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Usability Evaluation of Graphic User Interfaces for a Military Computer-Based Training System

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Objective: The present study was to improve the graphic user interface (GUI) of a military computer-based training (CBT) system in terms of usability.

Background: Existing studies have focused on usability evaluation of a particular GUI type such as sequence, hierarchy, or context type; however, few research has been conducted which identifies preferred GUI features based on a comparative analysis of different GUI types.

Method: A comparative evaluation was conducted by 9 CBT design experts using a 7-point scale (1: very low, 4: neutral, and 7: very high) on hierarchy and context GUI types of a military CBT system in terms of 10 usability criteria. Then, preferred features of the hierarchy and context types being accommodated, a new GUI was developed and validated by 22 CBT users.

Results: While the hierarchy type was found preferred by 1.6 times in terms of controllability to the context type, the opposite was found in terms of attractiveness, simplicity, and responsiveness by 0.6, 0.8, and 0.8 times, respectively. The proposed GUI was found superior to the hierarchy and context types in terms of accessibility and informativeness by more than 1.5 times, but inferior to the hierarchy and context type in terms of simplicity by 0.6 and 0.9 times, respectively.

Conclusion: The new GUI developed by accommodating the preferred features of the hierarchy and context types improves usability in terms of accessibility and informativeness except simplicity.

Application: The comparative analysis of various GUIs can be applied to develop an improved GUI in a systematic manner based on preferred features of the existing GUIs.

Keywords: Graphic user interface, Computer-based training, Usability evaluation, Design improvement

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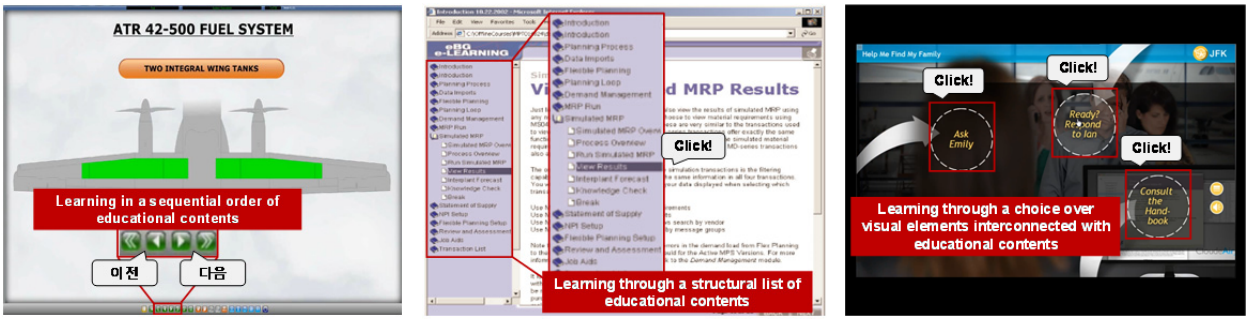
1. Introduction

Computer-based training (CBT) is used for military education and training. CBT is an educational media made by text, image, and video on a computer system environment and used to provide trainees with standardized education and training systematically (Park, 1997). CBT has been widely used in various military fields including radar operation and aircraft maintenance (Park, 1997) because the military is required to standardize education and training due to performing a mission for operation and

maintenance of state-of-the-art equipment by a large number of troops (Ha and Kim, 1997).

Ergonomic design of graphic user interface (GUI) is important for effective utility of CBT. CBT GUI is an interface that allows trainees to learn educational contents presented on the computer screen using visual elements such as icons and buttons (Harding, 1989) and can be classified into three types such as sequence, hierarchy, and context (Potelle and Rouet, 2003). A sequence type of CBT GUI presents educational contents in a sequential order (Figure 1.a), a hierarchy type through a structural list of educational contents (Figure 1.b), and a context type through a choice over visual elements interconnected with educational contents (Figure 1.c). A CBT GUI without consideration of human cognitive characteristics can lead to decrease efficiency and effectiveness of learning by causing cognitive overload, learning time increase, and human error (Jang and Byun, 2004; Kim and Byun, 2009; Lim et al., 2002). An ergonomically designed CBT GUI can contribute to effective education and training in the military using CBT and improve the efficiency, speed, and accuracy in performing a mission for operation and maintenance of high-tech military equipment (Ha and Kim, 1997; Park, 1997). Therefore, desirable CBT GUI designs are needed which incorporate ergonomic principles to enhance usability and learning effect through operating it efficiently.



