An Exploratory Study of User Interaction with Smart Products for Customization in the Usage Stage

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Abstract In this paper, we propose a new concept to provide customized and user-specific products, utilizing the opportunities of so-called smart products: product customization in the usage stage (PCUS) with smart products (SPs). Contrary to the existing concept of utilizing online toolkits to customize products during the time of sale, a new class of smart products (made possible by recent digital technologies and the Internet of Things) allows product adaptation and change according to each individual's needs in specific usage contexts through a new form of user-product interaction. This advanced ICT-enabled phenomenon offers many research opportunities. One of these fields is the perceptions of users of the SP's smartness, i.e., a potentially autonomous personalization of the product based on past usage behavior of a user. While such an autonomous adaptation is convenient and reduces complexity for users, users may perceive a loss of control. This paper explores the design parameters for companies to develop user interaction with SPs for PCUS. We propose that users and smart products should coadapt to better satisfy customization needs.

Keywords Smart products (SPs) · Product customization in the usage stage (PCUS) · Perceived autonomy · Perceived control · Design parameters · User interaction

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1 Introduction

Mass customization (MC) has been established as an important driver of consumer value by meeting heterogeneous preference and individual needs in customized products [16–19]. Customers specify and combine their preferred product options among a given solution space via computer-based interfaces, which are so-called toolkits for customer co-design (also configurator, choice board [14, 30, 38, 49, 52]). Toolkits usually have many features that support a trial-and-error learning process [19, 50]. After collecting the final design created by consumers when buying the product, the company produces and delivers the final product with the customized design for each consumer. We call this conventional customization approach *product customization at the point of sale (PCPS).*

However, the notable shortcoming of PCPS is that consumers have to make a decision about the final designs before they are manufactured. Due to the problem of low preference insight [16], consumers often have difficulties in evaluating whether an offering truly fits their preferences at the time of purchase. Moreover, the product usage context is diverse and changing, and it is impossible to predict every usage situation in PCPS. Simonson (2005) argues that customers often have no insight into their true preference or may even have no preference at all, so they “construct” preferences when they have to make decisions [47]. However, this spontaneous construction might be unstable or deviate from the true preference function. In such a case, the self-designed product would then not really generate value for them and might potentially lead to post-purchase dissatisfaction.

In the era of the Internet of Things (IoT), various smart products enabled by advancements in ICT (e.g., integrated sensors, microprocessors, big data technologies, machine learning, etc.) such as smart wearables, smart cookers, and smart thermostats have entered daily life. The rise of smart products leads to a new thinking for MC and offers great opportunities for new forms of customization and data-driven service personalization.

In this paper, we propose a new concept for consumers to achieve customized and user-specific products in the smart product age that is *product customization in the usage stage (PCUS) with smart products (SPs).* Contrary to the existing concept of utilizing online toolkits to customize products during the point of sale, a new class of smart products (enabled by recent digital technologies and Internet of Things) allows consumers to change them and create what they like via embedded toolkits in the usage stage. This advanced ICT-enabled phenomenon indicates many research opportunities, especially in the area of user and smart product interaction design for individualized usage. Therefore, apart from proposing the novel approach to customization, this study also aims to explore the design parameters for companies to develop user interaction with SPs for PCUS.

The paper is structured as follows. First, we elaborate on the new concept for customization – PCUS. Then we try to describe how smart products can be used for customization in the usage stage. This is followed by a discussion about user perception of control and autonomy from smart products, autonomous customization and theory of user system adaptivity, and user adaptability from user interface design. There is then a summary of design principles for user and smart product interaction to satisfy individual needs based on expert interviews and literature studies. In the final part, we discuss possible implications and future directions.

2 Product Customization in the Usage Stage (PCUS)

Contrary to the PCPS, we propose a new concept for customization named *product customization in the usage stage (PCUS).* It supports consumers to customize products to adapt to their changing needs and situations after they start to use them. The original idea for PCUS is to move product development into consumer domain [38]. For a successful implementation of this idea, the product has to be designed with the possibility to adjust and adapt to the preferences of a specific customer or context [25, 38]. So, consumers can, for instance, modify the parameters of the product attributes to fit with their changing needs, situation, and individualized usage. PCUS allows consumer learning and preferences to be detected by an immediate and easy-to-evaluate "trial-and-error" process in reality. Although PCPS allows for "complete cycles of trial and error" [50], consumers can manipulate the design over and over again virtually and, most importantly, only once the design is produced is it defined. According to connectionism learning theory, learning is an incremental process of creating and changing associations between different cues in a person's mind as a result of experiences [13, 46]. In PCUS, preference insight in a special context can be enhanced by creating a clear association between an action and result through real experience. Consumer learning can be supported by experimentation and immediate feedback. Thus, the perceived risk of making a wrong decision is reduced, and hesitation is taken away by being able to adapt the product more than once and improve it during usage.

