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A Usability Checklist for the Usability Evaluation of Mobile Phone User Interface

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In the last decade, the research of the usability of mobile phones has been a newly evolving area with few established methodologies and realistic practices that ensure capturing usability in evaluation. Thus, there exists growing demand to explore appropriate evaluation methodologies that evaluate the usability of mobile phones quickly as well as comprehensively. This study aims to develop a task-based usability checklist based on heuristic evaluations in views of mobile phone user interface (UI) practitioners. A hierarchical structure of UI design elements and usability principles related to mobile phones were developed and then utilized to develop the checklist. To demonstrate the practical effectiveness of the proposed checklist, comparative experiments were conducted on the usability checklist and usability testing. The majority of usability problems found by usability testing and additional problems were discovered by the proposed checklist. It is expected that the usability checklist proposed in this study could be used quickly and efficiently by usability practitioners to evaluate the mobile phone UI in the middle of the mobile phone development process.

1. INTRODUCTION

In the last decade, the mobile phone has rapidly evolved from a simple device to make or receive phone calls to a complex multimedia interactive system. Due to the rapid development of mobile technologies and memory devices, in recent years, a

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mobile phone has expanded its functionality to include an MP3 player, digital camera, and digital multimedia broadcasting (DMB) system. Consequently, the mobile phone has been regarded as a common consumer appliance (Klockar, Carr, Hedman, Johansson, & Bengtsson, 2003).

The research of usability in mobile phones is a newly evolving area. Mobile phones have been introduced to general consumers only since the 1990s, thus the related research community has had a relatively short history (Kjeldskov & Graham, 2003). Therefore, there is little knowledge, such as established methodologies and realistic practices, that captures usability in evaluating mobile phones (Klockar et al., 2003). Results of a recent literature survey (Beck, Christiansen, Kjeldskov, Kolbe, & Stage, 2003) indicated that 44 of 114 papers, which were extracted from recent publications in the area of mobile human–computer interaction (HCI), utilized traditional usability evaluation techniques such as heuristic evaluation and that 6 of these papers somehow employed new methods in realistic mobile use situation.

However, most of the studies fall short of evaluating comprehensive aspects of usability issues on mobile phones. For instance, none of these studies considered the newly evolving mobile technologies and added functions, such as MP3 players and digital cameras. For this reason, further study is needed to explore appropriate user interface (UI) evaluation methods to assess the usability of mobile phones quickly yet comprehensively to enhance user satisfaction.

The purpose of this study is to develop a "must-have usability" (Jokela, 2004; Kano et al., 1984) checklist that enables mobile phone UI practitioners to evaluate software UI design using the enhanced traditional UI evaluation approach and to explore potential usability problems comprehensively from a holistic perspective. The proposed checklist would contribute to a reduction in variation costs, which might be generated upon finishing the product development. The must-have usability checklist developed in this study is mainly based on heuristic evaluations that are commonly used and is intended to evaluate each software UI element of mobile phones from the viewpoint of mobile phone developers. To verify the effectiveness of the proposed usability checklist, a case study with advanced mobile phones has been conducted. In addition, conventional usability testing (UT) has been conducted, and its result has been compared with that of the proposed usability checklist.

2. RELATED WORK

Among mobile phone UI developers and users, there is some consensus, in that usability is an indispensable quality of software systems (Hartson, Andre, & Williges, 2001; Jokela, Iivari, Matero, & Karukka, 2003). From this point of view, leading mobile companies are trying to compile a checklist to ensure that software UI design conforms to the guideline (Scholtz, 2004). Major mobile companies such as Nokia are already trying to develop and apply UI design guidelines to the actual design process of mobile phones. However, the development phase of mobile phones is relatively short compared with consumer appliances, due to the limited life cycle of the mobile devices, rapid change in mobile technology, and the extensively com-

petitive market (Kallio & Kekalainen, 2004). Hence, there is certainly a great demand in the mobile industry to develop and implement "light" design approaches or evaluation techniques, which can be applied with time constraints and minimal efforts (Kallio & Kekalainen, 2004).

From a quality perspective adapted from the established Kano's quality model published in 1980s, Jokela (2004) related usability in mobile devices with user satisfaction and divided usability into three categories: must-have, more-is-better, and attractive usability. According to the model itself (Kano et al., 1984), the Kano model is dynamic over time in that attractive usability yesterday turns into more-is-better usability today and then must-have usability tomorrow. For instance, the possibility of including a digital camera function with the newer mobile phone was an attractive feature a few years ago. Today, it turns into a must-have usability for most mobile phone users, in that they would not consider such a device without the camera function. According to Jokela (2004), the minimum requirement in the mobile phone industry is to satisfy the must-have usability to avoid user dissatisfaction. Evidently, even serious attractive usability problems may be acceptable to consumers if their must-have usability expectations are met. Thus, by satisfying the must-have usability, user dissatisfaction can be substantially reduced. Users may even be satisfied with poor usability if they have had no prior experience with a newly emerging mobile technology regarded as an attractive usability. From this point of view, this study aims to focus on the must-have usability to comprehensively check out the potential UI issues affecting user dissatisfaction.

According to the literature that reviewed mobile HCI research methods (Kjeldskov & Graham, 2003; Scholtz, 2004), various usability evaluation methods (UEMs) are being developed to assess and improve usability of interactive systems. Interactive systems are usually designed through an iterative process involving design, evaluation, and redesign, as shown in Figure 1 (Kies, Williges, & Rosson, 1998). During the initial design phase, goals and guidelines are iterated to finalize the design specifications that ultimately lead to a prototype design. Formative evaluation focuses on usability problems that need to be solved during the prototype design stage, before a final design can be accepted for release. Summative evaluation is then conducted to evaluate the efficacy of the final design or to compare competing design alternatives in terms of usability. UEMs are used primarily for formative evaluations during the prototype design stage. These formative evaluations are focused on efficient and effective techniques to determine usability problems that need to be eliminated through redesign (Kies et al., 1998; Scholtz, 2004).

According to the literature on current practices of mobile evaluations, there is no consensus as to whether the usability of mobile devices should be assessed by heuristic evaluation or UT, as both of these methods have their own strengths and limitations.

