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User-experience based product development for mass personalization: a case study

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Abstract

Nowadays, with the rapid development of information technologies (e.g. web 2.0, cloud computing and virtual reality) and manufacturing technologies (e.g. additive manufacturing), users become more actively involved in the product development stage to create personalized products with higher efficiency. This emerging manufacturing paradigm is known as mass personalization, of which *user experience* (e.g. emotional factors and product utility), *co-creation* (e.g. user participation), and *product change* (e.g. modular design) are regarded as three key characteristics. In previous studies, researchers often treat each characteristic separately with an illustrative example to demonstrate its significant effect respectively. They, however, cannot fully reflect the product development process for mass personalization, and may cause inconsistency in implementing the existing methods into real cases. To fill the gap, this work proposes a three-model based (i.e. physical model, cyber model and user experience model) generic framework for conducting user experience based product development for mass personalization. A case study of a personalized smart wearable product development is described, of which the three key characteristics are considered collectively. It can also be seen as a typical case integrating the frontier techniques to enable mass personalization. The authors hope this work can provide some useful guidance to product designers and engineer-to-order companies.

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1. Introduction

Owing to the fast development of information and manufacturing technologies, products become more and more information densely (i.e. smart) and personalized (i.e. low volume in high variety) to meet user's individual requirements. In personalized product development stages (or innovative design process), users are more actively involved in the co-creation process even without much design knowledge. To facilitate it in a user-friendly manner, companies often provide co-design toolkits (e.g. product configurator) [1] in a virtual environment or embedded toolkits (e.g. product with built-in-flexibility) in a tangible way so as to achieve better user experience (UX) and satisfaction [2]. Moreover, product itself provides not only pragmatic functions, but also social and emotional interactions with the users [3]. As pointed out by [3], UX-based product design should emphasize the exploitation of implicit data (e.g., purchase history) aiming to predict users' unexpected needs.

In order to describe this manufacturing paradigm, several academic concepts have been proposed, two of which are widely accepted: mass personalization [4] and mass individualization [5]. The major difference lies in the consideration of sustainability and extendibility of a product in mass individualization. Nevertheless, three key characteristics of personalized product development are defined coherently, i.e. product change, co-creation and UX.

Though plenty of research works have been done in this area, each characteristic is addressed separately. For example, product change was studied by introducing adaptable, modular and scalable design methods [6]; co-creation was conducted by utilizing product configuration system and

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embedded open toolkits [2]; while user experience was elicited by marketing strategies in a certain context-of-use (e.g. questionnaire and focus group) or by digital equipment (e.g. virtual-reality headset and eye tracker) [3]. None of them can fully reflect the UX-based product development process for mass personalization and may cause some inconsistency in implementing the existing methods into real cases. To fill the gap, this paper offers a case study of a personalized smart wearable product development (i.e. respiratory mask) in a start-up business, of which three key characteristics are jointly considered. The rest of this paper is organized as follows. Section 2 gives a detailed review of related works of product development for mass personalization. Section 3 depicts an overall process of personalized product development with regards to the three key characteristics and proposes a conceptual framework. Section 4 describes the case study in details. At last, the conclusion and future work of this research are given in Section 5.

2. Related work

2.1. User experience

ISO 9241-210 defines UX as "*a person's perceptions and responses resulting from the use and/or anticipated use of a product, system or service.*" [7]. It is usually latent and difficult to exploit through marketing analysis. It originates from evolution of the user's affective states triggered by stimuli (events) along with a chain of cognitive tasks which is the most profound feature of mass personalization [8]. UX realization is based on product's functional performance, so that the elicitation of cognitive and affective needs can also lead to identification of unexpected performance related requirements. Thus, for personalized product development, both affective and cognitive requirements should be accompanied with functional requirements (FRs) concurrently [4], and users care more about the value, the identity and the experience of creating the personalized product rather than product itself [9]. Another important thing is the context-of-development, designers should pay more attention to the specific scenarios which are capable of influencing UX. Moreover, to create long-lasting hedonic products, it is suggested that designers should emphasize more on the experiential aspect of the interactions between users and products, so as to understand potential UX and to implement design for experience [10].

2.2. Product change

Generally, product change can be achieved by modular design in macro-level (i.e. functional modeling) and scalable design in micro-level (i.e. parametric optimization) [11]. For the former one, one of the prevailing method is the adaptable design which was firstly proposed by Gu, et al. [6] with product lifecycle sustainability concerns. It stands for the ability of a design or a product to be adapted to new requirements and reuse it when circumstance changes by adding or replacing certain modules through pre-defined adaptable interface [12]. Levandowski, et al. [1] utilized the design adaptability principles to develop a two-stage product platform for 'engineer-to-order' (ETO) product configuration. Koren et al. [5] adopted the adaptable design concepts in an open product platform development.