Contrary to the PCPS, PCUS supports consumers and allows them to customize products to adapt to their changing needs and situations after they start to use them. The original idea of PCUS is to move product development into the consumer domain [38]. Manufacturers cannot predict any service that every user may need in the future because of the limitations of the closed-design mode where a designer is responsible for product design for users to use and users are passive recipients. In fact, each user's needs are highly individual.

3 Smart Products for Customization in the Usage Stage

With the advent of the smart product age, PCUS is becoming reality. SPs are a core concept discussed today in the context of the Internet of Things [29]. SPs contain ICT in the form of, e.g., microchips, software, and sensors and are therefore able to collect, process, and produce information [42]. SPs possess different degrees of smartness (capabilities) in terms of, e.g., autonomy, adaptability, multi-functionality, or ability to cooperate [42].

A new class of SPs is equipped with the so-called embedded configuration capability, which means that some of the product features are adjustable and adaptive to the preference of a specific user or context [38]. We see three different types of SP scenarios for PCUS based on the existing products in the market:

1. Smart adaptable products: Some SPs provide the configuration toolkits (either embedded toolkits or connected Apps installed in smart devices) to facilitate user customization in use. For example, the Philips Hue smart light product allows customers to create different color effect and brightness for different situations like reading, romantic moments, lively parties, etc. All the light customization can be completed by consumers in a special toolkit called "Hue system" installed on a mobile phone.
2. Smart autonomous products: Some SPs are sustained by smartness, such as adaptability and autonomy, and can automatically adapt to the situation and reconfigure themselves accordingly without any dedicated user action. This is the case with the Nest thermostat. It is able to adjust temperatures autonomously to the preferred temperature based on learning about the home dweller's living habits and the conditions it senses. In this way, product smartness is utilized to save the entire effort of manual configuration. However, consumers perceive loss of control and risk from high levels of product autonomy [42]. Often, SPs with high product autonomy lead to perceived complexity since they work silently and automatically like a black box and are difficult for users to understand [42]. Furthermore, the self-creative value from self-customization may be lost by automatic adaptation through a SP [18].
3. Smart adaptive and adaptable products: Some SPs try to balance the benefits and disadvantages of autonomous automatic adaptation. Take the case of Nike HyperAdapt. These shoes can automatically lace themselves when the consumer puts them on, but it also allows consumers to adjust the lacing by the connected App in mobile devices according to their feeling of comfort.

Beyond that, PCUS with SPs, in comparison with traditional PCPS, broadens the scope of customization beyond fit, function, and aesthetic customization to product-related service customization. For example, enabled by sensors gathering and monitoring usage data, some SPs can report on themselves and their environment in real time and can tell how the consumers are using them. Many smart sport devices nowadays like smart balls or wearables are able to proactively provide individual real-time data and personalized diagnoses and performance analysis.

4 Theoretical Background for User and Smart Product Interaction Design

From the above, we can see that not all smart products offering customization possibilities can lead to customer satisfaction. For instance, smart autonomous products enabled with product smartness and capabilities can provide highly individualized products/services (i.e., product adaptations, individual interaction, and experiences) by themselves. But not all are wanted. On one hand, smart autonomous products can save time and effort for users [3], but on the other hand, they can increase users' 'perceived disempowerment, thus impact intention to adopt' [48]. The design of user and product interaction can take an important part in influencing adoption of smart products. Therefore, the question lies in how to design smart products and user interaction in a way that satisfies the customization needs better?

Earlier research in this domain mainly relied on the concept of embedded toolkits for customization [38], but did not deploy most functions and the abilities of SP (like autonomy, adaptability, etc.). So, in this part, we try to connect mass customization, smart products, and toolkits together. Our aim is to systematically explore which kind of smart products can be utilized for PCUS and how smart products can lead to higher customer satisfaction by customization. Specifically, we are focusing on the design parameters of user interaction with smart products.