Heuristic evaluation is an established usability evaluation technique originally proposed by Nielsen (1994) as a cost-effective usability technique. It is an inspection method in which a panel of experts formally assesses an interface design with respect to a set of heuristics or rules of thumb (Nielsen, 1994). The main strength of heuristic evaluation is its speed and affordability (Jeffries &

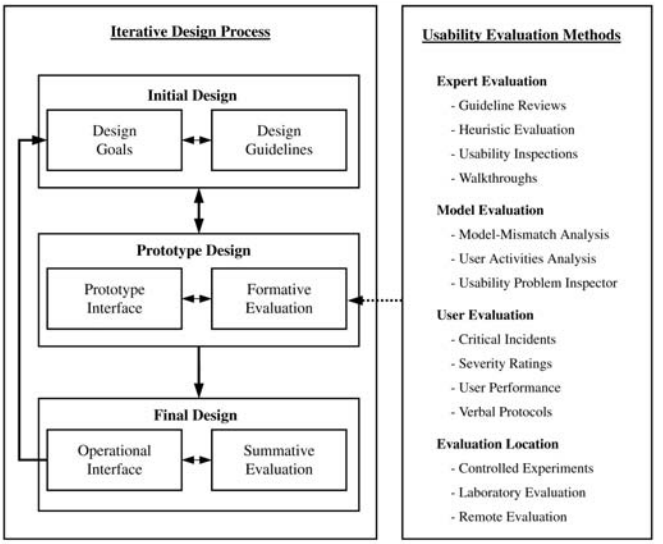

FIGURE 1 Usability evaluation methods in formative usability evaluation (based on Kies et al., 1998).

Desurvire, 1992; Law & Hvannberg, 2002). It also provides conciseness, memorability, meaningfulness, and insight (Paddison & Englefield, 2003). Published studies in the literature indicate meaningful points to improve the effectiveness of heuristic evaluation. A variety of UI design and evaluation guidelines have been developed to improve heuristic evaluation technique. Nielsen also suggested that the best result of heuristic evaluation can be gained if evaluators are experts both in usability engineering and in the domain of interest (Law & Hvannberg, 2004).

The nature of mobile phone development inherently requires a fast and inexpensive design and evaluation process. Because the development phase and life cycle of mobile phones is fairly short, heuristic evaluation can be performed without real end users or a working prototype in the early stage of design process. In addition, if heuristics such as a checklist are documented appropriately, they are easy to learn and apply and thus can be used effectively by nonusability experts (Nielsen, 1994). Hence, heuristic evaluation methods are recommended to evaluate software UI of mobile phones.

However, there are some limitations of heuristic evaluation: It does not approximate the conditions under which real users would use the mobile system. In addition, heuristic evaluation provides little information about the magnitude of the usability problems that are detected (Simeral & Branaghan, 1997). Moreover, the skills and experience of the usability experts can significantly influence the quality of heuristic evaluation. For this reason, heuristic evaluation should supplement UT rather than replace it (Law & Hvannberg, 2002). Subsequently, the focus of this study is to identify an opportunity for improving the traditional heuristic evaluation technique.

3. DEVELOPMENT OF A USABILITY CHECKLIST

The procedure to develop a usability checklist for the mobile phone UI of this study is illustrated in Figure 2. The procedure can be divided into three phases.

In Phase 1, previous research materials about the "style guide," which was developed by several mobile phone companies, are collected and analyzed to obtain "UI elements" that compose the mobile phone UI. Once UI elements are elicited, a hierarchical structure containing those elements is organized. This hierarchy forms the basis of the evaluation checklist, which will help to improve the effectiveness of heuristic evaluation.

During Phase 2, a literature survey about usability issues is conducted. Survey results are arranged and regarded as important usability principles that must be considered in the software UI design process of mobile phone. Arranged principles are carefully selected, deleted, and integrated into a structure ensuring classification of usability principles. This manipulation is surely performed under specific criteria.

In Phase 3, through the pairwise comparison, UI elements from Phase 1 and usability principles from Phase 2 are matched up. Then, for one UI element, questionnaire sentences relevant to matched usability principles are developed. The questionnaire was designed to be comprehensible and practical for usability experts as well as developers.

3.1. Style Guide Structure of Mobile Phone UI

To elicit UI elements related to the mobile phone UI, many style guides from mobile phone companies such as Nokia, Verizon, Sprint, and SK Telecom were collected and analyzed. The analyzed data were then classified by the keywords appearing in the style guide documents. There were 86 elicited elements. The style guide structure was specified through the element classifications and groupings of the relationship analysis. The elements were compared one by one, and the relationship inherent in each element pair was assessed by a focus group of 10 usability experts.

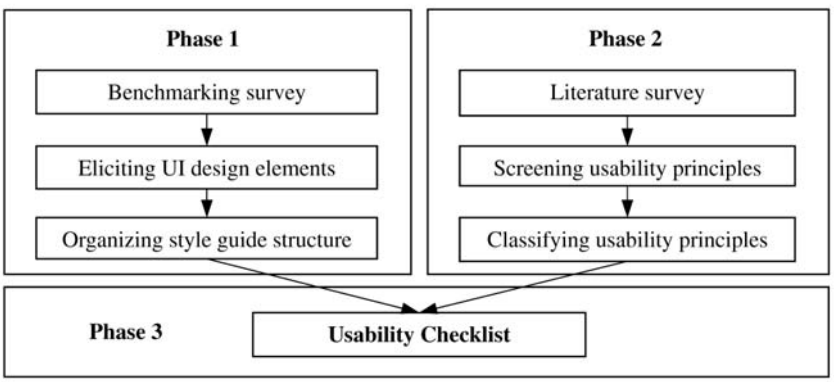

FIGURE 2 Development procedure for usability checklist of mobile phones.

Based on the assessed relationship, those elements were grouped, and each group was named to indicate its own representative characteristic: UI Policies, UI Screens, UI interactions, and UI components. As a result, a hierarchical structure of UI elements was developed as shown in Table 1.

3.2. Usability Principles of Mobile Phone UI

In this phase, as just stated, important usability principles of the mobile phone design process were arranged in regard to the literature survey on usability issues. For instance, Nielsen (1994) focused on several principles, such as visibility of system status, consistency, and freedom. Table 2 fully describes the resulting 43 usability principles and their sources.