(a) Sequence type (b) Hierarchy type (c) Context type

Figure 1. Representative types of graphic user interface of computer-based training system

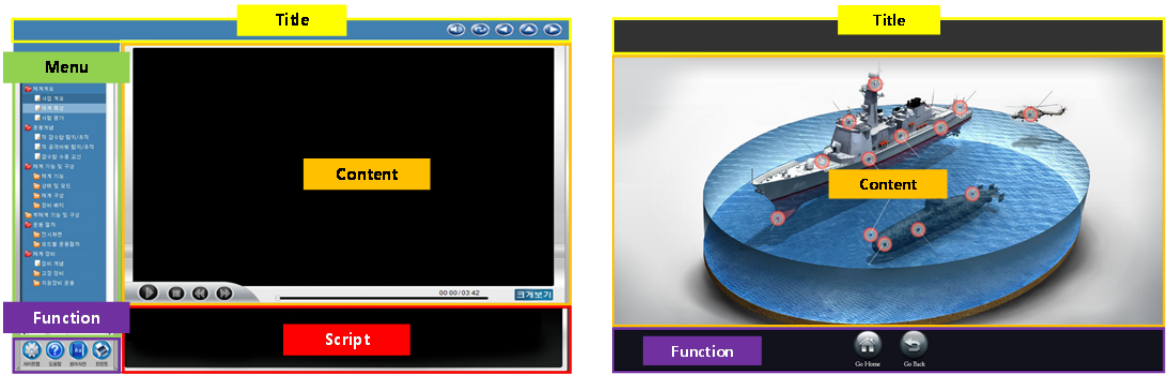
Although usability studies of ergonomic GUI design have been conducted, understanding on pros and cons of various GUI types based on a comparative analysis is lacking. For example, Han et al. (2007) identified usability problems of GUI in terms of controllability such as no scroll control of a progress list and complex interface configuration by performing an expert inspection on the process control room of a steel manufacturing company. Carvalho et al. (2008) found usability concerns of GUI in terms of distinctiveness such as ambiguity between pipe line and control flow line and confusion due to use of the same color to different elements by observing operator behaviors in a nuclear power plant simulator. The previous studies mainly evaluated the usability of a particular GUI type; thus, a comparative study of various GUI types in terms of usability is needed to systematically identify preferred features of each of the GUI types.

The present study proposed a new CBT GUI type based on a comparative analysis of hierarchy and context GUI types. A testing of the CBT GUI types was performed by CBT design experts using usability criteria selected by a literature review. Then, the present study developed an improved design of CBT GUI based on the usability testing results and validated the proposed CBT GUI design.

2. Usability Evaluation

2.1 Method

Hierarchy- and context-type GUIs presented in Figure 2 were used for usability testing in the present study. As shown in Figure 2.a, a hierarchy type GUI consists of title, menu, content, script, and function areas; the menu provides a list of educational contents and uses the folding and unfolding method to display sub menu items by pressing a top menu item. On the other hand, as shown in Figure 2.b, a context type GUI consists of title, content, and function areas; the content area presents visual elements such as icons and buttons of educational contents and applies the screen switch method to display detailed information by pressing a specific visual element. The present study chose four modules of educational contents (system overview, operation concept, system function and configuration, and system maintenance) for usability comparison of various GUI types. Note that the sequence type GUI which provides access to information in a sequential order using previous and next buttons was not included in the present study because its features are incorporated into the hierarchy- and context-type GUIs.



