

## DEVELOPMENT OF A QUANTITATIVE AND COMPREHENSIVE USABILITY EVALUATION SYSTEM BASED ON USER NEEDS

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The development of a user-centered product design is important to satisfy customers who want to use a product with ease of use and to keep the manufacturer competitive in the market. The present study developed a system to analyze and evaluate the usability of a product in a systematic and comprehensive manner based on user needs. The usability system was developed through five phases (product-user interface analysis, user needs collection, user-needs hierarchy development, user-needs importance survey, and usability evaluation system development) including various analysis topics in each phase. The system developed through the five-phase process was effectively applied to usability evaluation on refrigerator. The developed usability evaluation system would contribute to developing user-centered designs by providing comprehensive information on the usability of a product.

### INTRODUCTION

Usability evaluation is important in the development process of a user-centered product. The development of a user-centered product is important to keep the manufacturer competitive in the market (Jordan et al., 1996; Jordan, 1998; Courage and Baxter, 2005). Companies conduct various activities such as user needs analysis and usability evaluation to develop user-centered products (Nielsen, 1993). User-centered product based on user needs improve user satisfaction by providing effective interfaces and functions that users want (Griffin and Hauser, 1993). Efforts to develop product designs with better usability help manufacturers remain more competitive in the market (Zirkler and Ballman, 1994). Therefore, in the product development process concerns and efforts have been escalated on usability evaluation and design improvement based on usability testing.

For effective usability evaluation, the development of a user-needs based system is needed to comprehensively evaluate for usability of products. A usability evaluation system is necessary which considers product user interface (PUI) characteristics, tasks, and usage environments. For comprehensive evaluation, usability questions need to be prepared based on user needs (Griffin and Hauser, 1993) to survey usability problems for the target customer group. Also to fully analyze and synthesize evaluation results, a comprehensive usability evaluation system needs to be developed.

Existing studies related to usability testing have limitations in terms of effectiveness, cost, and applicability of results. For quantitative usability evaluation, several ergonomic experimental studies such as eye-movement analysis, and force analysis have been introduced. However, manufacturers mainly conduct quick and simple subjective evaluations based on their practical experience due to limited time allowed in product development. Also, most of experimental studies evaluate on certain design components or tasks; a systematic method is needed to evaluate comprehensive characteristics of a product (Haines and Wilson, 1998). On the other hand, several subjective usability evaluation methods such as questionnaire, focus group

interview (Caplan, 1990), and expert evaluation (Nielsen and Molich, 1990; Nielsen, 1992) have been introduced (Courage and Baxter, 2005). The subjective evaluation methods can survey usability issues quickly and easily; however, limitations exist in applying evaluation results systematically to product design and development. Therefore, an effective usability evaluation system needs to be developed for quick, easy, comprehensive, and quantitative usability evaluation.

The present study developed a quantitative and comprehensive usability evaluation system based on user needs survey. The usability system was developed through five phases (product-user interface analysis, user needs collection, user-needs hierarchy development, user-needs importance survey, and usability evaluation system development). The developed usability evaluation system was applied to refrigerator to examine the effectiveness of the proposed usability evaluation system.

### DEVELOPMENT PROCESS OF USABILITY EVALUATION SYSTEM BASED ON USER NEEDS

The present study developed a usability evaluation system through a five-phase process as shown in Figure 1. The process consists of analyzing the characteristics of product design from a usability aspect, collecting and analyzing user needs, and developing a usability evaluation system based on user needs and their relative importance. The detailed analyses involved in each phase are described below with examples on refrigerator.

#### Phase 1. Product User Interface (PUI) Analysis

A set of fundamental information on a product under study was collected by analyzing PUI characteristics. The PUI fundamental information was utilized in the subsequent phases to generate a questionnaire for collecting user needs, to create a user-needs hierarchy, and to develop a usability evaluation system.

The fundamental characteristics of PUI include product components (C), product functions (F), tasks (T), use environments (E), and usability measures (M). These PUI characteristics were surveyed from various sources including

operating manuals, empirical observations, and opinions of practitioners in product development. As illustrated in Table 1, the collected PUI characteristic information was organized into a hierarchy and the relationships between PUI characteristics such as  $C \times T$ ,  $F \times T$  and  $C \times M$  were analyzed. Table 1.a shows the components of refrigerator are arranged

by its major parts such as door, door-handle, and door guards. Table 1.b shows tasks related to use of refrigerator. Table 1.c defines measures that would be considered to evaluate the usability of the product. Table 1.d displays tasks that are involved to control each component of the product.