To explore this question, we rely on the following theoretical underpinnings for the proposed design principles of user and smart product interaction.

4.1 Product Autonomy

Product autonomy refers to the principle that a product does not need human intervention but instead takes over on its own [42]. Enabled by the capability of adaptive autonomy, some products can show proactive and self-starting behavior, perform physical tasks, and take over (some of) the user's normal decision-making tasks. According to Baber (2001) with the example of a washing machine, a product can be autonomous on four levels: the manual level, bounded autonomy, supervised autonomy, and symbiosis [3]. The highest level, symbiosis, assumes ongoing communication between the user and the product to fulfill some common goal. With the example of the smart washing machine, after all the laundry is put in, the user would close the door, and the machine would set the appropriate program and run it automatically. With the application of advanced sensors and ICT, many smart products are trying hard to reach the highest level of symbiosis where the users don't need to intervene at all and SPs sense the context, proactively make a decision, execute the tasks, and provide individualized solutions by themselves in the usage process.

In the following section, we discuss the problems related to user perception coming from autonomous customization enabled by high levels of product adaptive autonomy.

4.2 User Perceptions from Autonomous Customization by SPs

Perceived Autonomy

Individual autonomy is identified in self-determination theory as one of three innate psychological needs promoting intrinsic motivation for activities which lead to enhanced outcomes. It pertains to the degree to which individuals can feel the freedom, independence, and discretion to decide what should be done in a particular situation. In line with self-determination theory [44], when the task offers limited autonomy, the feeling of self-determination will be undermined, which results in diminished self-motivation and dissatisfaction of outcomes [34]. On the other hand, when individuals perceive autonomy, self-initiating and regulating work will lead to empowerment, and mental health (e.g., satisfaction) will be enhanced. Feelings of autonomy help individuals to identify with outcomes and perform tasks out of enjoyment and satisfaction. Previous research has shown that the intrinsic motivation through higher perception of autonomy is likely to be sustained over time and enables individuals to continue acting [34].

With regard to autonomous customization by SPs, users are likely to perceive lack of autonomy because SPs change and adapt to users and contexts automatically without any user dedication. Also, users cannot identify them as the independent and causal agents on the results, which is completely dependent on the SPs. This may lead to dissatisfaction with the performance of SPs that are responsible for the results. Although autonomous adaptations by SPs can save time and effort for the user to perform tasks, it also takes over the work done by users before, such as the freedom to make decisions about product adaptation. Hence the subjective perception of autonomy, in terms of freedom to act on their own to reach their personal needs, cannot be fulfilled by SPs with autonomous customization. Furthermore, the intrinsic motivation to perform out of enjoyment and satisfaction cannot be achieved.

On the contrary, some SPs allow user participation when producing and delivering preferred configurations or product solutions in the usage stage. For example, users are involved in developing their favorite solutions or making some decisions themselves. This kind of participatory behavior in satisfying the specific usage needs can be one of the main drivers of customer satisfaction with the performance and value perception [2, 9]. Continuous perception of self-determination through high user autonomy would be easily achieved and enable users to continue performing the product customization in use out of interest and enjoyment. This would enhance user satisfaction with the outcome, since users would recognize themselves as the cause of the outcome. In addition, according to a study about perceived autonomy from app developers, a platform developer will produce apps of higher quality and tend to continue to develop if they are empowered with a perception of high autonomy [26]. User engagement integrated with high-level product autonomy could be helpful for continuous co-design or creation with SPs over time. Based on the above, an optimal level of product autonomy with the option for users to customize for themselves would be better for perceived autonomy.

Perceived Control

Except for perceived autonomy, perceived control is also related to SPs for PCUS. Perceived control is seen as essential for individuals' general wellbeing and is often defined as the need to demonstrate competence and mastery over the environment [54]. It represents the extent to which individuals perceive that they are able to exert control over the environment and influence the process and outcome and is responsible for the outcome of a given situation [11, 15]. If the SPs do the autonomous adaptation and users are not responsible for the adaptation result at all, users would tend to perceive loss of control.

In fact, the feeling of control is connected to an emotional response of dominance in environmental psychology. As indicated by Mehrabian and Russell (1974), a person's level of control is reflected by dominance, influence, and autonomy [32]. Some previous research states that the concept of control is rooted in the need for competence in influencing the environment and for autonomy of behavior [7, 15, 54].

