



Evaluation of customer impressions using virtual prototypes in the internet environment

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ABSTRACT

This study aims to investigate a cost effective and efficient way of analyzing customer impressions on design alternatives by incorporating the benefits of virtual prototyping into the Internet-based experimental environment. It is hypothesized that the results of the Internet-based experiment using the images of virtual prototypes are comparable to those of the virtual reality-based environment using virtual prototypes. Two experiments were conducted. In the virtual reality environment, participants were employed to evaluate virtual prototypes while in the Internet environment participants evaluated images of the same virtual prototypes from their own places. For each experiment, 16 male participants were employed to evaluate 32 different virtual prototypes generated from the combination of 17 design elements of automobile interior. The results of the experiments indicated that there were no significant differences between the two experimental methods while the Internet environment-based method could save considerable time and efforts for experimentation. This study concludes that the Internet-based evaluation method using the images of virtual prototypes could be a cost effective and efficient way of analyzing customer impressions on design alternatives.

Relevance to Industry: This study showed that the results of the Internet-based evaluation method using the images of virtual prototypes are comparable to those of the virtual reality-based method using real virtual prototypes. The Internet-based evaluation method could be used as a cost effective and efficient way of collecting and analyzing various customers' impressions on design alternatives at the early stage of product development process.

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1. Introduction

The importance of satisfying a variety of customer needs for both basic functional requirements and affective aspects of a product becomes more critical in the era of global competitions and global markets (Dahan and Hauser, 2002; Kwahk and Han, 2002; Keeney, 2004; Chang et al., 2006; Bahn et al., 2009). To incorporate the wide range of customer needs and requirements into the product design, rapid conceptualization and evaluation of potential design alternatives becomes more important than ever. Recent development of new information and communication technologies has drastically transformed product development process. For instance, virtual prototyping technology has been utilized to make rapid visualization and implementation of design alternatives in the early phase of product development (Zhang et al., 2005; Kuo and Wang, 2007; Santos et al., 2009). The use of human simulation systems and three-dimensional

computer aided design also has been utilized as an effective tool to visualize and evaluate the human–workstation interaction (Godwin et al., 2008; Jung et al., 2009). In addition, the Internet environment and web technologies have shown a possibility for capturing the voice of diverse customers with minimal time and efforts (Kuo and Chu, 2005).

Over the decades, substantial research has been conducted to capture the customers' feelings and affective demands on a product and incorporate them into the design of the product. A number of previous studies analyzed the impact of design features on customer perceptions utilizing on-site experiments with the assumption, where affective reactions of customers can be explained by the functional relationship with design features (Nagamachi, 1995, 1999; Ishihara et al., 1997; Matsubara and Nagamachi, 1997; Kim and Moon, 1998; Han et al., 2000; Han et al., 2001; Yun et al., 2001; Kwahk and Han, 2002; Yun et al., 2003; Han et al., 2004; Schütte and Eklund, 2005; Chang et al., 2006; Bahn et al., 2009). In this regard, virtual reality technology has been utilized to visualize design alternatives that best fit customers' feelings and investigate their impact on customers' feelings (Matsubara and Nagamachi, 1997; Nagamachi,

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2002; Lee et al., 2004; Lai et al., 2006). Virtual prototyping allows customers to interact with and evaluate a product without actually making a physical prototype (Choi and Chan, 2004; Choi and Cheung, 2005; Bordegoni et al., 2006). Virtual prototyping provides several advantages for conducting an ergonomic evaluation experiment to investigate the relationship between customers' affective reactions and design elements. First, it is easy to generate various sets of design alternatives without much effort once the first prototype is developed. Second, it can reduce the noise effect caused by variations in the other design features which are not focus of study. It enables experimenters to focus on design features of their main interest by developing prototypes with the other design features being fixed. Moreover, immersive virtual reality environments may be the most appropriate test-bed for the experiment of evaluating virtual prototypes allowing the user to manipulate a test object with the realism close to the real product and the natural way of interaction during the evaluation process.

Although aforementioned benefits of virtual reality environments are somewhat evident in providing a more immersive evaluation environment, there has been no strong evidence that a more immersive environment is necessarily better for the affective evaluation experiments (Kuo and Chu, 2005). For instance, a previous study comparing three types of virtual environments reported that there were no statistical differences among the three types in the evaluation of the affective properties of mobile phones (Lee et al., 2004). In reality, it inevitably requires more expenses and participants' site visits to conduct the evaluation experiments since the virtual reality facilities are still expensive with limited accessibility.

