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Practicing universal design to actual hand tool design process

Kai-Chieh Lin [a], Chih-Fu Wu [b, *]

[a] The Graduate Institute of Design Science, Tatung University, Taipei, Taiwan
[b] Department of Industrial Design, Tatung University, Taipei, Taiwan

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ABSTRACT

UD evaluation principles are difficult to implement in product design. This study proposes a methodology for implementing UD in the design process through user participation. The original UD principles and user experience are used to develop the evaluation items. Difference of product types was considered. Factor analysis and Quantification theory type I were used to eliminate considered inappropriate evaluation items and to examine the relationship between evaluation items and product design factors. Product design specifications were established for verification. The results showed that converting user evaluation into crucial design verification factors by the generalized evaluation scale based on product attributes as well as the design factors applications in product design can improve users' UD evaluation. The design process of this study is expected to contribute to user-centered UD application.

1. Introduction

The term universal design (UD) was proposed by the American architect Ronald L. Mace in 1985 during the development era of "barrier-free design" (Kawauchi, 2001). The purpose of UD is to promote interaction between products and the environment, and to allow users to use the product effectively without having to adjust to the product (Connell et al., 1997). The concept of universal design is making mainstream products and services accessible for whom mainstream users and those with specific requirements without special adaptations (Keates and Clarkson, 2003). After North Carolina State University established the Center of Universal Design (CUD), its research teams formulated seven UD principles (Connell et al., 1997). Subsequently, Satoshi Nakagawa considered the economic, aesthetic, and environmental friendliness dimensions, and added three supplemental dimensions: durability and economics, quality and aesthetics, and health and environment (Nakagawa, 2006). This enabled designs to increase their interaction with users. Comparatively, the 3B principles proposed by Ronald L. Mace (better design, more beautiful, and good business; Mace, 1970) focused on the economic and aesthetics dimensions, but were overly abstract when used in actual applications. Therefore, in consideration of practical applications, the Japan Ergonomics Society employed equitable use as the basic principle and the three product dimensions of operability, functionality, and attractiveness to compile UD principles (Japan Ergonomics Society, 2007). The results indicated that the principles and context of UD evolved over time, and varied according to different requirements in various industries. Japanese industries have attempted to implement UD in actual applications. To facilitate the development of UD, Mitsubishi Electric built the UD-Checker UD evaluation tool (Sawada et al., 2006). Toyota applied UD thinking to conduct evaluations of the ergo-index and scene conformity level (Kanamori and Misugi, 2004). This indicates that the UD product market based on the "respect each individual to achieve self-actualization" ideal is rapidly growing. User requirements, market knowledge, and approaches that are easy to understand are used to design and produce products that can achieve maximal usability for individual users. However, in the nearly 30 years of implementation since Ron Mace proposed the term UD in 1985, industries still lack sufficient design-related knowledge to realize UD (Vanderheiden and Tobias, 2000). Actual applications typically involved the use of UD scales ("scales useable for everything") for conducting postevent product evaluations. There are several specific modules were developed to modify products so that could become universal has been brought up as strategies for universal design (Clarkson et al., 2003; Moon and McAdams, 2009). Based on target user simulation and product evaluation, University of Cambridge attempted to practice the idea of universal design into product design process (Clarkson, 2008; Clarkson et al., 2003, 2008; Langdon et al., 2008a,b; Waller et al., 2008). The research team

* Corresponding author. No. 40, Sec. 3, Zhongshan N. Rd., Zhongshan Dist., Taipei City 104, Taiwan. Tel.: +886 917 018 617.
E-mail address: wcf@ttu.edu.tw (C.-F. Wu).