Perceived control has also been widely investigated in research about the interaction between users and web-based environments or various information systems [33]. It measures the user's experience of level of control, frustration, and confusion during interaction with the system [10]. In web-based environments, the feeling of control can be present through manipulation achieved by virtual control, which allows consumers to exert their control over products directly by manipulating images and operating various functions [22]. When users are interacting with SPs, they directly manipulate the product, which contributes greatly to product understanding. In PCUS, product information and feedback are presented through multiple sensory cues and channels. Any adaptation changes made by users, e.g., changing the parameters, adding a new service or function, turning on or off the automation, etc., can be seen, and the outcome of the product can be easily evaluated in reality. Product customization by users (e.g., users specify the product changes at a certain moment) through connected toolkits in PCUS would be able to affirm their competence and impart a feeling that they are able to influence the product. In autonomous customization by SP autonomy, the SP completes every change for users, which does not give users the opportunity to demonstrate their competence and ability to influence. Furthermore, if the product works autonomously and makes the ongoing changes dynamically, users can get confused, face perceived complexity, and will probably reject the result since they are not aware of when and how the product works [42]. If users try to influence when they are not satisfied with automatic adaptation but do not have the supporting tools, they are likely to get frustrated. Therefore, in autonomous customization, users are not enabled to evaluate and determine but surrender and become a passive recipient.

As is found in previous research, having a sense of control has a positive influence on the performance of a task [4, 5]. The higher degree of control the users perceive, the more they are likely to exert cognitive effort, show interest while problem solving, and continue taking actions even in the face of difficulties and failures.

Furthermore, previous studies have found that, when users are granted the freedom to self-select, self-service, or get involved in the design practices based on technology such as tools, for example, by specifying their own settings on how an application should behave, they perceive a sense of control in their experience with the technology [6, 12]. To enable users to configure the product components or product-related services is a complex but applicable approach to grant user control. If users can configure the SPs and related services through embedded toolkits, they can gain a greater perception of control, which promotes the user's development and design activities, further enhancing consumer enjoyment and satisfaction with the outcome.

Moreover, Furby (1978) argues that the more a person is able to exercise control over an object, the more they will experience this object as part of the self and evolve a sense of ownership [20]. If users cannot attribute the outcome to themselves at all, the feeling of accomplishment and subjective contribution to the self-design process will be missing [17]. This proud feeling of accomplishment serves the need for feelings of competence and efficacy deeply embedded in human nature [21, 55].

We can assume that autonomous customization by SPs diminishes users' perceived control and would thus lead to a negative influence on satisfaction with the process and outcomes from SPs. The feeling of control can be achieved during the design of a system or the way users are integrated. However, if the user tries to extend or specify everything, they might be overwhelmed by the complex configuration process. So, there is a trade-off between smart product autonomy and user control complexity.

4.3 User Adaptability and System Adaptivity

In the area of adaptive user interface design, Bunt [8] says there are three different potential solutions to manage the complexity problem of interfaces: (1) an adaptable interface that allows users to customize the application to suit their needs, (2) an adaptive interface that performs the adaptation for the users, or (3) a combination of adaptive and adaptable solutions, which is an approach that would be suitable in situations where users are not customizing effectively on their own.

System adaptivity is defined as the ability of a system to adapt automatically to different users according to the context with respect to functionality, content presentation, content selection, and user interaction [23, 37, 45]. This system predicts the optimal product configuration or service and automatically adapts based on comparison of the customer's profile to certain reference characteristics [1, 43]. User adaptability places users in control of customizing or tailoring the system according to their individual needs and situational requirements [8, 31].

As we can see from the definitions, these two approaches keep the system adaptable and changeable during usage. However, the adaptive approach can suffer from some users feeling a lack of control over the process, a lack of transparency, and a lack of predictability [8, 37]. In addition, human preference is heterogeneous, and the situation changes over time so that it is impossible to anticipate the requirements of all users and always provide the best configurations. Therefore, it is necessary to allow a coexistence of automatic system adaptivity and user-controlled adaptability resulting in a flexible system through shared initiatives [37, 45]. An example of the combination of these is the auto-correct function. Users are able to switch off this function when auto-correct does things to the text that the user does not want. Fischer proposed shared decision-making between purely adaptive and purely adaptable systems, in which users and system components contribute to the modification of a system [45].

