Development of a Universal Design Index for Automobile Interior Design

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Abstract

The concept of universal design has recently emerged as an important aspect of product design. Universal design is considerably analogous to ergonomic design in a way that it takes the capabilities and limitations of users into consideration during the product development process. However, relatively few studies have been devoted to reflect the practical use of ergonomic principles on universal design. This research attempts to develop a universal design index for automobile interior design to quantify how well a product complies with principles of universal design. The research also emphasizes on ergonomic principles as a basis of evaluation. A generation of the index was done by cross-checking among the personal, activity and product components drawn from the scenarios of vehicle use. Personal components consist of human characteristics including age, physique, perceptual capacity, reach, etc.. Activity components were derived from those scenarios of vehicle use while product components were composed of interior parts to which a user interacts. Further analysis systematically generated an universal index from relationship matrices among the three components. The index was then used to test its suitability by applying to the evaluation of passenger cars currently on the market. This study demonstrates a development process through which evaluations can be made possible for universal design. The research suggests an improved approach to the appraisal of how well cars are universally designed based on ergonomic principles.

Keywords: Universal Design, Index, Car, Evaluation

Introduction

During recent years, the design of products is trending toward utilitarianism. Improved medical care and an increasingly ageing population are leading to the aging society, and people with congenital or long-term disabilities are living longer[1]. Older and disabled people have risen up as a new consumer class. The concept of universal design considering all classes of customers has emerged as an important aspect of product design.

Recent studies have shown design suggestions with the concept of universal design for several products such as a microwave oven for elderly, cellular phones for learning, symbol design on pointer input devices for disabled people and so on. Even a few attempts were made to the design of education systems and language tests[2,3,4,5].

Moreover, there were many studies on the developing of a survey instrument used during usability tests that would allow the rating of a product in terms of how well it complies with the principles of universal design. The Universal Design Performance Measures for Products is a representative example and is intended to provide a systematic way for designers to evaluate their design in terms of the principles of universal design[6]. However, there are significant limitations to applying

this method to complex or integrated products like cellular phones, home appliances, and cars.

Toyota Motor Corporation took the initiative on the development of universal design indices for vehicles. The two indices, the ergo-index and situational suitability index, were established at Toyota as a unique criterion and a method for both objectively and subjectively evaluating the level of delight and user-friendliness of a vehicle[7].

Since a vehicle is used for various activities with diverse users, its structures must employ complex features. Referring to the Toyota's program, this research attempts to develop a universal design index for automobile interior design to quantify how well cars comply with the principles of universal design. The research also emphasizes on ergonomic principles as a basis of evaluation.

Universal Design Center defines universal design as "the design of products and environments to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design." A group of experts in the area of universal designers have developed a set of simple principles that designers could use when developing products and environments. As listed in Table 1, the principles actually reiterate ergonomic design principles we use for product design[6].

Table 1. The seven principles of universal design†

Principle	Definition
1. Equitable use	Usable and marketable to people with diverse abilities
2. Flexibility in use	Accommodates a wide range of individual preference and abilities
3. Simple and intuitive use	Easy to understand, regardless of experience, knowledge, language skills, or current concentration level
4. Perceptible information	Communicates necessary information effectively to the user, regardless of ambient conditions or sensory abilities
5. Tolerance for error	Minimizes hazards and the adverse consequences of accidental or unintended actions
6. Low physical effort	Can be used efficiently and comfortably and with a minimum of fatigue
7. Size and space for approach and use	Appropriate size and space is provided for approach, reach, manipulation, and use regardless of user's body size, posture, or mobility

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The matrix analysis used in this study is not entirely new as seen in the concept of usability into which Iwarsson offers his insight. He emphasized that statements using the concept of usability must be based upon valid and reliable information gathered in four steps[8]:

(1) The personal component (description of functional capacity in the individual or group at target, based on knowledge on human functioning).

(2) The environmental component (description of barriers in the environment at target, in relation to the norms and standards available, but also based on user evaluation).

(3) The activity component (description of activities to be performed by the individual or group at target, in the given environment).

(4) An analysis integrating the personal, environmental and activity components (description of usability problems, i.e. description of the extent to which human needs, based on individual or group preferences, can be fulfilled in terms of activity performance in the environment at target).

As alluded previously, universal design is considerably analogous to ergonomic design in a way that it takes the capabilities and limitations of users into consideration during the product development process. However, relatively few studies have been devoted to reflect the practical use of ergonomic principles on universal design. In High Touch process suggested by

Lee et al., though it didn't hold the concept of universal design, it was suggested that the hierarchical structure of ergonomic variables be applied to product development process systemically[9].

For the universal design of home appliances and multimedia products, Lee analyzed human factors of elderly people that effects on using appliances and offered the relationship between seven universal design principles and ergonomic principles. In the research, listed ergonomic principles include visual, auditory and tactile sensing, kinesthetic and information processing[10].

Method

Existing research on universal design concentrated mainly on the product design and development processes. A few studies applied the ergonomic principles to those processes but those are not yet fully integrated. And there were relatively few studies on the development of evaluation index for universal design on products.

This study attempts to integrate the concept of universal design and the ergonomic principles into the development of an index. The whole process for the development of a universal design index was summarized in Figure 1.