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integrated user trials to identifying usability problems and exclusion calculation, an expert appraisal method based on demographic population estimated how proportion of the people would be excluded from universal evaluation of products and services due to lack of capabilities or limitations (Keates and Clarkson, 2003; Waller et al., 2009, 2010). It was recommended to use both methods meanwhile to provide different guidance needed which were identifying behavior capability problems or needs by exclusion calculation and were expecting unexpected user behavior and cognition (Clarkson et al., 2007; Goodman-Deane et al., 2014). However, it is hard to identify the user group and find out who the boundary user are. Besides, for the universal design tool of exclusion calculation, it is difficult to define who the expert is to evaluate vision, hearing, thinking, dexterity, reach & stretch and locomotion (Goodman-Deane et al., 2014). In the other hand, in the perspective of design practice in past researches, marketing, economy, feasibility and its evaluation with respect to disabilities and limitations were considered to develop a method and make decisions for universal product families' design (Moon and McAdams, 2009). The product platform was established by mathematical method of Bayesian Game to identify the best module of product families regarding uncertainly market environments (Moon and McAdams, 2010). Kostovich et al. integrated the activity diagram, a progression to examining user interaction from purchase to recycling or disposal of products (Otto and Wood, 2001), and functional model, a graphical illustration of product functionality (Hirtz et al., 2002; Otto and Wood, 2001), to create a product analysis framework which was called action–function diagram (Kostovich et al., 2009). The diagram based on the concept of graphical representation during the early stages of design, a single graphical representation of user activity and product function which thus made user centric thinking and information available. According to the differences within functionality, morphological and parametric, products were categorized into universal one and its typical counterpart and the comparisons were applied to each pair afterward in order to analyze and practice into the researches of universal design (McAdams and Kostovich, 2011). Furthermore, universal architectural systems and consumer products were compared formally at the function level (Sangelkar and McAdams, 2010); and the transferability of application from American with Disabilities Act (ADA) to universal design of consumer products was detailedly analyzed (Sangelkar and McAdams, 2012). However, managing differences in product attributes by using scale designs is difficult, and scale evaluations are typically conducted during product design or after mass production is completed. In addition, design teams often make speculations and decisions based on their own experiences, intuitions, and assertions (Mitsufuji and Uchida, 1993). Even if the design team is experienced and possesses accurate intuition, the team cannot accurately convert user evaluation data into design factors without establishing reliable information for evaluating design factors (Haapalainen et al., 1999/2000). In a situation where user evaluations cannot be converted into design factors, the team can expect the future product to have only certain functions, but cannot propose product attribute design factors that conform to the spirit of UD.

Therefore, a product design perspective was used in this study to propose a UD application methodology, which is expected to contribute to UD application in product design. Although industries generally use automated machines and automated production in contemporary product design, hand tools are still the primary and most direct contact medium for workers (Christensen and Bishu, 2000). Additionally, “do it yourself” (DIY) trends were used in this study to explore actual self-actualization ideals. Previous related studies have focused on the design product of using a tool in itself, and explored the quality of the design by using task-orientated results. In recent years, design thinking has extended to the work-place environment, and whether users can easily and comfortably implement work tasks has been investigated (Aptel et al., 2002; Marsot and Claudon, 2004). Because comfort in operating a product influences the purchase intentions of consumers, comfort is a factor that manufacturers have wished to explore (Vink et al., 2005). Feelings of discomfort can reduce users' operating performance and work satisfaction (Fellows and Freivalds, 1991). Numerous scholars have indicated that comfort and users' work performance are directly linked (Kuijt-Evers et al., 2006; Dempsey et al., 2002). Therefore, comfort is a factor that cannot be overlooked in hand-tool design. However, product attributes of hand tools differ greatly, and the overall value of exploring similar design factors is not high. Therefore, needle-nose pliers were used in this study as an example because many people use this product in daily life, and because needle-nose pliers have clear design factors. End users were invited to participate in the design process. In addition, this study focused on the following four aspects during the exploration of UD application in the product design model: 1) the context of UD which evolves with time; 2) development of an appropriate generalized evaluation scale based on product attributes; 3) examination of the importance of universal product design factors in conducting design verification; and 4) the proposal of new UD principles.

2. Research method and procedure

Research method and procedure are divided into four sections from discussing the changed in the context of UD and its evaluation scale. The concept and development of UD are dynamic and the scale may be varied by product types. Third, most of the past UD application researches belong to postevent evaluation instead of initial design process. At last, the new UD principle is proposed over time and with changes in user requirements. Needle-nose pliers were used as an example, and end users were invited to participate in the design. This study was not limited to design evaluations, and user evaluations and opinions were converted into design factors to implement UD in the product design process.

2.1. Changes in the context of universal design

UD has been recognized as the current design trend around world. In the past 30 years of UD development, numerous scholars and organizations have proposed theories and insights that enable people to understand UD concepts. The Japanese scholar, Naoaki Nippashi, proposed the “design for ourselves” concept in 2006. Nippashi investigated the implementation of UD in practical applications, how UD will be expressed in the future (Nippashi et al., 2006). The scope of UD thinking is broad and diverse, but a method for practical application has not been proposed.

The seven principles proposed by Satoshi Nakagawa, Ron Mace, and the Japan Ergonomics Society, and the supplemental principles of economics, aesthetics, and environmental friendliness reflect design and practical requirements, which increase the comprehensiveness of UD principles. This indicates that the context of UD will change over time and with changes in practical requirements.

2.2. The development of generalized evaluation scales

Comfort is a major factor that influences hand-tool design and use. However, the context of UD includes broad practical values, and comfort is only one part. Comfort alone cannot provide users with maximal benefit. UD concepts and comfort factors related to hand tools were used to conduct the research in this study. Based on the development and application of existing UD principles, 10