Collected principles were examined by the following three criteria: (a) Selection: Is there a practical impact on performance? (b) Integration: Is there any redundancy or similarity relevant to other principles? and (c) Deletion: Are users' subjective feelings included (or have the mobile phone UI considerations been

Table 1: Style Guide Structure

First Level	*Second Level*	*Third Level*
UI policies	Menu policies	Main menu, menu grouping, menu labeling
	Navigation policies	Main menu navigation, list navigation, photograph/video file navigation
	Soft key policies	Soft key arrangement, soft key allocation
	Pop-up policies	Notification pop-up, caution pop-up, selection pop-up, input pop-up
	Icon policies	Static icon, dynamic icon
UI screens	Menu screens	Idle screen, main menu screen, second depth menu screen, list menu screen, check box menu screen, radio button menu screen
	Status screens	Preview screen, animation screen, multisetup screen
	Function-based screens	Calling screen, search screen, MP3/video playing screen, photographing screen, multimedia contents management screen
	External screens	Idle screen, message screen, alarm/morning call/schedule screen, photographing screen, MP3 playing screen
UI interactions	Interaction task type	Confirmation, input, termination, backward/cancel, search
	Interaction feedback type	Send, task confirmation, move, lock, save, modify, delete, download, initiate, load, connect
UI components	Body area	Title area, subtitle area, contents area
	List types	Menu list, single selection list, multiselection list, markable list, view state form
	Widget	Roll-up box, scroll bar, radio button, check box, spin, progress bar, slider
	Text field	Multiline text field, single line text field
	Indicator	Status indicator, stage indicator, proceeding indicator
	Tab	Tab

Note. UI = user interface.

Table 2: Collected Usability Principles

Reference	*Usability Principle*
Constantine (1994)	Structure principle, simplicity principle, visibility principle, feedback principle, tolerance principle, reuse principle
Nielson (1994)	Visibility of system status; match between system and the real world; user control and freedom; help users recognize, diagnose, and recover from errors; recognition rather than recall; aesthetic and minimalist design; pleasurable and respectful interaction with the user; consistency and standard
Treu (1994)	Effort
Dix, Finlay, Abowd, and Beale (1998)	Learnability, predictability, synthesizability, familiarity, generalizability, consistency, flexibility, dialog initiative, multithreading, customizability, task migratability, subsitutivity, robustness, observability, recoverability, responsiveness, task conformance
Lauessen and Younessi (1998)	Ease of learning, task efficiency, ease of remembering, understandability, subjective satisfaction
Preece, Rogers, and Sharp (2002)	Effectiveness, efficiency, safety, utility, learnability, memorability

considered)? For example, in the case of simplicity, when the mobile phone interface is designed simply and clearly, users can conduct tasks easily and quickly. Because simplicity has influence on performance, it was selected by the selection criteria. In the case of familiarity and generalizability, the group's concept is that the interface must be designed to be generalized easily and familiar to users. Accordingly, generalizabillity was integrated into familiarity. Last, subjective satisfaction means that the interface should be pleasant and delight users. Because this falls under subjective sensitivity, subjective satisfaction was removed by the deletion criteria.

Examined principles were also screened in terms of degree of comprehension, causality or correlation, and hierarchical relationships. Through the screening process, 21 usability principles were selected. Table 3 shows the screened principles by the criteria.

Through this screening process, 21 usability principles were selected, and by comparing each principle one by one, relationships within all pairs of principles were specified: 2 indicated a strong relationship, 1 indicated a moderate relationship, and 0 indicated no relevant relationship. Ten usability experts took part in this analysis. A table was constructed with the relationship-indicating numbers (0, 1, 2) and was employed as an input dataset for principal component analysis (PCA) with varimax rotation The result of PCA is shown as Table 4.

Each factor includes usability principles, which have factor loadings greater than 0.4. However, flexibility, user control, and customizability (factor loadings < 0.4) were still included in the factor because of their importance in supporting mobile phone users. As a result, all Cronbach's alpha coefficients were well above the threshold (0.7).

From the result of the PCA, five groups were classified as follows.

1. Cognition Support relates to cognitive aspects of user.

Table 3: Results of Screening Usability Principles

Usability Principles	*Numbers*	*Numbers*
Removed usability principles	Visibility of system status (C2), match between system and the real world (C5), aesthetic and minimalist design (C2), pleasurable and respectful interaction with the user (C3), consistency and standard (C2), safety (C3), utility (C3), dialog initiative (C4), multithreading (C3), task migratability (C2), task conformance (C1), ease of learning (C2), task efficiency (C2), ease of remembering (C2), understandability (C5), subjective satisfaction (C3), robustness (C1), observability (C6), learnability (C2), tolerance principle (C5), reuse principle (C2), generalizability (C2)	22
Selected usability principles	Predictability, learnability, structure principle, consistency, memorability, ramiliarity, recognition, visibility, simplicity, subsitutivity, feedback, error indication, synthesizability, responsiveness, recoverability, flexibility, user control, customizability, effectiveness (C4), efficiency (C4), effort (C4)	21

Note. C1 = selection, C2 = integration, C3 = deletion, C4 = degree of comprehension, C5 = causality or correlation, C6 = hierarchical relationships.

Table 4: The Result of PCA with Varimax Rotation

	Factors				
	1	*2*	*3*	*4*	*5*
Predictability	0.6329				
Learnability	0.9235				
Structure principle	0.8875				
Consistency	0.9049				
Memorability	0.8497				
Familiarity	0.7475				
Recognition		0.6180			
Visibility		0.9041			
Simplicity		0.7014			
Subsitutivity		0.7838			
Feedback			0.8011		
Error indication			0.4853		
Synthesizability			0.7405		
Responsiveness			0.4161		
Recoverability				0.8068	
Flexibility[a]				0.2816	
User control[a]				0.0390	
Customizability[a]				0.1650	
Effectiveness					0.7006
Efficiency					0.6364
Effort					0.5474
Cronbach's alpha	0.9261	0.8791	0.8298	0.8141	0.8834

Note. PCA = principle component analysis.
[a]remained principles after adjustment even if the factor loadings were below 0.4.

2. Information Support relates to characteristics of mobile phone display and information.
3. Interaction Support relates to the interaction between user and mobile phone.
4. Performance Support relates to performance of the intended task of the user/mobile phone system.
5. User Support relates to the degree of intervention of user.

Table 5 shows the definition of each principle and grouped structure.