(a) Hierarchy type (b) Context type

Figure 2. Hierarchy and context types of graphic user interface for military computer-based training (illustrated)

A total of 10 usability criteria as shown in Table 1 were selected in the study for evaluation of CBT GUIs. Usability criteria candidates were extracted from existing studies of usability evaluation (Abran et al., 2003; ISO, 2001; Jung, 2013; Kwahk, 1999; Oh, 2013; Park et al., 2011; Park et al., 2012; Seffah et al., 2006), screened (e.g., excluding productivity as inappropriate criteria for CBT GUI usability testing), combined for similar or duplicate criteria (e.g., ease of learning, memorability, and understandability were combined into learnability) through a discussion among CBT design experts. The usability criteria were applied to evaluation of GUI components of a particular GUI type; for example, the simplicity of a menu structure refers to the degree to which the menu structure is simple to navigate and the distinctiveness of clickable and unclickable elements refers to the degree to which the clickable and unclickable elements are clearly distinguished from each other.

The hierarchy- and context-type GUIs were evaluated by CBT design experts using a questionnaire to collect qualitative and quantitative usability information. The GUI usability evaluation was conducted by 9 CBT design experts (age = 36.3 ± 8.5 year) while operating CBT systems prepared in the hierarchy- and context-type GUIs. The heuristic method of usability evaluation was applied to efficiently find usability problems and identify preferred features of each of the CBT GUI types. Note that heuristic evaluation is a method in which usability experts evaluate a system in terms of a set of usability principles (Nielsen, 1994); in

heuristic evaluation only a small number of usability experts such as three to five can find 74% to 87% of usability problems (Nielsen, 1992). The usability of each CBT GUI type was evaluated using a 7-point scale (1: very low, 4: neutral, and 7: very high) and information about usability problems and suggestions for improvement were collected. An example of quantitative and qualitative usability evaluation questionnaire of CBT GUI for simplicity is shown in Figure 3. The Wilcoxon signed-rank test was applied due to the small sample size to test the differences of usability scores between the hierarchy- and context- type GUIs at $\alpha = .05$.

Table 1. Usability evaluation criteria of graphic user interface for military computer-based training

No.	Evaluation criterion	Description
1	Attractiveness	Degree to which the interface is aesthetic
2	Simplicity	Degree to which the interface works in a simple manner
3	Responsiveness	Degree to which the interface rapidly responds to user input
4	Controllability	Degree to which the interface is easy to operate
5	Informativeness	Degree to which the interface provides meaningful information
6	Accessibility	Degree to which the interface is easy to access for system operations
7	Explicitness	Degree to which the interface is clear to understand
8	Legibility	Degree to which the interface is easy to perceive visually
9	Learnability	Degree to which the interface is easy to learn
10	Distinctiveness	Degree to which the information provided is distinguished from peripheral information

Usability criteria	Simplicity							Degree to which the interface works in a simple manner						
CBT GUI type	Hierarchy type							Context type						
Usability evaluation	Very low	Low	Slightly low	Neutral	Slightly high	High	Very high	Very low	Low	Slightly low	Neutral	Slightly high	High	Very high
	①	②	③	④	⑤	⑥	⑦	①	②	③	④	⑤	⑥	⑦
Usability problem														
Suggestions for improvement														

Figure 3. Usability evaluation questionnaire of graphic user interface for military computer-based training

2.2 Results

The hierarchy type GUI was preferred to the context type GUI in terms of controllability, informativeness, accessibility, and legibility; the opposite became true in terms of attractiveness, simplicity, responsiveness, explicitness, and distinctiveness (Figure 4). The

controllability of the hierarchy type GUI (5.0 ± 0.9) was significantly higher (1.6 times) than that of the context type GUI (3.1 ± 1.3) (W[8] = -2.25, p = .024). However, the informativeness, accessibility, and legibility of the hierarchy type GUI (5.1 ± 0.9 for informativeness, 4.6 ± 1.3 for accessibility, and 4.9 ± 0.9 for legibility) were higher (1.1 ~ 1.4 times) than those of the context type GUI (3.8 ± 1.6 for informativeness, 3.2 ± 1.2 for accessibility, and 4.3 ± 1.7 for legibility), but their mean differences were not statistically significant.

