INTL. JOURNAL OF HUMAN–COMPUTER INTERACTION, *27*(4), 383–404, 2011

ISSN: 1044-7318 print / 1532-7590 online
DOI: 10.1080/10447318.2011.540493



# *Menu Design for Computers and Cell Phones: Review and Reappraisal*

**K. Kim[1], J. Jacko[2], and G. Salvendy[1,3]**
[1]Purdue University, West Lafayette, Indiana
[2]University of Minnesota, Minneapolis
[3]Tsinghua University, Beijing, China

Menu systems have been key components in modern graphical user interfaces, and there has been a lot of research about menu design. Menu design features play a significant role from the perspective of customer satisfaction. Therefore, researchers have investigated various features in menu design. 3D menus have been investigated because these can display more items and provide a natural and intuitive interface. Small screens of the type used on mobile phones are limited in the amount of available space, and thus it might be more beneficial to use 3D menus in cell phones. A review of previous menu design studies for human–computer interaction suggests that menu design guidelines for computers and mobile phones need to be reappraised, especially toward the use of 3D interfaces in cell phones.

The main objective of this article is to propose an overall framework for 3D menu interfaces in cell phones. The second objective is to propose guidelines for 2D and 3D menu design in computers and cell phones based on a literature review. Three main factors that might influence the performance of menu retrieval task in cell phones are included in the proposed model: the presentation type, the number of items, and menu type.

## *1. INTRODUCTION*

The menu method has proven to be a popular alternative to more traditional forms of retrieving information. Menu systems are key components in modern graphical user interfaces, either for traditional desktop applications or for the latest web applications (Troiano, Birtolo, Armenise, & Cirillo, 2008). There has been much research about two-dimensional (2D) menu design for computers and cell phones (see sections 2 and 3). Researchers have investigated menu structure, adaptation function, menu ordering effect, task effect, chunking, menu type, individual differences, and helping fields about 2D menu design. Early research has focused on menu structure and menu ordering. Recently, the focus has shifted to individual differences and menu-type studies.

Correspondence should be addressed to K. Kim, School of Industrial Engineering, Purdue University, 315 North Grant Street, West Lafayette, IN 47906. E-mail: kim561@purdue.edu

Research on cell phone menu design has been conducted recently compared to computers, and the focus of research is not much different from the one in computers. Ling, Hwang, and Salvendy (2007) prioritized the design features and aspects of cell phones based on user feedback to optimize the customer satisfaction. Although physical appearance and body color had an influence on overall satisfaction, menu design features also played a significant role (Ling et al., 2007). Therefore, menu design on these devices warrants careful and ongoing research.

Three-dimensional (3D) menus are able to convey more information than menus with text or 2D images, and they may also enhance the usability of the limited screen on a typical wireless device. As a result, interactive 3D menus are being used to remove some of the complexity and clutter present on menu systems of today's handsets (Beardow, 2004). Even though 3D menus have several advantages—a better use of space and a natural and intuitive interface—3D interfaces still remain among the greatest challenges. Therefore, the superiority of 3D menus depends on certain conditions, and the several factors that can influence 3D menu's performance are investigated in this study.

In 2008, there were 3.9 billion mobile phones in the world; this number should rise to 5.6 billion in 2013 ("Worldwide Mobile," 2008). People use mobile phones not only to communicate with friends, family, and business partners but also to obtain information through the mobile Internet. Moreover, people use embedded mobile phone features, such as games and cameras, for various purposes, including entertainment and shopping (Ling et al., 2007). Due to an increase in features, mental workload while using cell phones has increased. Therefore, this situation demands the use of 3D menus in cell phones, as 3D menus are more beneficial when there are many items.

The review of previous menu design studies suggests that it is imperative to consider 3D menu design factors in the context of cell phones. Thus, the main objective of this article is to propose an overall framework for 3D menu interfaces in cell phones. The second objective is to propose guidelines for 2D and 3D menu design in computers and cell phones based on a comprehensive review of the literature.

