MEANING-DRIVEN CUSTOMIZATION
A BIO-INSPIRED APPROCH TO THE CUSTOMIZATION

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ABSTRACT

Recently we have been witnessing a new customization culture that is shaped through the emerging and ongoing development of new digital fabrication technologies. The technologies, such as 3D printers, enable designers to act independently from the mass manufacturing system and directly collaborate with end-users. The results are products that are developed according to a particular user's needs and preferences. In this paper, a customization approach is proposed with the aim to help designers create more optimized custom products. The paper discusses how users' anatomical and physiological characteristics along with emotional preferences can affect the functionality and efficiency of the product. Moreover, it describes how the proposed customization approach can impact the user's perception towards a product or a category of products such as medical devices and enhance the user experience. The proposed approach is intuitively inspired by nature, where forms are created as a result of environmental forces and material structural constraints.

1.INTRODUCTION

The emergence of individualism is an inevitable result of modernity. It plays an important role in modern philosophical, political, social, and economical theories and provides unimagined opportunities for personal freedom and self-expression (Ham 2000). The importance of individualism arises once a society is economically developed and politically stable which results in a transition from a traditionally collectivistic culture to a creative, progressive, entrepreneurial and individualistic culture. Meanwhile, although manufacturers have constantly been seeking for new ways to increase the satisfaction of the majority of their consumers, they have sometimes disregarded the difference between individual needs and desires (Global Consumer Trends 2010).
Starting in 1980, manufacturers and marketers aimed to seek mass appeal by offering mass customization as a response to growing consumers' demands for tailored products. Nowadays, mass customization is a common marketing strategy, not only for those established companies trying to survive in competitive market, but also for startups in order to ensure consumers about the uniqueness of their products (Weintraub 2013). Although manufacturers can utilize mass customization to satisfy their consumers, keeping the cost of the customization process low is often a high priority. The dimensions of mass customization for most manufacturers are limited to the definition of a few flexible options to increase the sense of empowerment for each individual customer (Turner 2011). In other words, for many manufacturers, mass customization is restricted to alternation of features of a predetermined product that are designed based on customer's average needs and requirements. Customers are not proactive entities in the process of design and manufacturing. They do not significantly contribute to the process of idea generation and conceptual design. Customers' contributions take place after the idea generation and concept development are accomplished by designers and manufacturers.
Alternatively, a new customization culture has gradually been emerging based on recent developments of new digital fabrication technologies. In this new culture, the manufacturer is able to produce a *custom product* tailored to the individual customer based on his/her physical and psychological characteristics, limitations, and preferences. In fact, each custom product is unique. It is interactively co-designed and co-created to best serve the individual customer's needs. This culture is a breakthrough change in the realm of design and manufacturing and is based upon two major factors: 1- The mass distribution of information and knowledge 2- Advanced manufacturing technologies such as digital fabrication and 3D printing. These two factors empower individuals to create much more complex and customized products and to actively participate in all processes of design and manufacturing from identifying a need to fabricating the final product.

In describing the new customization culture, this paper intends to explore the opportunities for designers to entirely define, design, and make custom products based on the individual user's characteristics. We propose an approach to enhance the user's contribution in the process of design and manufacturing through extracting information about his/her physical needs and emotional preferences. The proposed approach is intuitively inspired by nature where all products are uniquely developed and highly customized. In nature, forms are gradually designed and created to be adapted to natural forces and environmental constraints (Oxman 2011). In the proposed approach, the designer first extracts the exact anatomical and physiological characteristics of users using related technologies such as portable 3D scanners. Then, this information is directly used to design and fabricate custom products that are highly matched with the individual user's needs and limitations. Since the product is collaboratively designed and manufactured in presence of the user, the proposed approach can also significantly enhance the user emotional interaction with the product by considering his or her emotional preferences and desires during the process of design and manufacturing.