For the latter one, scalable design focuses on offering a wide range of functionality to different customer groups by changing the parameters of existing attributes in a vertical manner [13]. In such a way, changes of CRs can be postponed to the latter stage of product development so as to lower the cost. One of the most accepted method is Claesson's configurable component (CC) concept [14] and it was further developed to involve concepts such as: bandwidth [15] (i.e. the total range of parameters of design solution) and geometry interface modelling [16] (i.e. determine the geometric parameters of the interfaces between features).

2.3. Co-creation

In literature, there are two typical ways of enabling co-creation effectively and user-friendly. The first one is the online configuration system (e.g. NikeID and Dell), which plays a significant role in offering tailored products with shorter lead time to market [17]. It consists of a set of predefined attributes with constraints (rules) for customer to select within the product family scope [18]. Generally, it operates in a 'configure-to-order' (CTO) model, which utilizes customers' specifications as input, and the system would derive the recommended or target product fulfilling customer needs as output. In such ways, it bridges the gap between CRs and the end-product by a series of attribute selection process [19]. The main challenge is to effectively define personalized modules beyond the existing product family in an ETO model.

The other is the embedded toolkits for user co-creation [2] (e.g. Adidas One) which is proposed to design products with build-in flexibility by shifting some specifications of the product into the domain of the user. It is known as a postponement method to increase design flexibility. According to Gross and Antons [20], it should contain: 1) *a flexible architecture* where design parameters are adaptable; 2) *a set of rules* to verify the feasibility of possible combinations; 3) *an interface* for individual users to manipulate the values according to their own preferences. Moreover, Bénade et al. [21] combined the modern C-K theory to develop a theoretical framework for use generation of smart products with built-in flexibility.

3. A generic framework of UX-based personalized product development process

Personalized product development process, similar to the innovative design process, aims to deliver unique product with specific values to achieve customer satisfaction [22]. Fig. 1 gives an overall picture of personalized product development in regards to the three key characteristics (i.e. product change, co-creation and UX).

The co-creation process can be seen as a two-type innovation: 1) *utilitarian innovation* process which emphasizes on the use generation (e.g. airbag for human protection); and 2) *hedonic innovation* process which focuses on the specific meaning delivery (e.g. fancy appearance) [23].

To realize *utilitarian innovation,* either new technologies (e.g. cloud computing) or new functionalities (e.g. smart detection of car crash) need to be developed or utilized. Also, for *hedonic innovation*, sensorial and emotional features (e.g. coca cola with personalized signature) or symbolic features (e.g. kiwi bird represents New Zealanders) should be considered in the product development process as well. In personalized product development process, these product changes should be either pre-defined as built-in-flexibility or modularized with adaptable interface for future upgrade or add-on (Fig. 1). Correspondingly, for personalized product development, the UX can be evaluated by certain types of value created. According to Rokeach [24], values are, enduring beliefs that certain processes or goals are better than others. Therefore, UX can be determined by usability value, sensorial, emotional and symbolic values created by the users along the whole product development process (Fig. 1).

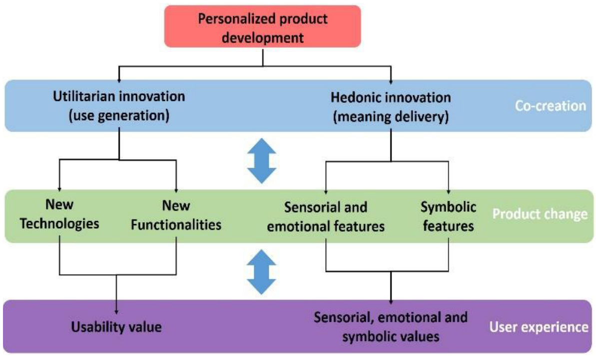

Fig. 1 Overall picture of personalized product development process in regards to UX, co-creation and product change

Following the above definitions, and inspired by the concepts of cyber-physical system [25], a proposed conceptual framework of UX-based personalized product development process is given in Fig. 2. It consists of three models: *physical model, cyber model* and *UX model.*

Physical model stands for the physical products (e.g. wrist band) and services (e.g. app subscription) in the real world. In personalized product development process, it mainly contains three parts: 1) personalized attributes, such as unique appearance or functions; 2) 3D-printed product prototype, which is utilized for rapid prototyping in a tangible way; and 3) smart functions, which act as the services attached to the product.

Cyber model stands for the web-based virtual co-design resources. It normally consists of: 1) CAD models, which are the virtual presentation of the real product; 2) co-design product configuration system (or embedded co-design toolkits), which aims to facilitate the complicated co-creation process in a user-friendly manner; and 3) support of social media tools, such as online community (e.g. Facebook and Twitter), which is mainly adopted to discover latent design information.