## 2. 2D MENU DESIGN: OVERVIEW

The most significant difference between computers and handheld devices is not the computational power of the respective devices but the sizes of their respective screens. Therefore, it is ill-advised to simply apply the user interfaces employed for desktop computers to cell phones. For example, multiple windows open in parallel, often employed on a desktop, are not effective on handheld devices given the small screen space available (Rekimoto, 1996). Another major difference between PCs and small-screen devices is often the input method employed. Pens and touch screens are often used for handheld device input, whereas a keyboard and mouse are utilized on desktop models. The former requires much more precision during use to be effective than the latter (Rekimoto, 1996). It follows, then, that menu design may also differ substantially. Studies of various 2D menu design features are investigated to know how menu design should differ in each case.

## 3. 2D MENU DESIGN FEATURES IN COMPUTERS

### 3.1. Menu Structure

Studies about whether it is better to have a broadly designed or a deeply designed menu structure have proliferated in the literature (Jacko, Salvendy, & Koubek, 1995; Kiger, 1984; Lee & MacGregor, 1985; Miller, 1981; Schultz & Curran, 1986; Seppala & Salvendy, 1985). Optimization of the depth/breadth trade-off has been shown to be an important design consideration in tasks requiring speed and accuracy. This is because depth and number of options significantly affect the response time (Allen, 1983). The breadth of a menu structure refers to the number of menu options present on a given menu, and the depth refers to the number of levels a user encounters as the user moves through the menu to a target item.

Menu structure was first examined by Miller (1981). He performed experiments with four menu structures and found that subjects were slower and less accurate with menus with two choices at each of six levels and one menu with all 64 choices. Meanwhile, the eight-choice/two-level tree structure proved to be the best when considering both errors and speed. Therefore, Miller concluded that the number of hierarchical levels should be minimized, while avoiding display crowding.

Many researchers extended Miller's study. Kiger (1984) suggested minimizing the depth of menu structures by providing broad menus of eight or nine options without producing unnecessarily deep menu structures. Several researchers also drew the conclusion that a broader menu was more effective than a deeper one (Seppala & Salvendy, 1985; Snowberry, Parkinson, & Sisson, 1983; Tullis, 1985; Wallace, Anderson, & Shneiderman, 1987). Increased depth decreases the speed and accuracy of performance because it involves additional visual search, decision making, and greater uncertainty about the location of target items (Chae & Kim, 2004; Jacko & Salvendy, 1996; Jacko et al., 1995). In other words, as the depth increases and the number of responses increases, more time for decision making and responding is required (Seppala & Salvendy, 1985). Schultz and Curran (1986) provided support that menu breadth is preferable to depth as well. They described advantages of a broad menu structure as follows: (a) a broad structure prevents "path errors" and (b) a broad structure minimizes the need to remember the location of items. Even though menu breadth has been shown to be preferable to depth, excessive breadth can result in a crowded display. Hence, moderate levels of depth and breadth should be implemented (Larson & Czerwinski, 1998).

On the other hand, the optimal menu structure in computers was examined using a simulation model (MacGregor, Lee, & Lam, 1986). Using a criterion-based decision model, MacGregor et al. (1986) found out that the optimal breadth level on database menu pages was four to five. This decision model extends a search-time model and makes predictions about how breadth level affects performance.

Although most research focused on balanced menus, K. L. Norman and Chin (1988) investigated unbalanced menu structures and concluded that the concave menu was superior when searching for scenario targets and the increasing menu was slightly superior when searching for explicit targets. More studies on unbalanced menus need to be investigated, because these menus are common in reality.

Menu structure trade-off is sometimes dependent on other factors. To begin, Dray, Ogden, and Vestewig (1981) showed that expertise and menu structure were interactively related. Naïve users are faster when using broad menus, but experts perform faster with deep menus because experts already have knowledge about menu structure. Second, Wallace et al. (1987) compared a broad menu and a deep menu structure under conditions of time stress for novices. However, time stress both slowed the completion time and increased errors regardless of menu structure.

In this way, menu structure has been focused in menu design studies. Because excessive breadth can slow the completion time due to a crowded display, moderate levels of breadth should be implemented considering the conditions such as screen size and other factors.