2.CUSTOMIZATION PARAMETERS

Customization often involves the accommodation of the difference(s) between individuals. These differences are mostly related to either variations in *physical needs* or *emotional preferences* between people. Traditionally, the most common way to address such elements is mass customization. Kaplan and Haenlein defined mass customization as "a strategy that creates value by some form of company-customer interaction at the fabrication and assembly stage of the operations level to create customized products with production cost and monetary price similar to those of mass-produced products" (Kaplan and Haenlein 2006). Two key points can directly be extracted from this definition. The first is that customization applies at the later stages of production— the fabrication and assembly stages. This is emphasized by Chase et al. (2006) who claim that mass customization is the method of "effectively postponing" the process of customization of a product "until the latest possible point" in a manufacturing and supply system (Aquilano and Chase 2006). The second point is that the first priority for manufacturers is to keep producing goods and services as quickly as possible. Tseng and Jiao mention that the main goal of mass customization is to produce goods "to meet individual customers' needs with near mass production efficiency" (Tseng and Jiao 2001). This strategy is becoming more commonplace among manufacturers and corporations in order to attract customers by addressing differences between individuals (Zipkin 2001). A potential problem of mass customization is that since it applies at the later stages of manufacturing processes, it cannot perfectly respond to a wide range of customer's needs. For covering different desires among consumers, various physical needs and emotional preferences should be taken into consideration throughout the earlier stages of manufacturing. This cannot be addressed through the mass production system mainly because it decreases the rate of production. Customization in the context of mass customization offers restricted solutions to respond to distinct needs of customers. In the following paragraphs, two common mass customization strategies regarding consumers' physical needs and emotional preferences will be discussed and elaborated.

Physical need is a primary reason for many mass customization ideas. Manufacturers constantly seek avenues to make their products and services adaptable to wider range of consumers. The common solution is to use advanced ergonomics techniques to promote and optimize systems, products, and devices according to human physical and psychological constraints and limitations. However, instead of customizing products based upon the physical needs of an individual user, manufacturers study the anatomical specifications of a sample focus group and then design systems and devices based on average user's requirements. Apple EarPods, the new generation of earphones is an example of such solution. In order to design this product, the manufacturer 3D-scanned hundreds of ears and extracted the common features and patterns. Then the product was designed based on physical commonality to fit a broad range of human ears (See Figure 1). However, this solution results in a product that is customized based on the average physical characteristics of customers. EarPods or similar products do not exactly address specific physical need of an individual customer. They compromise on a solution that fairly fit many different types of ears and at the same time can be mass-produced.

In addition to physical characteristics, there are some personal and emotional components attached to products. Emotional response has an impact on our feelings, behavior, and decision-making processes (Norman 2005). There are so many cognitive and emotional differences among people that make it almost impossible to address

Figure 1. “EarPod” is the latest generation of Apple’s earphone, which is designed based on the 3D-scanned geometric of thousands of ears in order to optimize the comfort and performance of the product for wide range of users. Sources: https://www.youtube.com/watch?v=8Rme3uZ_abc

them through a single object. These individual differences are the details that make each person unique. Offering mass-customization from manufacturers has been a response to these emotional differences among their consumers. They introduce flexible and configurable products that consumers can adapt to suit their special needs. Nikeid is an online customization service that provides consumers with esthetical choices and lets them create their own customized sport shoes by modifying the product’s color. Although this service empowers consumers to make the product better fit their personal preference, it is restricted to a predetermined list of options defined by Nike based on their marketing strategy, manufacturing capabilities and economical limitations (See Figure 2).

The abovementioned solutions for customization cannot completely address the increasing needs for personal custom products. Many consumers know what exactly they want and try to differentiate themselves from others by creating tools and products that satisfy their distinct needs (Global Consumer trend 2010). However, whether customers tailor a product’s appearance to their own emotional preferences or modify its physical aspects to their own anatomical specification, the result is a mass-customized product. Moreover, the processes of idea-generation and concept-development are fed by information from the average consumer’s needs and preferences. The new advances in technology together with mass distribution of knowledge and information provide a new mode of customization where customers can interactively participate in all processes of design and manufacturing. The components of such a customization approach are presented in the next two sections.