UX model stands for the user's affective factors (e.g. emotions) and cognitive behaviors (e.g. feedback) in the context of product development stages. Mostly, 1) marketing strategies (e.g. focus group and questionnaires); 2) real time analysis (e.g. eye tracker); and 3) design and usage context (e.g. virtual environment or physical environment) are exploited to modeling the UX.

In the personalized product development, each model interacts coherently with others in a certain product development context. The existing *physical model* can be utilized for new design concept generation for product innovation, while in return, the established *cyber model* will be manufactured into the physical one as the end product. Also, users can obtain either tangible experience in a *physical model* or a visible experience in the *cyber model*, and reversely, specific co-design behavior or product-service evaluation can be derived based on the *cyber model* and *physical model*, respectively.

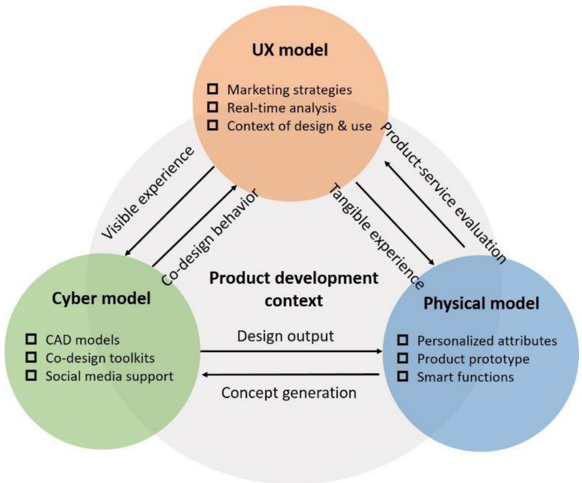

Fig. 2 The proposed conceptual framework of UX-based personalized product development process

4. Case study

With the rapid development of wireless body sensor network, more and more wearable devices have been brought up in recent years (e.g. wristband, shoes, earphone, etc.). According to Gartner report [26], the total global market share of smart wearable devices will reach 28.7 billion USD, of which 20% are healthy related. However, only 15% people worldwide are aware or ever try-on these products. There lies a huge market prospect in the future.

Traditionally, respiratory mask is regarded as a mass production product with little changes. Due to the ever increasing concerns about air quality and demands of personalized requirements, several new types of masks have been promoted to the market. Among them, a start-up company in New Zealand is working on developing personalized smart respiratory masks for different application scenarios (e.g. running/cycling mask, anti-smoke mask, etc.).

Before undertaking a series of innovative co-creation process, the company has done a comprehensive study of the existing products by utilizing the following marketing strategies among young people aging from 20 to 30: (1) Analysis of existing products in niche market, and classify them by attributes, such as: application scenario, functions, asthetics, and smart attributes. (2) Conduction of online questionnaire to discover the shortages and advantages of existing products, and to understand the potential demand for personalization and smartness. (3) Enrollment of lead users and undertake focus group to elicit main CRs for product innovation. (4) Utilization of affinty diagram to classify the key requirements, and determine the relative importance of them.

Based on the above steps, the designers decided to developing a new product mainly considering four aspects:

Healthy. The healthiness and comfortableness are the key functions of the respiratory mask. The product should be seamlessly attached to the face and be comfortable for long time wearing. *(utilitarian innovation)*

Pesonalized. A large portion of participants argues about the apperance and functionality of the existing products. The tendency towrds personalized product is promising. *(hedonic innovation)*

Smart. Micro-nano sensors and low energy consumption technology (e.g. Bluetooth 4.0) are the key enablers. A smart mobile APP should be developed for better UX and interaction. *(utilitarian and hedonic innovation)*

Hyperconnected. An IoT (Internet of Things) platform should be established to monitor user's breathing conditions and undertake Big Data Analytics to give users better advice of healthy breathe. *(utilitarian and hedonic innovation)*

Guided by the proposed framework, a nine-step UX-based personalized smart respiratory mask co-development process is established, as shown in Fig. 3. Lead users are invited for the co-creation process as follows:

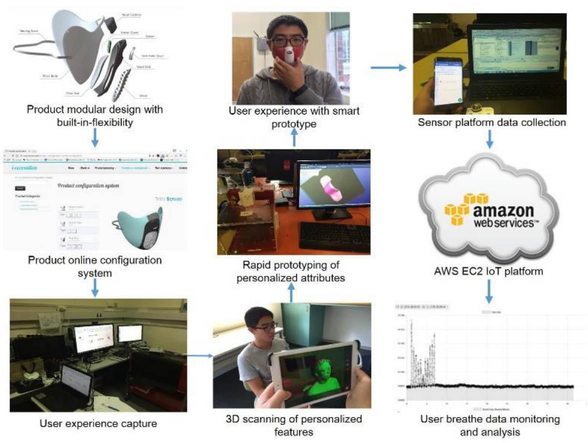

Fig. 3 UX-based personalized smart respiratory mask co-development process

Step 1. Modular product design with built-in-flexibility.