Actually, this applies to PCUS with SPs as well. System adaptivity is quite similar to autonomous customization by SPs, in which SPs supported by sensors and advanced data analysis that can detect the surroundings personalize content, change the product function or form, or come up with great suggestions for the service in different contexts. However, it is difficult to anticipate every usage situation. For personalization without users by SPs, the actions done by algorithms may not exactly fit with user preference, which requires a thorough understanding of the users' context and habits. This becomes especially difficult when situations are constantly changing. In the end, it is the user who knows best. Moreover, automatic personalization might not always be sufficient. End users might want not only to reconfigure the product, but they might also want to add new a behavior such as a new service or applications specific to their needs.

We propose that there should be a coadaptation between user and smart product, which means a trade-off between SP automatic personalization and user-controlled customization. By means of coadaptation, this can enhance user productivity, optimize workloads, and increase user satisfaction with increased control and autonomy.

An illustration for the coexistence of SP adaptivity and user adaptability is the Nike smart shoe. It provides consumers with the option to customize after they have bought it in a way that the shoe itself can do itself automatically and personalized tying. The consumer can also adapt the tying according to their preferences via the connected toolkits.

5 Design Principles for User and Smart Product Interaction Design for PCUS

Complementing the theoretical discussion in the last section, we conducted a number of semi-structured interviews to derive additional insights into the research topic. Our objective was to learn from designers and product developers commissioned with developing smart products about how smart products enable our idea of PCUS. We were especially interested in the design parameters companies follow when developing the user interaction with SPs. We conducted five expert interviews with experienced smart product designers (Table 1), which helped us to suggest

Table 1 Semi-structured expert interviews

Interview no.	Company	Area
1	Ambihome, product designer	Smart home
2	Philips Hue, product designer	Smart light
3	Physiosense, product designer	Smart chair
4	Vestel, product designer	Smart TV
5	University of Southern California, professor	Product development engineering

three preliminary design principles to develop SPs for PCUS. These principles are proposed to elevate the feeling of autonomy and control through certain user and smart product interaction designs.

5.1 Cooperative Adaptation: Shared Control Between Users and Smart Products

5.1.1 User and SP Coadaptation: Cooperation Between Users and SPs to Better Fulfill Customization Needs

According to theory of system adaptivity, a system can perform tasks for all stages from observing communication, deciding whether to adapt, generating and evaluating different variants, to finally selecting and executing one of these options [36]. User adaptability and system adaptivity should compensate for each other due to the shortcomings of each approach [28].

SPs that customize products to specific user needs should be under user control. Smart, connected products can be controlled through toolkits embedded within them or that resides in the cloud. Users have an unprecedented ability to tailor product functions and personalize interactions as they wish [39]. It is also confirmed in the interviews that it is important for users have the option to reconfigure automatic adaptation by SPs (Interview 3,5). Users should always have easy access to self-controlled customization (Interview 1,2).

In the early usage stage, users should be more active in specifying their preferences, and SPs need to be talkative to gather more usage data and lead users to express their preferences themselves (Interview 3). At this stage, default starting solutions can be provided to reduce user effort in specifying the product at the beginning. Self-customization could be dominant at this stage. In the mature usage stage, SPs could play a more active role. Based on the learning of user habits or preferences and continuous improvement, the SPs could provide adaptive solutions to users. Therefore, users don't need to expend effort on always controlling the product but still adapt the product in accordance with their preferences (Interview 2).

Even during the mature usage stage, the user's involvement is important to fulfill needs in specific situations. When the SPs recognize missing values or capabilities to perform the task automatically, the users should be informed to take action.

5.1.2 SPs Perform Routine Tasks to Reduce Effort for Users and Prepare Support and Suggestions for Users, but Users Are Empowered to Make Decisions [39]

The experiment by Opperman et al. in evaluating adaptable and adaptive software systems showed that users prefer to deal with systems based on shared decision-making: the user can act on their own and get support from the system whenever they like. Based on this, the adaptive SPs should do more of an assisting job than an executing one. That means SPs are responsible for preparing support and suggestions for the users, but users have the freedom to accept or reject the suggestions [37]. Whenever possible, more than one adaptation suggestion should be offered, as SPs are usually not able to identify the users' needs precisely. The user should have the freedom to select from a number of different adaptations suggested by the system.

