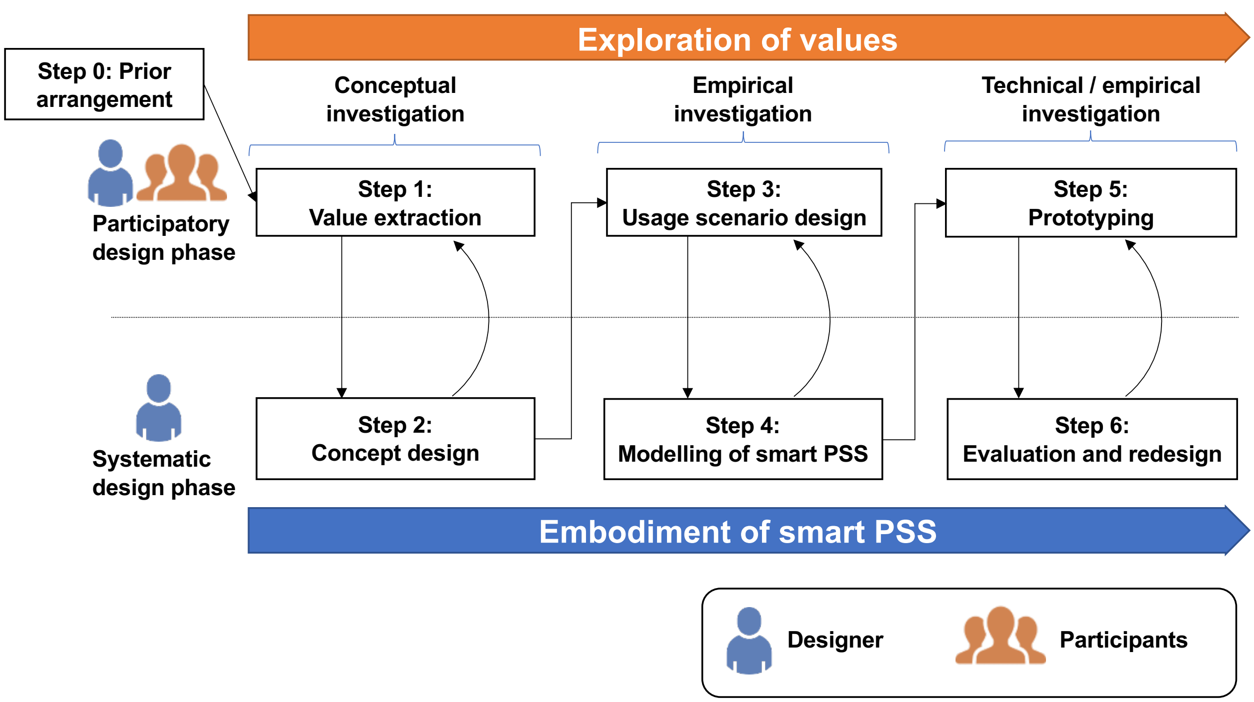

Figure 2 Proposed design process of smart PSS

Figure 3 Scene in the prototyping workshop

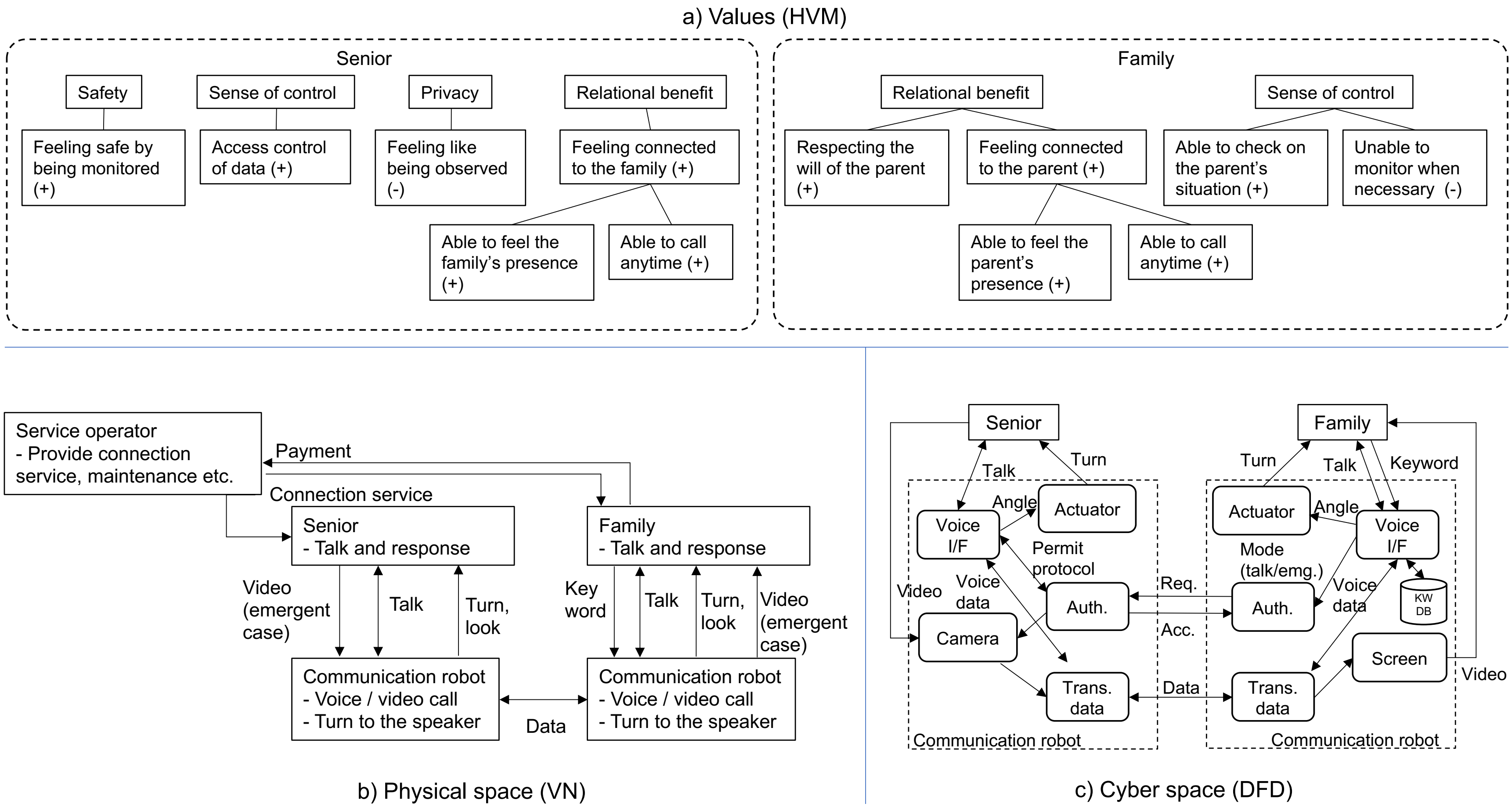

Figure 4 Smart PSS models in the case study (partial)

Table 1 Value typology for smart PSS design (based on Leroi-Werelds (2019) and Friedman et al. (2013))

Value type	Description
Efficiency	Refers to making the life of the actor easier.
Excellence	Refers to high quality.
Status	Refers to positive impressions on others.
Self-esteem	Refers to positive effects on the actor’s attitude.
Enjoyment	Refers to fan and pleasure.
Aesthetics	Refers to appealing. This involves the attraction of the object’s design and atmospheric aspects.
Escapism	Refers to allowing the actor to relax and escaping from reality.
Novelty	Refers to creating curiosity and/or satisfying a desire for knowledge.
Relational benefit	Refers to a good relationship with other actors.
Trust	Refers to expectations that exist between people who can experience good will, extend good will toward others, feel vulnerable, and experience betrayal.
Sense of control	Refers to being able to operate as the actors want.
Safety	Refers not to inflict the actor injury.
Autonomy	Refers to people’s ability to decide, plan, and act in ways that they believe will help them to achieve their goals.
Accountability	Refers to the properties that ensure that the actions of a person, people, or institution may be traced uniquely to the person, people, or institution.
Ownership and property	Refers to a right to possess an object or information, use it, manage it, derive income from it, and bequeath it.
Accessibility	Refers to making all people successful users of information technology.
Ecological benefit	Refers to sustaining ecosystems such that they meet the needs of the present without compromising future generations.
Well-being	Refers to people’s physical, material, and psychological well-being.
Privacy	Refers to a claim, an entitlement, or a right of an individual to determine what information about himself or herself can be communicated to others.
Fairness	Refers to systematic unfairness perpetrated on individuals or groups, including pre-existing social bias, technical bias, and emergent social bias.