Figure 2. NIkeiD, An online service that allows consumers to change and modify products’ color to make them better fit people’s preferences. Source: http://www.nike.com/us/en_us/

3. BIO-INSPIRED CUSTOMIZATION

Physical ergonomics involves addressing the needs of the user to continuously keep products, machines and systems adapted to human anatomical characteristics and limitations. For nature, adaptation is a solution to the environmental forces in order to grow and survive. External forces shape organic forms. In nature, material structure is defined based on the required functional and structural requirements. In other words, the form-generation processes in the nature are constantly informed by environmental and structural constraints which result in a high level of material efficiency and customization (Oxman 2011). Unlike nature, we customize our

products at the very last step of fabrication and not throughout the whole process of creation. Furthermore, the customizable options are limited to the aesthetics of the object. But people are anatomically different and even small changes in the form of a product, such as a medical device, can remarkably impact the level of comfort, safety and efficiency for the user. Such differences can serve as criteria for optimizing the form of a customized product based on user's physical needs. According to the proposed customization approach in this paper, the general form of the object results from the distribution of required material properties informed by the individual user's anatomical requirements and also by environmental constraints, not unlike nature. Designing an earphone is good example. People have various shapes of ears so that a standard earphone designed based on an average form of ears cannot satisfy this diversity of needs. For optimizing comfort and functionality, we need to develop the form of the earphone according to the physical characteristics of each ear. There are two parameters involved in the process of computational form-generation. First, it is the specific geometry of each ear which defines the general structure of the object and second is the required material behavior in terms of stiffness and strength. Although, it was not previously possible to use digital fabrication tools to make objects from more than one material at a time, the 3D printer Objet 500 Connex introduced by Stratasys has the ability to inject two kinds of material simultaneously. It could be a combination of two stiff materials, two flexible or one of each with ability to change transparency of the materials (Oxman 2011). This feature allows the generation of more complex objects with varied material properties, which can potentially enhance the product's structural performance and also increase efficiency by using material as both a structural and a functional component while reducing the amount of needed materials (Oxman 2010).

However, it is not only physical characteristics that make each user unique. People also differ in terms of emotional preferences, which are representations of their unique personalities. Baudrillard discusses that the products that we use are not only objects, but they together portray an image of who we are and reflect our internal propensity (Baudrillard 2006). Addressing the user's emotional preferences and linking those to the product's appearance (through the use of color, pattern and texture) can affect his/her interaction with the product. According to a research conducted by Dr. Isen at The Ohio State University, even low-leve,l general feeling states that are caused by small things can have remarkable effects on our social behavior and cognitive processes (Isen 1984)). People not only feel better while interacting with products that are aesthetically satisfying for them, but also they perform more creatively when they feel good (Norman 2005). An aesthetically customized product can enhance the user's emotional attachment to the product through increasing the owner's senses of individuality and ownership. For example, people enjoy hobbies because they create things that are specifically theirs. Hobbies allow people to express their own sense of beauty, creativity, and usefulness. They feel satisfied and have "a personal sense of accomplishment" (Norman 2005). The type of customization proposed in this paper provides an opportunity for people to make an active contribution towards developing the idea and modifying the design based on their particular tastes and desires.