With Iwarsson's concept of usability, the personal, environmental and activity components were used as a foundation for index generation process. And, the definitions of personal and activity components are

similar to those of Iwarsson’s suggestion. Environmental component was revised to product component referred to in High Touch process since the application area of interest in the study is mainly automobile interior design. Based on these definitions, each component was constructed in the following:

- (1) The personal component consists of human characteristics including visual, auditory and tactile sensing, information processing, motor function, anthropometry/biomechanics, and physical work capacity. User groups were classified according to age, gender, the handicapped and the relationship with the human characteristics was extracted from ergonomics experts.
- (2) The activity components were derived from the scenarios of car use through scenario-based activity generation. Each activity has direct relationship with product components which are involved in the activity.
- (3) The product components were composed of interior parts to which a user interact for car use activity. The newest technologies which give conveniences to car users were surveyed broadly and listed.

An analysis systematically generated a potential list of the universal index from the relationship matrix among the three components, as shown in Figure 2. A

generation of the index was done by cross-checking among the personal, activity and product components drawn from scenarios of car use. Table 2 shows an example of the analysis process. Each cell in the matrix becomes a potential list of universal design index and the draft list was then used to generate questionnaires for actual evaluation.

Figure 2. The relationship Matrix

Results

From the list of activities observed from the vehicle use, five typical activities were chosen to test the validity of the proposed process. Selected activities include door opening, climate control, gearshift change, seat adjustment, hood opening.

Table 2. A process of the index generation by the relationship matrix

			Personal components																
			Sensing				Information processing			Motor function			Anthropometry/ Biomechanics				Work load		
			Visual	Auditory	Tactile	Kinesthetic	Attention	Detection	Processing	Memory	Reaction	Motion	Coordination	Dimensions	Reach	Posture	Clearance	Strength	Fatigue
Activity Component	Product Component																		
Climate control	Display	Type	⊙	○			○	○	⊙	○									
		Size	⊙					○											
		Location	⊙					⊙											
	Control	Type			○				⊙			○	○			○		○	○
		Size												⊙					
		Arrangement						⊙	○	○									
		Location						○							⊙	⊙	○		○
Gearshifts changing	Display	Type	⊙	○			○	○	⊙	⊙									
		Size	○					○											
		Location	⊙					○											
	Control	Type			⊙				○		○	○	○			○		○	⊙
		Size												○					
		Arrangement						○	○	⊙	○								
		Location						○			○				⊙	⊙	○		○
Seat Adjusting	Control	Type			○	○		○	○			○	⊙			⊙		⊙	
		Size												○					
		Arrangement							⊙										
		Location													⊙	⊙	⊙		○
User groups related to Personal components	Olds Handicapped Children Female Large people Small people		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓		✓	✓
			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
							✓	✓	✓	✓	✓	✓	✓	✓				✓	✓
															✓		✓		
															✓	✓			

⊙ : Strongly related, ○ : Related, ✓ : with disadvantages to each human characteristic

Table 3. An example of the questionnaire used as a universal design index

Question	Reference Materials	Rating
Are the controls for seat adjustment within the comfortable reach of drivers and passengers while seated?	<ul style="list-style-type: none"> • Evaluation subject: distance of the seat adjustment controls • General principles: The closer, the better. • It is thought to be good if you don't need to bend your body and can stretch arms comfortably • Related situation: Small women with the seat belt fastened can stretch arms for seat adjustment. • Related user group: Olds, Handicapped, Small people

29 questions were developed for the questionnaire through the proposed process as a universal design index. A form for universal design index consists of the questions, reference materials and 9-point scale paragraph for rating as shown in Table 3. Reference materials have descriptions of ergonomic principles related to the questionnaire and specific activities of user groups at a disadvantage. Also those inform the newest technologies and interior facilities with related figures so that the respondent can properly evaluate the efficacy of the universal design.

The proposed index was used to test its suitability by applying to the evaluation of passenger cars currently on the market. A total of 12 adults including 8 males and 4 females participated in the usability study. Participants were presented with three different passenger cars. Two types of indices were presented to subjects for comparison by asking the level of satisfaction on the wording and format of each index. Index Type I is Beecher's consumer product universal design scales[6], while Index Type II is the index proposed in the study.

Results showed that response deviation of Type II was smaller than Type I ($p < 0.05$) and there was no effect of car models. And, the subjective preference of Type II was higher than that of Type I ($P < 0.1$). However, subjects commented that both indices similarly incorporated the concept of universal design.

Discussion

This study demonstrates a development process on which evaluations can be made possible for universal design. The research suggests an improved approach to the appraisal of how well cars are universally designed based on ergonomic principles. The proposed index was verified by applying to the evaluation of passenger cars. Consequently, this research broadens the fields of application of universal design by using the ergonomic evaluations. The suggested process has a potential for practical applications to other products like cellular phones, home appliances and so on.

What remains to be explored and extended by future research are: how to prioritize the importance among the potential lists of the index, how to define 'universally best designed' among the designs of cars, and how to evaluate the degree of multi-use from ergonomic principles such as ease of use or ease of handling.

Further research will be in need to improve the efficacy of universal design index.

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