Courtesy	Refers to treating people with politeness and consideration.
Identity	Refers to people’s understanding of who they are over time, embracing both continuity and discontinuity over time.

Table 2 An example of the intermodel influence map

Number	Target value (Value)	Service contents (Physical / Cyber)	Side effect (Value)
1	- Reducing the physical burden (caregiver+)	- Lifting by a robot	- Feeling worried (care recipient-)
2	- Feeling worried (care recipient-)	- Frequent communication	…
…			

+: positive, -: negative,

Table 3 Value classification table (partial)

	Relational benefit	Safety	Privacy	Trust	Sense of control
a) Calling device	- Unable to see the faces of the family (S-)	- Able to call anytime at home (S+)	- Same level as smart phones (S+/F+)	- Familiar functionality (F+)	- Able to receive the family call only (S+)
b) Incognito	- Neglecting relational benefit (S-/F-)	- Feeling safe by being monitored (S+)	- Feeling like being observed (S-)		- Easy to understand the situation (F+)
c) Activity recording	- Able to understand the behavior patterns (S+/F+)	- Feeling safe by being monitored (S+)	- Feeling like being observed (S-)	- Dependent on the family's available action (S-/F-)	- Access control of data (S+)
d) Automatic problem detection		- Feeling safe by being monitored (S+) - Able to receive a warning (F+)	- Uncomfortable about the data sent to the family without notice (S-)	- Not clear what to do when receiving a warning (F-)	- Less control (S-)

+: positive, -: negative, S: senior, F: the family

Table 4 Intermodel influence map in the case study (partial)

Number	Target value (Value)	Service contents (Physical / Cyber)	Side effect (Value)
1	- Able to check on the parent’s situation (F+)	- Connecting a camera for monitoring (P/C)	- Feeling like being observed (S-)
2	- Feeling like being observed (S-)	- Covering the camera physically (P)	- Unable to monitor when necessary (F-)
3	- Unable to monitor when necessary (F-)	- Measuring the time of camera being covered (C) - Unveil camera after a certain period (P/C)	-

+: positive, -: negative, S: senior, F: family, P: physical space, C: cyber space