The automation capability of SPs should be utilized to enhance the work of users, making users more capable and effective [39]. As discussed in robotics design, automation should be used to augment human abilities by taking the dirty, dull, and dangerous tasks and assisting users to finish exciting, creative works [35]. For example, user-controlled SP adaptation should allow the user to take the initiative and issue the demand. Specifically speaking, SPs should take care of the routine tasks (proposal and execution) and entrust the creative tasks (initiative and decision) to the user.

When we design tools for PCUS, we should think of users and SPs as collaborators, not as replacements. To realize this, there should be shared control and collaborative work on the product adaptation between SPs and users. SPs can provide users with personalized solutions, suggestions, and feedback, and users can decide what the smart products should do and select their own content via embedded toolkits. However, suggestions or feedback from the SPs should not disturb the user unnecessarily in their work. SP automatic adaptation features are only aids to the user, and suggestions should not take the user's attention away from the real task.

5.1.3 Provide Possibilities for Users to Override or Change an Autonomic Adaptation from SPs

The feeling of user empowerment derives from flexibility in defining their own choice [53]. Therefore, users should have the possibility to control the autonomous choice set composition via self-choice. This means that users have the ability to reconfigure and adjust actions from SPs.

In addition, the user should always have complete control over product smartness. There should be an option to stop the work of the SP or interrupt actions of SPs at any time, so that users feel they are in control of the product. For example, users are provided with a switch to turn the automation function on or off. If the SPs are doing something that users don't want them to do, users can disconnect the service, and SPs lose control over the outcome [56, 40].

5.2 Empower Users with Control by Product-to-User Communication About the Product Progress

Unlike with PCPS, users have to translate their needs into virtual product design. In PCUS with SPs, the interaction of the product and user can be both direct and mutual. It is more like a "communication." In PCUS not only do users directly communicate with SPs by transferring their preferences into the product and controlling the product via embedded toolkits (user to product interaction), but also SPs can present information to users in different ways (product-to-user interaction) [36]. This makes SPs dramatically different from traditional products. To create high-quality product-to-user interaction, embedded toolkits play an important role. The toolkits are the intermediary medium for users to collaborate with SPs based on the output from SPs and should be designed to reduce user customization effort, empower users with control by improving product transparency, and convey individualized feedback to users.

5.2.1 Present Sufficient Indicators and Feedback About the Product Progress, so that Users Can Feel in Control of Smart Product Actions

A good design provides users with a conceptual model for what is happening, with feedback and visibility that promotes product understanding and a feeling of control. Except for enabling users to self-select content, which is realized in the user customization we proposed before, delivering feedback to users is also identified as one main source of user empowerment [51]. For autonomous smart products that operate automatically without direct input from the user, some actions may be unwanted or illogical from the user's perspective, so it is important to inform users about why the product performs these actions. By equipping users with feedback on what the product is performing at a certain moment, the visibility of the SP's actions will be increased [40, 56], and the perceived complexity from not understanding the product functions will be reduced [41].

5.2.2 Increase the Process Transparency of How the Different Product/Service Adaptation Is Generated

The transparency of the service process in smart service products is proposed to positively influence users' attitudinal and behavioral responses to these services [56]. Users want to know not only what actions the product has taken but also why and how an outcome is generated. This kind of transparency is also proven to be able to improve users' perception of control [56].

Especially when generating individualized services, different sources of usage data are collected and integrated by the SPs autonomously. Users can easily feel loss of control not only in the function of the product but also in the data usage. This perception of control over the process will improve if the transparency of data usage is available to users when they want to know. One example of the transparency would be that users are able to be informed about what kind of data is collected and how the data is transmitted and integrated. Users therefore not only see the aggregated data or personalized suggestion but also feel in control of how the solution is generated. The transparency of the process can be reflected in the form of the protocol or working documentation stored as a feature in the service system [56].

5.3 Trial-and-Error Learning by Both SPs and Users

In the smart product age, the trial-and-error learning process applies not only to users but also to SPs. One of the big advantages of SPs is the ability to learn actively from users about their needs by collecting, integrating, and analyzing daily usage data. Trial-and-error learning processes are experienced by both users and SPs. Since the product functions are changing dynamically to fit with different environments and users, users have to learn not only about their preferences but also about the SP's actions and processes via interaction with toolkits as mentioned in principle 2. In addition, a lot of in time usage data is generated. Users have to learn to interpret the data and understand the meaning behind it.