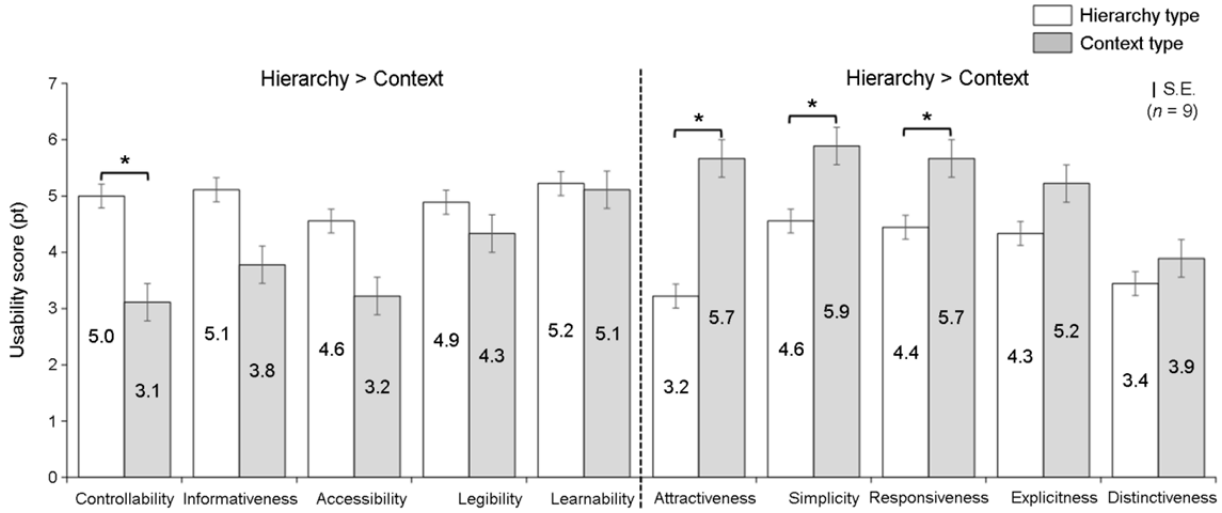


Figure 4. Usability comparison results of hierarchy and context types of graphic user interface for military computer-based training (the Wilcoxon signed-rank test was conducted, *p< .05)

On the other hand, the attractiveness, simplicity, and responsiveness of the context type GUI (5.7 ± 0.5 for attractiveness, 5.9 ± 0.3 for simplicity, and 5.7 ± 0.5 for responsiveness) were significantly higher (1.3 to 1.8 times; W[8] = -2.70, p = .007 for attractiveness; W[8] = -2.46, p = .014 for simplicity; and W[8] = -2.16, p = .031 for responsiveness) than those of the hierarchy type GUI (3.2 ± 1.0 for attractiveness, 4.6 ± 1.0 for simplicity, and 4.4 ± 1.0 for responsiveness). However, the explicitness and distinctiveness of the context type GUI (5.2 ± 0.7 for explicitness and 4.3 ± 1.4 for distinctiveness) were slightly higher without statistical significance than those of the hierarchy type GUI (3.9 ± 1.6 for explicitness and 3.4 ± 1.7 for distinctiveness).

3. GUI Design Improvement

3.1 Method

Improvements of CBT GUI were proposed as shown in Table 2 by accommodating the usability evaluations results of the hierarchy- and context-type GUIs. An improved CBT GUI was constructed by incorporating preferred features of the hierarchy- and context-type GUIs identified from the usability evaluation results. For example, a function of adjusting a video playback speed related to controllability, which was a preferred feature of the hierarchy type GUI, and a function of playing a video when clicking on the video screen related to responsiveness, which was a preferred feature of the context type GUI, were incorporated into the improved CBT GUI. Furthermore, the improved CBT GUI incorporated novel functions proposed to solve usability problems of the hierarchy- and context-type GUIs. For example, a novel function of unfolding all menu structures to solve the difficulty in searching information due to complexity of the menu structures in the hierarchy type GUI and a function of indicating the learning page

and time to solve the inconvenience due to unavailability of learning page and time in the context type GUI were added in the improved CBT GUI.