4. MEANING-DRIVEN CUSTOMIZATION

Although addressing people's distinct needs is one of the main catalysts for developing a customization culture, it has been the accessibility of digital fabrication tools that allows designers to design and fabricate customized products easier and in shorter time periods (Doustmohammadi and Valamanesh 2013). New technology can affect design at many different levels; from causing small improvements in the process of manufacturing to providing opportunities for radical inventions. Although all the changes in the world of design are not caused by technology, a new technology frequently leads to incremental or radical innovation in design (Norman and Verganti 2012). In order to differentiate radical and incremental inventions, Norman and Veraganti compare innovation to hill climbing. Incremental innovation is like moving toward the peak of the hill, leading to continuous improvement of existing design. Radical innovation is like looking for a higher hill which can happens only through meaning or technology change. The "Technology Epiphanies" is one the four different types of innovation that they categorized based on these two factors (technology and meaning). They claim that radical change in the product's meaning can also lead to "radical meaning-driven innovation". They discuss that emergence of a new technology or investigating new applications for an existing technology can radically change the meaning of an existing product or a category of products for users. Through using new digital fabrication tools such as 3D printers designers now can generate more complex customized products with higher level of functionality and aesthetics, which can have deeper impression on user's feeling toward the products. According to Norman and

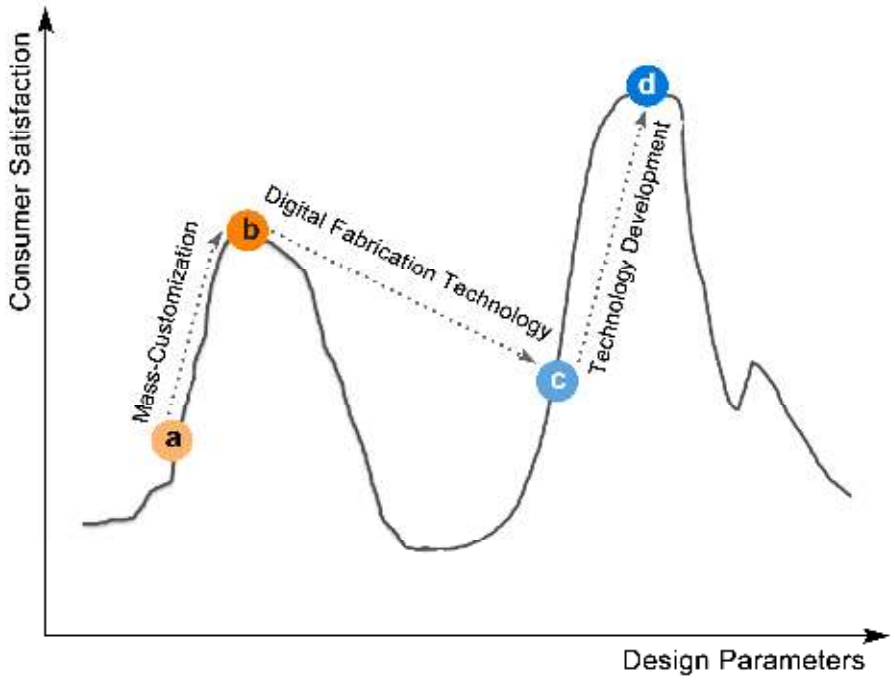

Figure 3. Through mass customization a product can move from point ”a” to point “b”. However, using digital fabrication technology can move the product to a different yet higher hill and lead to a radical innovation. Also advancement in fabrication technologies might move the product to the peak of the new hill, point “d”. Inspired by: Norman, D. A.;Verganti, R. (2012). “Incremental and radical innovation: Design research versus technology and meaning change.” Design Issues, 30(1), 78-96.

Verganti, mass-customization helps designers to reach the peak of the hill, while new customization approaches can lead designers to climb a newer, higher hill (See Figure 3). This may be particularly true for medical product and devices. Although medical products and devices are critical elements in the patient’s treatment process, patients may not be willing to use them. They may be poorly designed in terms of functional and aesthetical parameters, which make them unpleasant for the patient to use. The patient’s emotional needs, in particular, have tended to be ignored due to an underestimation of the importance of aesthetic aspects. The new customization approach can not only improve the functionality and aesthetic of an medical device, but also it can change its meaning for patient and possibly result in “radical meaning-driven innovation”.