3.3. Usability Checklist of Mobile Phone UI

Style guide structure and arranged usability principles were then utilized to develop a checklist. This checklist was intended to support the assessments of design alternative in terms of usability. Through the pairwise comparison, style guide structure components were matched with 21 usability principles (see Figure 3). For each component, the usability principle that must be met in the design of the mobile phone UI was elicited by usability experts' discussion. Table 6 shows a part of the result.

Based on the relevant principles, evaluation questionnaires for each element of style guide structure were derived from the unanimous decision of the focus group, which consisted of an equal number of usability experts and mobile phone developers. The proposed evaluation checklist is fully described in the Appendix. With the checklist, evaluators will be asked to rate their degree of satisfaction for each evaluation item using a 7-point Likert-type rating scale and to describe suggestions if necessary.

4. IMPLEMENTATION: CASE STUDY

4.1. Usability Evaluation of Mobile Phone UI

To measure and demonstrate the practical effectiveness of the proposed usability checklist, comparative experiments on both usability checklist and UT were conducted, respectively, with simulated task scenarios in laboratory.

Mobile phones for usability evaluation. Samples of mobile phones for usability evaluation of the mobile phone UI were chosen considering state-of-the-art functions such as an MP3 player, QVGA displays (resolution: 320 × 240), and a digital camera. As shown and described in Table 7, three brand-new mobile phones in the Korean telecommunication market were selected to be used in the experiment.

Task-based usability checklist evaluation. The three mobile phone samples were evaluated using the proposed usability checklist developed in session 3.3

Table 5: The Definition and Structure of Usability Principles

Usability Principles	*Definitions*
Cognition support	
Predictability	The user interface must produce results that are in accord with previous commands and states.
Learnability	The user interface must be designed for user to learn easily the use of mobile phone.
Structure principle	The user interface must be organized purposefully, in meaningful and useful ways that put related things together and separate unrelated things based on clear, consistent models that are apparent and recognizable to others.
Consistency	The user interface must be designed consistently.
Memorability	The user interface must be easy for users to remember how to use the mobile phone.
Familiarity	The user interface must be familiar to users.
Information support	
Recognition	The user interface must be easy for users to recognize the status of systems or the use of mobile phone.
Visibility	The user interface should always keep users informed about what is going on, through appropriate feedback within reasonable time.
Simplicity	Make simple, common tasks simple to do, communicate simply in the user's own language and provide good shortcuts that are meaningfully related to longer procedures.
Subsitutivity	The information about numerical values must be easily understood by users.
Interaction support	
Feedback	The user interface must keep users informed of actions or interpretations, changes of state or condition using clear, concise, and unambiguous language familiar to users.
Error indication	The representation of errors must be clear to users.
Synthesizability	The user must be able to construct the proper model of the system. The system must display the correct clues to construct a proper model.
Responsiveness	The system must respond in an appropriate time.
User support	
Recoverability	If the user makes a mistake or the application fails, the user must be able to recover the work.
Flexibility	The user interface must be flexible so that adapts to various environments and users.
User control	The users must be able to control the system by their own decisions.
Customizability	The user must be able to modify the interface in order to improve efficiency.
	The customizing features must be easily accessible.
Performance support	
Effectiveness	The required range of tasks must be accomplished at better than some required level of performance by some required percentage of the specified target range of users within some required proportion of the range of usage environment.
Efficiency	The system should be efficient to use so that once the user has learned the system, a high level of productivity is possible.
Effort	The user interface should be designed to minimize the user's effort for using the system.

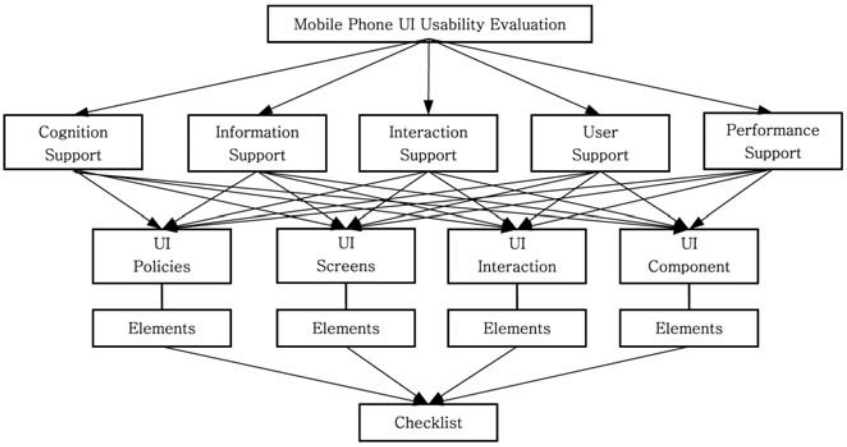

FIGURE 3 Conceptual structure of usability checklist.

Table 6: A Part of the Result of Eliciting the Relevant Usability Principles

	Principle				
Component	*Cognition Support*	*Information Support*	*Interaction Support*	*User Support*	*Performance Support*
Main menu		Recognition, simplicity		Customizability	
Menu grouping	Structure principle, consistency				
Menu labeling	Consistency, memorability, familiarity				
Main menu navigation			Responsiveness		
List navigation	Consistency				Effort
Photograph/video file navigation	Predictability			Flexibility	
Soft-key arrangement	Consistency				
Soft key allocation	Consistency				
Notification pop-up		Visibility			

and fully described in the Appendix. Ten graduate students (5 men and 5 women) with at least 2 years of mobile phone experience were recruited from Seoul National University; they had advanced mobile phones with QVGA resolution and functions, such as an MP3 player and digital camera. In addition, they has at least 1 year's experience using mobile phones with an MP3 player, QVGA displays, and a camera. Their average age was 24.5 years. At the beginning of the experiment, each participant was provided with an informed consent form and a brief description of the goals and procedures of the experiment. They were compensated for their time and participation. Between questionnaires for each sample phone, participants

Table 7: Mobile Phones for Evaluation

Type	*Sample 1*	*Sample 2*	*Sample 3*
Feature			
Specifications	• Manufacturer: LGT • Model No. HS8000 • Release date: 2005/05 • LCD resolution: 320 × 240 • MP3 function: support • Camera: 2 mega pixels CCD	• Manufacturer: Samsung • Model No. SPH–V6050 • Release date: 2005/07 • LCD resolution: 320 × 240 • MP3 function: support • Camera: 1.3 mega pixels CCD	• Manufacturer: Ever • Model No. KTF–X6000 • Release date: 2004/12 • LCD resolution: 320 × 240 • MP3 function: support • Camera: 2 mega pixels CCD

were given a 5-min rest. The mobile phones were evaluated in random order, whereas the questionnaire itself was identical across all three sample mobile phones. The participant was expected to spend about 2 hr on the evaluation.