Table 2. Novel functions proposed to improve the usability of graphic user interface for military computer-based training

No.	Evaluation criterion	Evaluation type	Preferred CBT GUI type	Function
1	Controllability	Quantitative	Hierarchy	Adjust playback speed and sound volume
2	Responsiveness		Context	Play video by clicking video image
3	Distinctiveness			Indicate clickable and non-clickable elements
4	Informativeness	Qualitative	–	Provide information of learning page and remaining time
5	Explicitness			Use color to the linkage of subtitle and narration
6	Simplicity			Unfold all menu structures
7	Learnability			Provide a learning map

3.2 Results

The improved hybrid type GUI was developed as shown in Figure 5 by accommodating 16 functions. The hybrid type GUI consisted of title, content, menu, script, and function sections by incorporating the preferred features of the hierarchy- and context-type GUIs and novel functions proposed for solving the usability problems identified. The hybrid type GUI incorporated two functions such as providing information about learning page and time in the title section, five functions such as adjusting playback speed and volume in the content section, six functions such as opening all menu structures in the menu section, one function such as providing color feedback for linkage of subtitle and narration in the script section, and two functions such as provide learning map

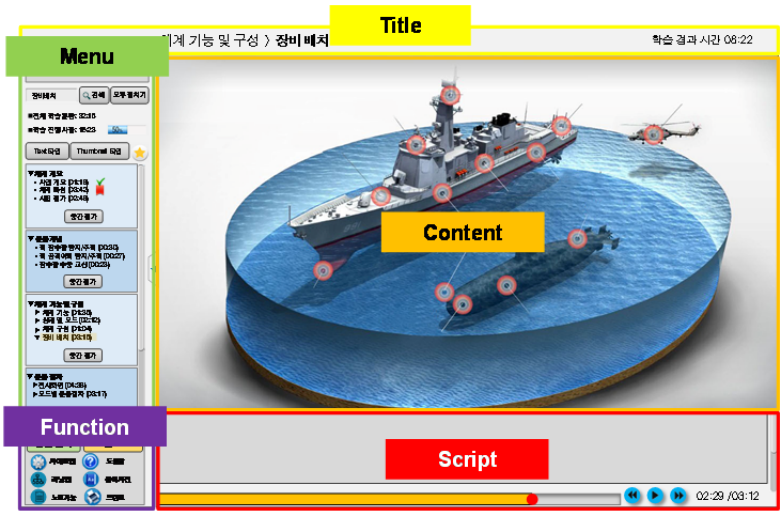


Figure 5. A hybrid type of graphic user interface (GUI) proposed for military computer-based training (illustrated). The hybrid GUI was developed by combining the preferred features of hierarchy- and context-type GUIs

in the function section.

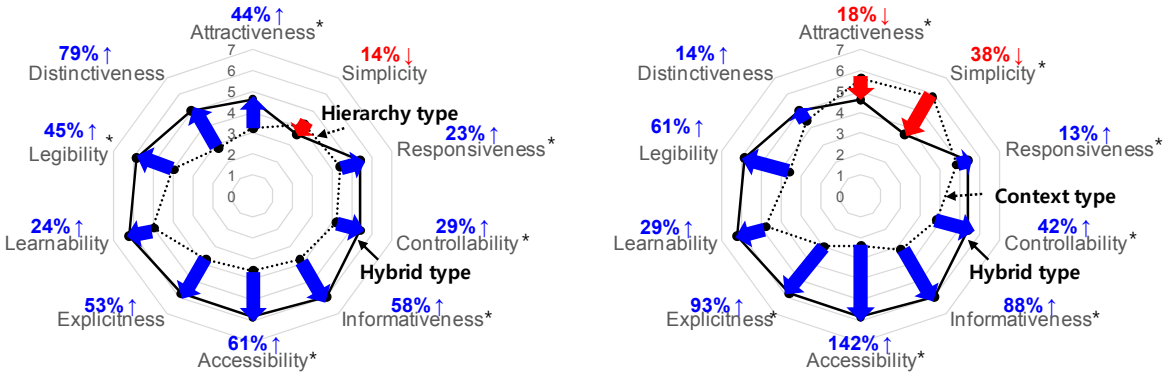
4. GUI Design Validation

4.1 Method

Usability evaluation results of the hybrid type GUI were obtained using the same CBT GUI usability questionnaire and a statistical analysis was conducted to test the differences among the CBT GUI types. Preferred features of the hybrid type GUI were analyzed to compare with the hierarchy- and context-type GUIs in terms of usability. The hybrid type GUI was evaluated in terms of the 10 evaluation criteria in Table 1 using a 7-point scale (1: very low, 4: neutral, and 7: very high) by 22 users (19 males and 3 females, aged in 20s to 40s) with experience of CBT GUI. Even if n = 22, the paired t-test was conducted at α = .05 to test usability differences between the CBT GUI types because the normality assumption was found satisfied.