5. EXAMPLES

PROTECTIVE HELMET

Through the case study that is still under development, the researchers intend to design a customized helmet for children suffering from epilepsy. Children with epilepsy need to wear the helmet, which protects them from head banging, or traumatic brain injury caused by sudden drops or falls. Because the seizure behavior is unpredictable, the patient needs to wear the helmet most of the time during their daily activities. The helmets that are currently available have been designed according to average patient’s physical needs with an average level of protection. Moreover, although there are significant differences between the emotional needs of an adult patient and child patient, the existing helmets are designed the same for both with only size and color differentiation (See Figure 4). In both cases, the aesthetic elements of the product are ignored which help to make the helmet an unpleasant product to use. The helmet is not only a product that physically interacts with patient, but it can also have significant effects on the patient’s social life as clothing does for many people. Research conducted by Professors Adam and Galinsky at the Kellogg School of Management at Northwestern University shows that the experience of wearing a piece of cloth can influence the wearer’s psychological processes, an effect which they call “enclothed cognition” (Adam and Galinsky 2012). They claim that, similar to our body positions that make us feel

Figure 4. The current protective helmets for children suffering from seizures disorders are usually mass-produced and designed based primarily on average human factors and ergonomics information. Sources: http://www.ukepilepsy.com/epilepsy/seizure-types/seizure-types-atonic-seizures/ and

more empowered, our outfit can even raise the level of testosterone and cause us to feel more confident. The mass-produced helmet has an unfamiliar appearance for most people, which is likely to make a patient feel uncomfortable during his/her public and social activities. The case study will attempt to increase the patient's emotional attachment to the object through creating sense of individuality and uniqueness by designing a customized helmet based on the child's preferences. Customizing the helmet also can change other people's perceptions. An aesthetically attractive helmet no longer performs only as the patient's medical condition statement, it is also an expression of one's self. In addition, it is easier to deal with products that make people feel good (Norman 2005). Making a medical product such as helmet aesthetically more pleasant can also help patient's relatives, in this case parents, feel more positive about the child's medical situation.

CORTEX CAST

Jake Evill, a recent graduate from the University of New Zealand, designed a 3D-printed cast for healing broken bones called Cortex Cast. Instead of a solid block of plaster, Cortex Cast is made from a lightweight honeycomb structure determined by the required material properties based on each patient's physical needs (See Figure 5). The material structure is more dense when more support is needed and is sparse to perform as structural component. The process starts with 3D-scanning the patient's arm to provide data needed for creating a digital 3D model. Unlike old casts, Cortex Cast is easy to clean, shower-friendly, recyclable, and more importantly, it is elegant.

Figure 5. The "Cortex Cast" is a customized cast for healing broken arms. The distribution of the material is determined based on the required material properties such as stiffness and strength.
Source: http://jakevilldesign.dunked.com/cortex

According to the innovation categorization introduced by Norman and Verganti, Cortex Cast can be considered a “Technology Epiphany”, which can lead to a radical meaning shift. It has changed the cast from an unpleasant and annoying product to a pleasant personal statement. It is aesthetically attractive enough that it does not negatively affect the user’s appearance during the treatment time period. Adding some customizable options such as color might also significantly change the patient’s perception and feeling about this medical device.

6. CONCLUSION

The customization approach proposed in this paper can be affordable through using digital fabrication technologies. Radical innovations can happen when new technologies are developed, although it takes time for a new technology to become accepted by the public and to reach a state of maturity (Norman and Verganti 2012). The current mass-customization methods are not capable of providing opportunities for consumers to express their personal needs and preferences. The proposed customization approach can help designers to create more comfortable, functional and optimized products when considering user’s physical and emotional needs. However, it should be mentioned that this approach to customization cannot be currently applied to many types of products due to technology restrictions. It can be a practical solution when a need for a medical device is discovered yet ignored by mass-manufacturers. It usually happens when the mass-production is not economically advantageous for manufacturers due to limited number of audiences. The proposed customization approach can also lead to more sustainable consumption behavior and extend product longevity by increasing the user’s emotional attachment to the product.

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