UT evaluation. UT refers to a process that employs participants who are representative of the target population to evaluate the degree to which a product meets specific usability criteria. Among various UT handbooks, Rubin's (1994) handbook was used to conduct usability testing in this study.

Rubin (1994) said that UT employs techniques to collect empirical data while observing representative end users using the product to perform representative tasks. Conducting a usability test can be divided into six stages: developing the test plan, selecting and acquiring participants, preparing the test materials, conducting the test, debriefing the participants, and transforming data into findings and recommendations.

In this study, UT was performed as a laboratory experiment. Ten participants (5 men and 5 women) who had at least 2 years' mobile phone experience were recruited from student population of Seoul National University. Their average age was 23 years. The same mobile phones were employed in this usability experiment, but different participants were employed to prevent the learning effects from the experience of checklist evaluation. UT scripts, which were utilized for UT, consisted of questionnaires on personal backgrounds, instructions of the experiment, task scenarios, and subjective satisfaction questionnaires. Figure 4 briefly shows the experimental procedure of the UT.

At the beginning of the experiment, a brief orientation was provided with an informed consent form to explain the details about UT as well as the procedures of the experiment. Participants for UT were also compensated for their time and par-

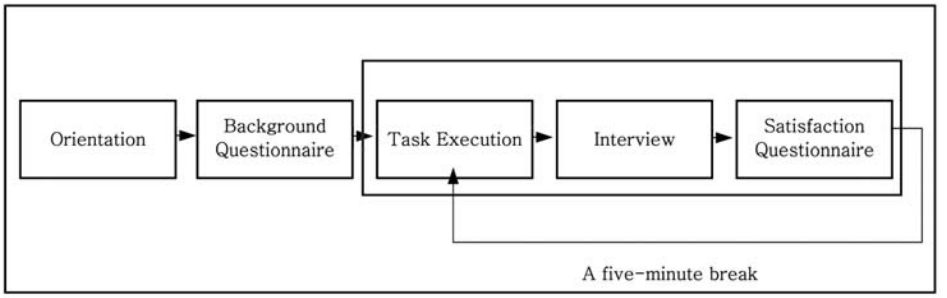

FIGURE 4 The procedure of usability testing.

ticipation. During the experiment, every task for three sample mobile phones was recorded using a digital camcorder (DCR–PC105; Sony, Tokyo, Japan). The recordings were to be further analyzed in terms of error frequencies, task completion time, and task success rate. After finishing each of the 19 task scenarios for each sample mobile phone, an interview was held to note remarks on errors or problems related to the task. Between experimentation for each sample phone, participants were given a 5-min rest. The sequence of 19 task scenarios for UT was randomized for each sample phone, whereas the task itself was identical across three sample mobile phones.

Based on the Questionnaire for User Interface Satisfaction (QUIS; Chin, Diehl, & Norman, 1988), questionnaires for evaluating subjective satisfaction were given upon completion of all task scenarios for each sample phone. QUIS was designed to measure users' subjective satisfaction about the product interface. The questionnaires were divided into one section for overall satisfaction and sections for satisfaction for four specific interfaces. Participants were asked to rate their degree of satisfaction for each evaluation item using a 7-point likert-type rating scale. As shown in Table 8, 19 task scenarios involving frequently used functions were briefly described. The scenarios can be classified as 8 top levels and 18 sublevels.

4.2. Results of Case Study

Summary of results. The results of usability evaluation for sample mobile phones using the checklist and UT are summarized in Table 9. Subjective satisfaction from the checklist was analyzed as a numerical score.

According to the result of usability checklist evaluation, the overall rating on Sample 1 was the highest (5.14), Sample 2 ranked the second (5.07), and Sample 3 received the lowest score (4.49). With the exception of UI interactions, users' ratings on other parts were similar to the overall score, whereas the mean rating of Sample 2 was the highest among the three phones in terms of UI interactions. The result of the UT was similar to that of the checklist. The overall satisfaction on Sample 1 was

Table 8: Task Scenarios

Top Level	*Sublevel*	*Description of Task Scenarios*
Phone book	Phone number registration	1. Starting at the idle screen, register following phone number. (Phone number: 012-3456-7890, Name: ¬¬¬, Address: 20, Category: mobile phone, Group: family)
		2. Starting at the idle screen, Enter the phone book menu by menu navigation and then register following phone number. (Phone number: 111-1111-1111, Name: ¬¬¬, Address: 30, Category: mobile phone, Group: family)
	Phone number searching and modification	3. Starting at the idle screen, press the short key and search the number of "¬¬¬." Then, modify the number to '098-7654-3210'.
		4. Starting at the idle screen, enter the phone book menu by menu navigation and rearch the number of "¬¬¬." Then, modify the number to "012-3456-7890."
Message	Message sending	5. Starting at the idle screen, enter the message sending screen and input "¬¬¬¬¬¬¬¬¬¬" at the first line, "ADADADADADADADAD" at the second line, "'0123456789012345" at the third line, "¬¬¬¬¬¬¬¬¬¬" to cover the full page. Then, modify '8' at the third line to "¬" and send the message to "¬¬¬."
	Message receiving and reply	6. Starting at the idle screen, enter the message storage screen and check the 15th message. Then, input "¬¬¬" in reply to the message.
	Sending a multi-message	7. Starting at the idle screen, enter the multi-mail menu and append the second picture at the second folder. Then, send it to "¬¬¬" with the title "¬¬¬¬."
Camera	Take a picture and check it.	8. Starting at the idle screen, change the resolution to "640*480," the white balance to "fluorescent light," the brightness to "+3" and take a picture. Then, check the picture immediately.
	Take a picture and send it to a friend.	9. Starting at photographing menu, take a picture and send it to "¬¬¬" with the title "¬¬¬¬."
Contents	Play MP3 music.	10. Starting at MP3 playing screen, play the second song and change volume to the middle level. Then pause the playing.
	Check the picture.	11. Starting at the idle screen, find the latest picture and check it. Then, press the "sending" button.
	Move the picture to other folder.	12. Starting at the idle screen, enter the data folder menu and find the latest picture. Then copy it to "Myself" folder.
	Delete the picture.	13. Starting at the idle screen, find the copied picture and delete it.
Idle screen	Set up the idle screen.	14. Starting at the idle screen, enter the screen set-up menu and modify the screen as follows. (Background image: "Lee Hyolee," Text arrangement: Slide)
Scheduler	Register a schedule.	15. Starting at the idle screen, enter the schedule management menu and register a schedule as follows. (Date: 2005/07/27, Time: 3:30pm, Content: "¬¬¬¬," Category: appointment, Alarm: an hour ago)
	Check a schedule and modify it.	16. Starting at the idle screen, enter the schedule management menu and check the nearest schedule. Then, modify the content to "¬¬¬¬."
	Set up the alarm.	17. Starting at the alarm menu, set up the alarm as follows. (Date: Today, Time: 6 pm, Frequency: one time)
Contents download	Download a game.	18. Connect to "Downtown" and enter the game menu by menu navigation. Then download "tetris 2004."
	Download a ringtone.	19. Connect to "EZ-i" and download the 4th ringtone at "Best 30" menu. Then set up it to the default ringtone.