5.3.1 SPs Learn to Continuously Adapt to Users and Provide Exciting Features for Users

Adaptability is an essential capability for smart products to continuously offer customized products/services to users. Enabled by adaptability, SPs can improve themselves by learning from the user's profile, usage pattern and habits, and so on. For example, if the SP has noticed that the users don't like a certain kind of activity at all, the smart product will not make proposals about what the users don't like any longer. With the advanced intelligence embedded into SPs, the age of symbiosis is arriving. Smart products are working together with users to achieve the same goal. With learning and the error process, SPs stay flexible in gathering and processing information, making decisions and thus providing individualized solutions dynamically.

Moreover, SPs can be used by a manufacturer as a means to collect usage data on users' everyday activities. Utilizing this daily usage data, SPs can continuously provide exciting features to users to satisfy the unmet but not noticed needs of specific users (Interview 5; Lu 2016). As is stated in Kano model, exciting features are those that are unseen by users but, when implemented, will yield increased user satisfaction [27]. This distinguishes PCUS in the smart product age from traditional mass customization where it is impossible to get information about usage behavior and only performance features can be provided (Interview 5, Lu 2016) [24].

5.3.2 User Learning About the Meaning and the Value of the Data

The special problems coming from PCUS with SPs are information overload due to the large amount of behavioral data and understanding the information. If the data are not presented to users in an appropriate way, confusion and loss of control would likely result and thus decrease the value SPs create.

To facilitate user learning about usage data, it is necessary to provide users with high-quality data interpretation. This must be easy to understand, insightful, user-friendly, and presented with the aim of helping users truly understand the meaning of the data and how to improve [49, 51].

5.3.3 Smart Products as Tools to Facilitate the Trial-and-Error Learning Process of User Co-creation in the Usage Stage

SPs are not finished products that are just for users to consume but rather unfinished and open products allowing users to become both consumers and producers. Based on the embedded toolkits or interfaces that are part of SPs, users are enabled to create the extension of the SPs according to their needs and experiences. Take the example of the Philips Hue, which provides modules for users to develop their own apps connected to the product system or program to add new functions. These modules consist of end user-friendly navigations, programming language, and programming examples as starting points to help users to explore their co-design activities (Interview2; [37]). In addition, the user community can be included in the toolkits to learn and exchange knowledge and experience with others, so that users can be empowered to resolve their own problem. Users feel empowered. Through the learning and trial creation process supported by smart products, users not only achieve the preferred products and services but also achieve creative value [16].

6 Conclusions

This paper discusses users' perceptions of control and autonomy in situations of autonomous customization with a smart, i.e., adaptable, product (SP) in the usage stage. To enhance users' positive perceptions and reach higher consumer satisfaction, our research strives to understand how smart product can realize the idea of PCUS and which design parameters in the interaction process between users and SPs support this process. Based on theoretical foundations and semi-structured expert interviews, three preliminary principles to develop SPs for PCUS are proposed. Especially, we propose the concept of user and smart product coadaptation, which means that user participation is included to complement autonomous customization by SPs.

This research connects the fields of mass customization, toolkits for user co-design, and smart products enabled by the IoT by proposing a new customization concept to be realized in the smart product age. PCUS with SPs extends our traditional understanding of customization into a new horizon. This research provides a different perspective for companies to transfer NPD especially to the users. It also explores how smart products can be used for customization in the usage phase and how smart products can lead to higher customer satisfaction through the design of user and smart product interaction. Specifically, it could be insightful for companies to design SPs for offering better customization or service-driven personalization.

PCUS with SPs provides a new opportunity for user co-design, where the design process is not just based on the ability of expert designers. In the conventional toolkit-based customization approaches (PCPS), novice users lack knowledge about product characteristics and hence are dependent on what the provider has suggested before. In the new customization approach proposed in this paper, however, they become able to experiment with real feedback during the usage stage and build consumption competence that then enables them to complete a more meaningful customization. However, the proposed principles of the design parameters for smart and user interactions still need to be tested in a larger empirical study. A special focus should be how consumers react to the shared control and collaborative adaptation in different usage contexts.

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