In order to meet the ever increasing demand of personalization, designers decomposed a new product into three categories: common parts (e.g. N95 filter), customized parts (e.g. product size) and personalized parts (e.g. nasal part, color). Common parts stand for the ones that used all among the existing product family. Customized parts stand for the ones that can be changed by selecting from the existing options. Personalized parts are the ones can be defined by the users themselves. Both customized and personalized parts can be changed or upgraded easily by adaptable interfaces. Also, for scalable design, in order to give users certain degree of freedom, a new product should be able to scale up or down some specific parameters (e.g. mask size). That is known as built-in-flexibilty.

Step 2. Product co-creation by online configuration system.

To facilitate user's co-creation process, a user-friendly configuration system is developed for customized parts selection. Users have the freedom to select each attribute with specific parameters based on the rules defined by the system to achieve their own satisfaction.

Step 3. UX real time capture.

In order to capture the real time UX along the co-creation process, both eyetracker equipment and camera are utilized to observe the user's gazepoints and facial expressions, respectively. The data is further analyzed in combining with the questionnaires to elicit UX.

Step 4. 3D scanning of personalized parts.

For personalized parts, 3D scanner is utilized for establishing a specific cyber model. For example, the nasal componenet is a key part, which enables the air-tightness of the respiratory mask. In this regard, the scanned model is further optimized by parametric modeling.

Step 5. Rapid prototyping of personalized parts.

3D printing is utilized in the product development process for a rapid prototyping of personalized parts. For common and customized parts in small batch, 3D printing can also be exploited, depending on the complexity of the product itself.

Step 6. UX with smart prototype.

Sensors with microprocessor (i.e. ARM) are embedded in the prototype, and users are asked to test on the prototype. Their UX data is recorded by a face-to-face communication.

Step 7. Sensor platform data collection.

A smart phone APP is developed to monitor user's breathing condition (e.g. pressure and humidity), reminder of users' proper wear, etc. All the sensor data is transmitted to the users by low energy consumption protocal, i.e. Bluetooth 4.0. The user-friendly interface also maintains the active interactions between the user and the smart product with better UX.

Step 8. IoT platform development.

In this case, Amazon EC2 platform is utilized to develop the IoT platform. All the monitored data can be transmitted from the mobile phone to the platform by 3G/4G network. The platform works as a data centre.

Step 9. User breathe data monitoring and analysis.

In the final development stage, users' breathe data can be utilized for product improvement by the designers. For example, if the humidity is too high, it can somehow be undertood as air circulation is not well-designed. Also, the collected data can be further utilized to establish some healthy breathe guidelines for individual user.

With the above steps in co-creation, one can find that, among the overall product development process: *Step 5 and 6* are physical models which both customized parts and personalized parts are tangible in the real world. *Step 1, 2, 4, 7 and 8* are cyber models which the virtual models are established in corresponds to the physical models. *Step 3, 6* *and 9* are UX models which users obtain both visible and tangible experience during the personalized product development process. Each model interacts with others coherently to enable the success of end product.

5. Conclusion

UX plays a significant role in the product development process, which not only affects the co-creation effectiveness, but also the success of end product. This work provided a three-model generic conceptual framework (i.e. cyber model, physical model, and UX model) of UX-based personalized product development process by considering three factors, i.e. product change, co-creation and UX coherently. In order to fully describe the proposed framework, a case study of personalized smart respiratory mask development was given. To achieve each user's satisfaction, products were decomposed into various customized modules. Users were involved in the co-design process by selecting from each module in the online configuration system (cyber model). To capture UX, both real time monitoring equipment (i.e. eye tracker and camera) and questionnaires were exploited in the configuration process. Moreover, the personalized components were 3D scanned based on each user's facial features, and optimized for rapid prototyping (physical model). Smart functions were realized by embedding the sensor platform in the prototype to capture the real time breathe data. An IoT platform with mobile APP was developed for data display and analysis. UX is elicited and captured seamlessly with the cyber model and physical model in both visualized and tangible manner all along the co-creation context. The authors wish the proposed framework with the case study can provide some useful guidance to the ETO-based companies in their product development process.

Despite its feasibility and advantages, there still lies some issues to consider about before implementation, such as the upfront cost plan (e.g. budget for equipment purchase), the complexity or type of the product itself (e.g. smart product or usual product), and the design of human participation studies (e.g. focusing more on affective factors or cognitive ones). Moreover, in order to establish a more concrete framework, three main aspects need to be considered in the future: 1) novel design theories and methodologies should be utilized or proposed for the UX-cyber-physical model establishment; 2) specific data-driven design methods should be developed to analyze multi-user generated big data; 3) more design studies on various products should be undertaken, so as to enable personalized product development success.

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