Table 9: Summary of Results From Usability Checklist and Usability Testing

		Rating Score					
		Sample 1		*Sample 2*		*Sample 3*	
Evaluation Type	*Dimension*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Usability checklist	1. UI policies**	5.15	0.655	5.04	0.422	4.36	0.514
	2. UI screens*	5.17	0.482	5.12	0.424	4.59	0.351
	3. UI interactions*	4.88	0.618	4.90	0.585	4.15	0.541
	4. UI components	5.36	0.671	5.20	0.558	4.85	0.590
	Total*	5.14	0.573	5.07	0.389	4.49	0.439
Usability testing	1. Overall reaction***	4.86	0.618	4.68	0.271	2.66	0.162
	2. Screen**	4.88	0.311	4.51	0.182	3.03	0.109
	3. Terminology and system information**	4.88	0.358	4.78	0.163	3.42	0.515
	4. Learning**	5.08	0.259	4.83	0.192	3.50	0.308
	5. System capabilities**	4.98	0.349	4.73	0.238	3.45	0.456
	Total***	4.93	0.081	4.71	0.170	3.15	0.323

Note. UI = user interface.
*$p < 0.05$. **$p < 0.01$. ***$p < 0.001$.

the highest (4.93), Sample 2 ranked second (4.71), and Sample 3 ranked the lowest (3.15). The mean score of all dimensions showed similar tendency.

To investigate the difference in satisfaction among the intended phones, an analysis of variance (ANOVA) was conducted. As a result of usability checklist, the ANOVA suggested that overall satisfaction on Samples 1, 2, and 3 was significantly different, $F(2, 27) = 4.99$, $p < .05$. Satisfaction in UI policies, $F(2, 27) = 5.55$, $p < .01$; UI screens, $F(2, 27) = 5.15$, $p < .05$; and UI interactions, $F(2, 27) = 4.74$, $p < .05$, were also significantly different. But the satisfaction of UI components was not significantly different, $F(2, 27) = 1.63$, $p = .216$, because all intended phones indicate the UI components appropriately. In the case of UT, overall satisfaction on Samples 1, 2, and 3 was also significantly different, $F(2, 27) = 12.41$, $p < .001$. Every satisfaction of overall reaction, $F(2, 27) = 10.17$, $p < .001$; screen, $F(2, 27) = 7.04$, $p < .01$; terminology and system information, $F(2, 27) = 8.00$, $p < .01$; learning, $F(2, 27) = 7.97$, $p < .01$; and system capabilities, $F(2, 27) = 7.16$, $p < .01$, showed significant differences.

Post hoc analysis was conducted to further investigate the difference of mean scores between two intended phones using Tukey's test. The results of Tukey's test revealed that there were significant differences of overall scores from the usability checklist between Samples 1 and 3 ($p < .05$) as well as between Samples 2 and 3 ($p < .05$). However, mean scores on Samples 1 and 2 did not show a significant difference ($p = .947$). The result of UI policies, UI screens, and UI interactions was the same ($p < .05$). As a result of UT, there were also significant differences of overall mean scores between Samples 1 and 3 ($p < .001$) and Samples 2 and 3 ($p < .01$). The mean scores on Samples 1 and 2 did not show a significant difference ($p = .236$). The result of overall reaction, terminology and system information, and system capabilities was the same ($p < .01$). In the case of screen and learning, means scores between Samples 1 and 3 showed significant differences, but others did not.

Comparisons between usability checklist and usability testing. The problems found from checklist and UT was compared. In the usability test, usability problems were identified by the analysis of user observation and user interviews. As a result, a greater number of problems were found through the checklist evaluation compared to the usability test. Furthermore, usability problems that occurred frequently in the usability test were also codiscovered by the checklist. However, the checklist evaluation failed to identify six additional problems for Sample 1, five for Sample 2, and eight for Sample 3 (see Table 10). These problems were closely related to practical usage of mobile phones. In the case of Sample 2, participants hardly perceived the speed of fast forward when using the MP3 Play function, but this fact was not discovered when performing a checklist evaluation. However, problems such as icon indication for caution pop-up or consistency about soft-key labels were discovered through the checklist evaluation, although the UT failed to recognize such problems.

In the result of experiments, the characteristics of UT and checklist evaluation could be compared and contrasted. The UT could discover the serious problems of interaction occurring in the mobile phone usage, whereas the proposed checklist evaluation could find various problems of specific UI elements. Compared to the traditional heuristic evaluation, it was revealed that the checklist enabled evaluators to find majority of interaction problems found in the UT.

Improvement. To improve the mobile phone UI, usability problems discovered by the usability checklist were taken in account. Among the various usability problems, the low-scoring and frequent ones were extracted, and the solution alternatives were generated. Table 11 shows an example of usability problems found by usability checklist and proposed alternatives.

In addition, the proposed usability checklist was modified and supplemented so that it could be used easily by mobile phone UI developers. This procedure was carried out through discussions with usability experts and mobile phone UI developers. After the discussion, the questionnaire items were presented more concretely and clearly from the viewpoint of developers. Additional questionnaire items were created so that usability problems found by UT could be recognized by the usability checklist in the future.