With the expansion of the web technologies, the Internet has been utilized to help designers in various stages of the design process from conceptualization to product realization (Zhang et al., 2004). The benefit of the Internet-based ergonomic evaluation methodology is evident in that it allows broad range of participants working at the same time without limitation of regions and costly involvements of experimenters. It was also reported the advantages of remote evaluation in terms of cost, freedom from facilities, and time saving (Dray and Siegel, 2004; Kuo and Chu, 2005). Some empirical studies of comparing in-lab evaluation with remote environment supported that remote evaluation method might be an alternative way of conducting usability evaluation experiments (Hartson et al., 1996; Tullis et al., 2002). The Internet-based evaluation of static and animated virtual prototypes provided a close match to the results generated in the on-site environment using physical prototypes (Dahan and Srinivasan, 2000).

This study seeks for a possibility that employs the Internet environment as an alternative experimental test-bed and the images of virtual prototypes as alternative evaluation materials. This study aims to investigate an efficient way of analyzing customer impressions on design alternatives by incorporating the benefits of virtual prototyping into the Internet-based experimental environment. The use of images would ease implementation of the experimental settings in the Internet environment. It is expected that Internet-based experiment could help participants to relieve the burden of interacting with complicated virtual prototyping technologies during the experimentation. Accordingly, it is hypothesized that the results of the Internet-based experiment using the images of virtual prototypes are comparable to those of the Virtual environment-based experiment using virtual prototypes.

2. Methods

Fig. 1 summarizes the overall framework of this study. At first, the design elements of interest were selected and then their design alternatives were generated using virtual prototyping. Two

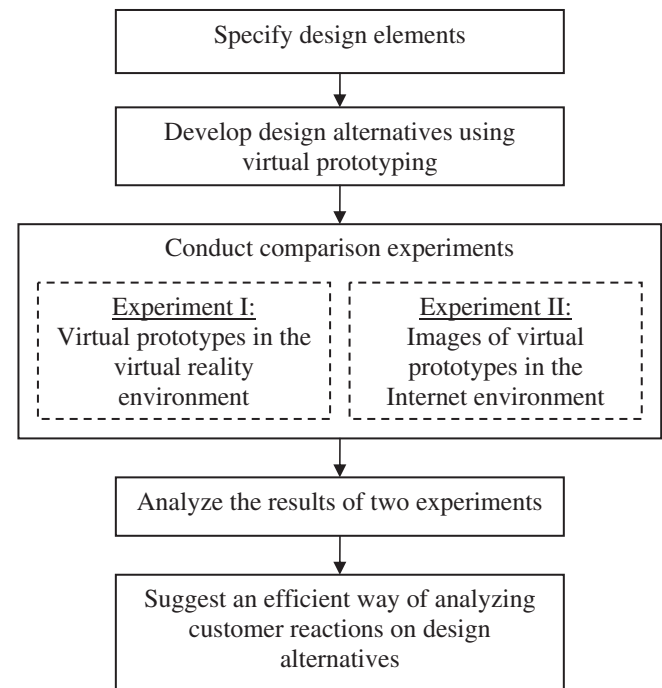


Fig. 1. Research framework of this study.

experiments were conducted in the virtual reality environment using virtual prototypes and in the Internet environment using the images of virtual prototypes, respectively. The results of the two experiments were analyzed and compared to test the research hypothesis. Finally a more efficient form of experimental technique was discussed and suggested based on the results of the two experiments.

2.1. Development of virtual prototypes for automobile interior design

The design elements of automobile interior design were originally selected from the list provided by an automobile interior design team. Considering the practical size and prototyping efforts of design elements, 17 design elements were selected by three subject matter experts based on two criteria of their implementation difficulties in the virtual reality environment and relative importance. Table 1 summarizes the 17 design elements used in the experiments. Two variations of each design elements were developed and combined according to 2^{17-12} fractional factorial design (resolution III) (Montgomery, 1997). Thirty-two virtual prototypes were generated with the variations of 17 design elements. The two variations of each design elements are shown in Appendix A.

2.2. Experimental procedures

Two experiments were conducted to compare the two different experimental environments: one in the virtual reality environment using virtual prototypes and the other in the Internet environment using the images of the virtual prototypes. The two experiments were setup as a between-subject experiment with the experimental environment being an independent variable.

A total of 16 male participants from university population were paid to participate in the virtual environment-based experiment (VE). The ages of the participants ranged from 19 to 33 with the average of 24.0. The VE experiment was conducted in the virtual reality environment of a spherical screen with three projectors and Silicon Graphics Onyx 2 visualization system as shown in Fig. 2(a).

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