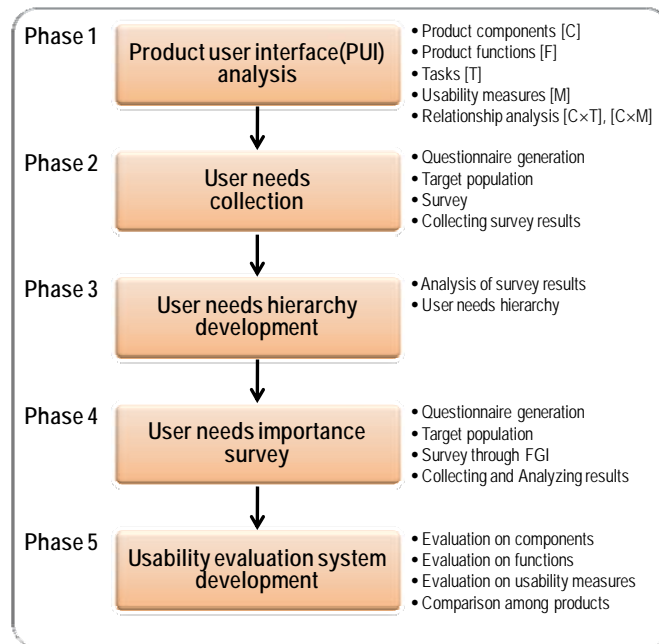


Figure 1. Process for development of comprehensive usability evaluation system based on user needs

Table 1. Analysis of product-user interface characteristics (illustrated for refrigerator)

a. Hierarchy of product components [C]

Category	Subcategory	Component
Exterior components	Door	Door
		Door-handle
Interior components	Door guards	Dairy guard
		Half guard

b. Hierarchy of tasks [T]

Task	Subtask
Door open/close	Open and close the refrigerator door
	Open and close the freezer door
Cleaning	Cleaning
	Disassembling/assembling the component

c. Usability measures [M]

Measure	Definition
Ease of use	The extent to which a user easily operates the product
Ease of control	The extent to which a user easily controls a button
Ease of cleaning	The extent to which a user easily cleans a part
Fit to the hand	The extent to which the handle or grip fits to the size and shape of the hand

d. Relationship analysis of between tasks and components [C x T]

Component [C]			Task [T]			
			Door open/close		Cleaning	Disassembling/assembling the component
			Open/close the refrigerator door	Open/close the freeze door		
Exterior components	Door	Door	O	O	O	
		Door-handle	O	O	O	
Interior components	Door guards	Dairy guard			O	O
		Half guard			O	O

**Phase 2. User needs collection**

Based on the understanding of the PUI characteristics, a questionnaire was prepared to collect needs from users. The questionnaire consisted of questions to survey likes, dislikes, necessary improvements, and improvement ideas for the identified PUI components (C, F, and T). Table 2 shows an example of questions and answers on door and dairy guard in refrigerator. User needs were comprehensively collected by the user survey and utilized to establish a user-needs hierarchy.

Table 2. Questions and user responses (illustrated for refrigerator)

Component	Questions		
	Preference	Improvement needed	Improvement ideas
Door	Can be opened with a low force.	Does not open enough.	Make the operating range larger.
Dairy guard	Its cover can be opened smoothly.	Cannot see inside through the cover.	Make its cover transparent.

**Phase 3. User-needs hierarchy development**

The collected user needs were analyzed and organized into a user-needs hierarchy by C and F (see Table 3). The user-needs hierarchy displays user’s explicit and implicit needs on a product under consideration in a comprehensive, systematic manner. The hierarchical structure of user needs for refrigeration consisted of three levels (first level: C or F, second level: M related to each component or function; third level: user needs related to each usability measure of component). The user-needs hierarchy was applied to prepare a questionnaire for surveying relative importance of user needs; and it was also used to develop a needs-based usability evaluation system.

Table 3. User-needs hierarchy (illustrated for refrigerator)  
a. Component hierarchy

Component	Usability measure	User needs
Door	Ease of control	Smooth open
		Open with low force
Door-handle	Ease of grasp	Good grip fit
Door guards	Ease of use	Appropriate height from the floor
		Appropriate size to storage

b. Function hierarchy

Function	User needs
Cooling	Rapid cooling without frost
	Feedback whether rapid cooling is operating or not
	Appropriate temperature
Home-bar cooling	Independently cooling

**Phase 4. User-needs importance survey**

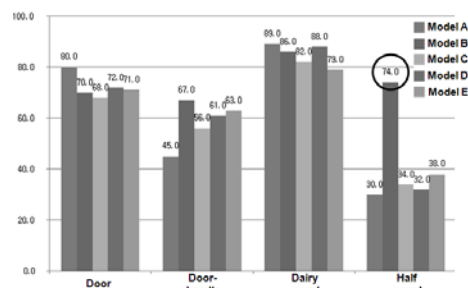
Based on the user-needs hierarchy, the relative importance values of user needs were surveyed. When usability is evaluated for a certain aspect of user-need, its result needs to be adjusted based on its relative importance. An importance questionnaire was prepared based on the user-needs hierarchy. As shown in Table 4, each user need was evaluated using a seven-point scale (1: least important, 4: neutral, 7: most important) by a user group. The importance survey result of user needs was applied to develop a usability evaluation system.