Table 10: The Number of Problems Found From Checklist and Usability Testing

	Sample Phone 1		*Sample Phone 2*		*Sample Phone 3*	
	Checklist	*UT*	*Checklist*	*UT*	*Checklist*	*UT*
The number of problems	76	54	59	54	92	73
The number of problems not found by checklist	6		5		8	
The number of additional problems found by checklist	28		10		27	

Table 11. Examples of Usability Problems and Design Alternatives (Sample 1)

Elements	*Snapshot of Problems*	*Causes of Problems*	*Improvement*
Roll-up box		In the photographing screen, the reaction time after pressing the menu button is much longer than other screens.	Reduce the reaction time to be same with other cases when photographing
Scroll bar		The width of scroll bar is too thin so that it is not clearly visible.	Increase the width of scroll bar
Progress bar		The progress bar does not represent the current status clearly.	Indicate the percentage of process with texts or bar graphs

5. DISCUSSION AND CONCLUSION

The usability checklist developed in this study is mainly based on heuristic evaluation methods that are the most popular usability evaluation methods. According to Law and Hvannberg (2004), the effectiveness of heuristic evaluation closely depends on the importance of selecting usability guidelines. Accordingly, we have developed 21 usability principles that are crucial in the mobile phone UI design.

Beck et al. (2003) asserted that most of the previous studies on usability evaluation fall short of evaluating comprehensive aspects of usability issues on mobile phones. Due to the limited life cycle and rapid change in mobile technology, a usability checklist for heuristic evaluation should be updated quickly and easily by including the additional UI elements and appropriate usability principles into the evaluation framework. In this study, the mobile phone UI style guide structure was developed to evaluate the comprehensive aspects including state-of-the-art functions such as an MP3 player and digital camera.

In the proposed usability checklist, there exists a promising methodological benefit to enhance the effectiveness and efficiency of heuristic evaluation as follows. The result of comparative experiments on both usability checklist and UT revealed that about 90% of usability problems identified by UT were covered by the pro-

posed usability checklist. According to the literature (Law & Hvannberg, 2002), heuristic evaluation reports typically do not predict 30 to 50% of usability problems found by UT. Given the result in this study, it can be asserted that the proposed checklist evaluation might improve the traditional heuristic evaluation technique. In addition, the checklist developed in this study could supplement UT, because it could cover the majority of usability problems found in UT.

The result of case study reached the following conclusions. This study developed a suitable usability checklist systematically, which enables mobile phone UI developers to quickly and easily evaluate the usability of software UI. The structure of style guide, including comprehensive mobile phone UI elements, was specified, and relevant usability principles were collected and then classified into five meaningful groups. In addition, the usability checklist was developed through the pairwise comparison of UI elements and usability principles. To improve the practical effectiveness of the developed checklist, various usability principles were used to clearly specify evaluation items, which were relevant to the software UI of mobile phones, and items themselves were expressed concisely to facilitate the developer's interpretation.

The results of the case study successfully demonstrated the practical effectiveness of the usability checklist. In addition to the commonly recognized usability problems, the checklist of this study also enabled evaluators to identify the serious usability problems that could be identified by the UT. It may suggest a possibility that the proposed checklist evaluation could supplement the UT. The scores of subjective satisfaction from the checklist and UT showed similar tendencies and justified the effectiveness of the proposed checklist.

We expect that the usability checklist developed in this study can be used by usability practitioners to evaluate the mobile phone UI concurrently during the process of development, because it is intended to evaluate each UI element without time pressure and excessive experimental efforts. Finally, we should mention that further continuous efforts are needed to update the checklist as new mobile technologies emerge.

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Appendix: Usability Checklist

First-Level Element	Second-Level Element	Evaluation Items	Evaluation (Most Negative←Negative←Normal→Positive→Most Positive) 1	2	3	4	5	6	7	Suggestion
Part 1: UI Policies										
Menu policies	Main menu	Is the menu type easy to recognize?								
		Is the main menu visually simple and clear?								
		Can users change the main menu type as they desire?				Yes / No				
	Menu grouping	Is the main menu composed of related submenus?								
	Menu labeling	Does the menu labeling follow the screen guideline?								
		Is the menu labeling familiar and easy to remember?								
Navigation policies	Main menu navigation	When users press the direction keys to move to other top menus, is the response immediate?								
	List navigation	Is the method of page movement or scroll consistent in every menu navigation?								
		Is the list selectable with the number key?				Yes / No				
	Photograph/video file navigation	Is the navigation method between folders or files easily predictable?								
Soft key policies	Soft key arrangement and allocation	Is the soft key which performs the same function always in same location?								
		Is the method of soft key naming always consistent?								
		Is the naming of soft key consistent with actually performed function?								
		Is the confirmation key allocated in the middle?				Yes / No				
		Is the use of soft key confused by "cancel" soft key?[a]				Yes / No				
		Is the button on the keypad which performs soft key function correctly allocated?				Yes / No				
		Is the button in soft key area compatible with the button on the keypad?[a]				Yes / No				
Pop-up policies	Notification pop-up	Is the content of pop-up indicated clearly?								
		Is the maintenance time of pop-up appropriate for users to understand the content clearly?								
	Caution pop-up	Do the icon, content, sound of pop-up mean caution correctly?								
		Is the maintenance time of pop-up appropriate for users to understand the content clearly?								
	Selection pop-up	Is the content of pop-up indicated clearly?								

		Is the indication of selected items clear?	
		When users select an item, is there a feedback of selection?	Yes / No
	Input pop-up	Is the title of pop-up clear?	
		When there is no input or a wrong input, is there a indication of error?	Yes / No
Icon policies	Static icon and dynamic icon	Is the icon interpreted equally by users?	
		Is the icon familiar to users?	
Part 2: UI Screens			
Menu screens	Idle screen	Is the information indicated on idle screen clearly visible?	
	Second depth menu screen	Is the list area distinguished clearly from the title area?	
		Is the configuration of second-depth menu screen simple and clear?	
	List menu screen	Is the list area distinguished clearly from the title area?	
		Is the subtitle indicated clearly?	
	Checkbox and radio button menu screen	Is the visual indication about which items can be selected clear?	
		When users select an item or move to other items, is the visual indication clear?	
Status screens	Preview screen	Is the preview screen understandable?	
		Is the ease of use increased by the preview screen?	
	Animation screen	Is the animation easily recognizable?	
	Multisetup screen	Is the arrangement of items consistent on the multi-setup screen?	
		Do the selected items distinguish clearly from other items on the multi-setup screen?	
Function-based screens	Calling screen	When users input phone number, is the numbers indicated on the screen visually clear?	
		When users input the phone number, is the time from pressing the number key to displaying the number on the screen appropriate?	
		Is the configuration of the calling screen familiar to users?	
		Is the indication of which functions are executable visually clear?	
		Does the sending screen clearly indicate that users are making a phone call?	
		Does the receiving screen clearly indicate that users are receiving a phone call?	