4.2 Results

As shown in Figure 6, the hybrid type GUI showed significant improvements in eight out of the ten usability criteria except simplicity and attractiveness and large improvements more than 50% especially in accessibility and informativeness. The hybrid type GUI showed significantly increased usability scores over the hierarchy type GUI by 23% to 79% in all the usability criteria except simplicity and over the context type GUI by 13% to 142% exceptive attractiveness and simplicity. The simplicity of the hybrid type GUI (4.1 ± 1.3) was significantly decreased by 38% compared to that of the context type GUI (6.0 ± 0.9) (t[21] = 4.99, p< .001) and the attractiveness of the hybrid type GUI (4.4 ± 1.1) decreased by 18% compared to that of the context type GUI (5.9 ± 0.9) (t[21] = 5.41, p< .001).



(a) Hierarchy vs. hybrid (b) Context vs. hybrid

Figure 6. Comparison of usability testing results between hierarchy, context, and hybrid types of graphic user interface for military computer-based training (the paired-t test was conducted, *p< .05)

5. Discussion

The present study compared various types (hierarchy, context, and hybrid) of CBT GUI to identify preferred features of each GUI type. Most GUI studies (Carvalho et al., 2008; Han et al., 2007; Letsu-Dake and Ntuen, 2010) conducted an usability evaluation

for a particular GUI type. The usability comparative method of various GUI types in the present study would be of help to identify the usability features of GUI types in an effective and systematic manner.

The controllability of the hierarchy type GUI was significantly preferred 1.6 times compared to that of the context type GUI, while the attractiveness, simplicity, and responsiveness of the context type GUI were significantly preferred 1.8, 1.3, and 1.3 times, respectively, to those of the hierarchy type GUI. The superiority of the hierarchy type GUI in terms of controllability to the context type GUI can be attributable to that the hierarchy type GUI enables an overall information flow recognition, systematic learning, and convenient screen change by a hierarchy menu. The superiority of the context type GUI in terms of attractiveness, simplicity, and responsiveness to the hierarchy type GUI can be attributable to that the context type GUI enables an intuitive acquisition of necessary information and a quick provision of user interaction feedback (e.g., confirmation, warning). The preferred features of each CBT GUI type identified in the study can be referred for design of CBT GUI by considering the characteristics of educational contents by CBT application.

The usability of the hybrid type GUI developed by considering the preferred features of the hierarchy- and context- type GUIs was improved by more than 50% overall, especially in accessibility and informativeness. The hybrid type GUI in the present study was developed by solving usability problems of the hierarchy- and context-type GUIs. The accessibility and informativeness of the hybrid type GUI were superior more than 1.5 times to those of both the hierarchy- and context- type GUIs. The aforementioned result can be attributable to that the hybrid type GUI has high accessibility to necessary information and ease of systematic learning by understanding an information flow in a comprehensive manner. Therefore, the hybrid type GUI considered with efficiency of learning can contribute to improving usability and effectiveness of learning.

As for further research, a usability evaluation with real CBT users and establishment of a framework for GUI usability evaluation are needed. The present study evaluated the usability of CBT GUI by nine CBT design experts. In addition, the present study determined the usability evaluation criteria applicable to CBT GUIs by discussion of CBT design experts; however, a comprehensive GUI usability evaluation framework needs to be established for comprehensive usability testing of GUIs. For example, a GUI usability evaluation framework can be established by GUI design components (e.g., layout, menu structure), usability evaluation criteria (e.g., consistency, explicitness), objective and subjective usability evaluation metrics (e.g., operation time, error frequency, and Likert scale), and usability evaluation techniques (e.g., questionnaire and cognitive walkthrough) based on literature reviews. A GUI usability evaluation framework can contribute to ease of selection of evaluation criteria and customization of usability testing based on GUI characteristics.

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