Table 4. Questionnaire for user needs importance survey (illustrated for refrigerator)

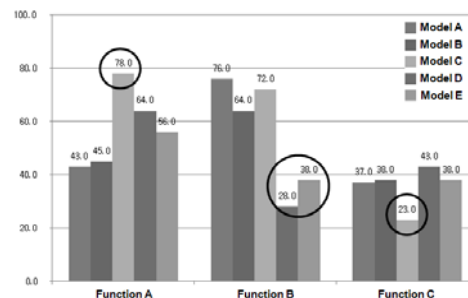
Component	Usability measure	User needs	Importance
Door	Ease of control	Smooth open	①②③④⑤⑥⑦
		Open with low force	①②③④⑤⑥⑦
Door-handle	Ease of grasp	Good grip fit	①②③④⑤⑥⑦
Door guards	Ease of use	Appropriate height	①②③④⑤⑥⑦
		Appropriate size	①②③④⑤⑥⑦

**Phase 5. Usability evaluation system development**

Based on the understanding of user needs and their importance, a usability evaluation system was developed. Using the evaluation system, the usability of a particular product can be evaluated by a seven-point scale by evaluators. The evaluation results are calculated by considering their weights of importance. Figure 2 shows examples of evaluation



a. Comparison of usability scores of product components



b. Comparison of usability scores of product functions  
Figure 2. Usability evaluation results (illustrated for refrigerator)

results that present the total scores of product models and their partial scores in terms of C and F of refrigerator. In Figure 2, a functionality to compare results of several product models in terms of total score and partial scores was also implemented in the evaluation system; circles on the graph indicate models C and E should be analyzed in depth because of their relatively high or low scores.

### APPLICATION TO PRODUCT EVALUATION

A usability evaluation system was effectively developed for side-by-side (SBS) refrigerator. The questionnaire was developed based on a PUI analysis and surveyed on a selected customer group (N = 89, average (SD) age = 41.7 (6.9)) who were using SBS refrigerators. The surveyed user needs were analyzed to establish a user-needs hierarchy for refrigerator's components and functions. Then, a questionnaire for collecting the importance of user needs was prepared and surveyed by a focus group interview (N = 72, average (SD) age = 39.5 (4.0)). Lastly, a user-needs based usability evaluation system was developed by MS Excel software.

The developed evaluation system can compare SBS refrigerators of different brands in terms of various usability aspects in a comprehensive, systematic manner. Based on usability evaluation results, design features preferred and/or requiring improvement can be systematically identified. For example, by comparison of several refrigerators, design parameters such as the height of home bar, the maximum opening angle of door, and the depth of shelf can be identified to be improved and design guidelines were suggested.

### DISCUSSION

The present study developed a usability evaluation system based on user needs. A short-term cycle of product development is one of important competitive aspects (Ragatz et al., 2003). Particularly, in the product design and development phase, the quick and comprehensive evaluation of usability and applying the results to product design are needed (Zhou, 2007). The usability evaluation system in the present study was developed based on analyses of PUI and user needs. The comprehensive usability of a product can be evaluated using the system. As evaluation results, total and partial usability scores of C, F, and M can be calculated; and product developer can analyze the specific usability problems. Also, usability testing results of several products can be compared to find desirable or undesirable design parameters and identify design features requiring design changes.

The present study developed a usability evaluation system by a systematic process of collecting and applying user needs. To develop a user-centered product in terms of good usability, it is important to identify user needs on the product design and development phase. Existing survey methodologies such as questionnaire, focus group interview, or expert evaluation can evaluate subjective users' opinions, and have limitations for quantification and synthesis. In the

present study, the usability evaluation system for the quantitative evaluation of usability of a product was developed based on qualitatively surveyed user needs and its importance. In the present study, usability of refrigerator was quantitatively evaluated using the usability evaluation system according to usability questions extracted from subjective user needs.

The present study developed a system for the comprehensive and effective evaluation of usability based on systematic analysis of PUI. Existing studies evaluated usability of the certain product in terms of specific components or representative benchmark tasks. For example, some studies evaluated button push task of several different cell phones using force or motion measurement system to find a proper size or shape of cell phone buttons (Drury and Hoffmann, 1992; Brand and Hollister, 1999; Colle and Hiszem, 2004). On the other hand, the proposed usability evaluation method in the present study is effective in terms of comprehensiveness. To consider the comprehensive characteristics of a product, the fundamental information of a product was collected by analyzing PUI characteristics and its relationship. Also, the present study surveyed questionnaire for collecting various user needs related to the PUI characteristics. Therefore, the developed evaluation system can evaluate the usability aspects of a product in a comprehensive manner.

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