(continued)

Appendix: Usability Checklist (Continued)

First-Level Element	*Second-Level Element*	*Evaluation Items*	*Evaluation* (Most Negative←Negative←Normal→Positive→Most Positive) 1	2	3	4	5	6	7	*Suggestion*
	Search screen	Is the search screen simple and clear so that users can search the items easily?								
		When the input is wrong, is the information about the error indicated clearly?								
		Is the response time from input to displaying the result adequate?								
	MP3/video playing screen	Is the control area of playing screen familiar to users?								
		When playing the music, can the users easily find functions like stop or search?[a]								
	Photographing screen	When taking a picture, is the indication of which functions are selected adequate?								
		When taking a picture, is the preview about the selected function easily recognizable?[a]								
		Can the users easily control the functions related to photographing?								
	Multimedia contents management screen	Are the categories which contain multimedia contents appropriate?								
		Are there other classification methods to save photograph files other than dates?				Yes / No				
		Is there a numerical indication of current storage level and maximum storage level?				Yes / No				
		Is the numerical indication of current storage level and maximum storage level understood easily?[a]								
External screen	Idle screen	Are the indicators on the external screen visually clear?								
	Message screen	Is the indication of received the message visually clear?								
	Alarm/morningcall/ schedule screen	Is the information of alarm/morning call/schedule recognized clearly?								
	MP3 playing screen	When playing music, is there the information about the indicator, current time and music title?				Yes / No				

Part 3: UI Interactions			
Interaction task type	Confirmation, input, termination, backward/cancel, search	Is functional indication of soft key consistent?	
		Is functional indication of soft key clear?	
Interaction feedback type	Send	Is send-on-going visually articulated?	Yes / No
		Does pop-up notice failure or cancel of sending process?	Yes / No
	Task confirmation	Does pop-up notice terminate requested task?	Yes / No
	Move	Is expression to indicate file-movement inside terminal memory correct?[a]	Yes / No
		Is the information on consequences of movement offered literally or visually?	Yes / No
		Is movement delay notified?	Yes / No
		Is passage to cancel movement provided?	Yes / No
	Lock	Is locking easily discerned?	
		Is there proper feedback for inability under the request of usage of locked system?	
		Is password input window offered for the selection of locked item?	Yes / No
	Save	Is the visual expression of save process proper?	
		Is there an appropriate visual indicator for save delay?	Yes / No
	Modify	Is sign on modification clear and proper?	
		Is modification reconfirmation properly done?	
		Is modification success and failure properly notified?	
	Delete	Is sign on deletion clear and proper?	
		Is deletion reconfirmation properly done?	
		Is deletion success and failure properly notified?	
	Download	Is sign on downloading or contents downloaded proper?	
		Is download success and failure properly notified?	
		Is there any feedback for delaying download?	Yes / No
		Is there a notification how to cancel download?	Yes / No
	Initiate	Before initialization, is reconfirmation process provided?	

(continued)

Appendix: Usability Checklist (Continued)

First-Level Element	*Second-Level Element*	*Evaluation Items*	*Evaluation* (Most Negative←Negative←Normal→Positive→Most Positive) 1	2	3	4	5	6	7	*Suggestion*
		Is there a proper visual display in case of long initiating task?				Yes / No				
		Is initialization success or failure properly notified?								
	Load	Is sign on loading terminal properly designed?								
		Is there a visual display to show the process of loading?				Yes / No				
		Is loading success or failure properly notified?								
	Connect	Is sign on loading well recognized by proper display?								
		Is there a way to stop the process of connection?				Yes / No				
		Is connection success or failure properly notified?								
Part 4: UI Components										
Body area	Title area	Is the title area familiar?								
		Is the title area discriminated from other area clearly?								
		Are the icons, texts size, and colors visible?								
	Subtitle area	Are the form and location of subtitle area consistent?								
		Are the subtitle areas discriminated from the other area clearly?								
	Contents area	Are the contents discriminated from the other area clearly?								
List types	Menu list	Is the selected item discriminated visually from the others clearly?								
		Is there any way to select items besides scrolling?				Yes / No				
	Single selection list	Is the selected item discriminated visually from the others clearly?								
	Multiselection list	Is the selected item discriminated visually from the others clearly?								
	View state form	Are the titles of items visible?								
Widget	Submenu	Are the appearance types and forms of submenu consistent?								
		Is the response time of submenu (when pushing the key) appropriate?								
	Scroll bar	Is it possible to predict the quantity of contents through the scroll bar?[a]								

		Is the visual discrimination between scroll bar and background image clear?	
	Radio button	Is the visual discrimination of activated button clear?	
	Checkbox	In check box, is it easy to check?	
	Spin	Is the operation type of spin easy to recognize?	
	Progress bar	Is the shape of progress bar consistent in all over the menus?	
		Can user recognize the processing state through the progress bar?	
	Slider	Is the extent of increase and decrease that slider represents easy to recognize?	
Text field	Multiline text field	Is the discrimination between the lines clear in multiline text field?	
		When input text, is the type of indicating current input location appropriate?	
		When input text, is the capacity feedback type appropriate?	
		If the input tasking ends without pushing the "Confirm" key, is the record of previous task remaining?	Yes / No
	Single line text field	In multiline field, is the visual discrimination between selected line and unselected line clear?	
		When input text, is the indication of current input location appropriate?	
Indicator	Status indicator	Is the indicating type simple and recognizable?	
	Stage indicator	Is the indicating type simple and recognizable?	
	Proceeding indicator	Is the indicating type simple and recognizable?	
Tab	Tab	Is the visual discrimination between selected item and unselected item clear?	
		Are the shape and location of tab visible?	

[a]Additional evaluation items by the result of implementation.