### *3.2. Adaptation*

Adaptation has now been adopted in some applications (Gajos, Czerwinski, Tan, & Weld, 2006). For example, the Start menu in the Microsoft Windows operating system has an adaptive function. The Microsoft Office system also provides an adaptive function where infrequently used menu items are hidden from view. In this manner, flexibility through adaptation has become more popular in the design of user interfaces.

For decades, researchers have presented adaptive user interfaces and discussed the pros and cons of adaptation on task performance and satisfaction. To begin, advantages of adaptation are that a flexible system can decrease cognitive workload, enhance productivity, and improve task efficiency (Greenberg & Witten, 1985). Therefore, adaptive menu structures had a significantly faster completion time and significantly fewer errors (Bayman, Civanlar, & Whitten, 1989; Gong & Salvendy, 1995; Greenberg & Witten, 1985). Gajos et al. (2006) designed and implemented three adaptive menus and evaluated them in experiments with a static menu. As a result, the split (adaptive) interface was strongly preferred over the nonadaptive menu and resulted in significantly improved performance. The split menu is the interface that incorporated easy access for frequently used items and the alphabetical ordering that is useful for low frequency items (Sears & Shneiderman, 1994).

Moreover, Ro, Choi, Lee, and Ko (2008) introduced a new adaptation concept and proved to show enhanced performance. They described an event-based self-adaptation of user interface (UI) using events that could be obtained easily. This approach utilizes an agent concept for UI adaptation. Therefore, menu categorization and ordering can be obtained dynamically based on user's menu selection events. As a result, event-based self-adaptation of UI showed enhanced job performance by reducing time for menu search and showed better accuracy.

However, adaptation may include increased learning time. Under this disadvantage, Mitchell and Shneiderman (1989) revealed a conflicting finding. They compared dynamic versus static menus using a menu-driven computer program and found that for the first set of tasks, adaptive dynamic menus were significantly slower than static menus. Moreover, 81% of the subjects preferred working with static menus to working with dynamic menus. This preference is likely because dynamic menus can slow down first time users, at least until they become accustomed to this interaction style.

In addition to comparing adaptive and nonadaptive menus, Findlater and McGrenere (2004) extended past research by comparing two adaptation menu conditions: adaptable and adaptive. This means a comparison between user-driven and system-driven adaptation. In terms of performance, the adaptable menus were faster than the adaptive menus, when other menus were shown first. In other words, when people understand the value of customization, user-driven customization is a more viable approach for personalizing UIs than system-driven adaptation. The majority of users preferred the adaptable menu overall and ranked it first for perceived efficiency as well.

Therefore, adaptation may not be efficient in the first place, but once users understand the value of customization, the adaptable menu is very useful for people.

### 3.3. Menu Ordering

Many studies concerning menu ordering are interested in an interaction effect with other factors. First, the relationship between menu ordering and target type was investigated (McDonald, Stone, & Liebelt, 1983; Mehlenbacher, Duffy, & Palmer, 1989). McDonald et al. (1983) showed that categorical menus were superior to an alphabetical menu when definitions are provided as targets, and Mehlenbacher et al. (1989) showed that the functional menu was more effective than the alphabetical menu for the synonym and iconic cues as well. In other words, categorical menus are useful when menu categories can help to find targets. Second, Hollands and Merikle (1987) investigated interrelationships among menu ordering, task type, and expertise. As a result, when the categorical menus were used, performance was improved with expertise. Experts were faster with definition-matching task than novices were, regardless of types of menu ordering. Performance on the term-matching task was not influenced by expertise when alphabetic and random menu orderings were used.

On the other hand, Card (1984) found superiority of alphabetical ordering. However, this effect applied to initial trials, and in a later experiment, the effect disappeared. Schultz and Curran (1986) also showed that menu structure and ordering were interactively related and alphabetical ordering was superior to random ordering only during the initial block of trials, and only when a deep structure is presented. This is because users can guess structure of the menu items in the next levels.

In summary, categorical menus are useful when menu categories can give a clue to target items. Alphabetical menus are better than random menus in a deep menu because people can easily guess a location of items in the next levels.

### 3.4. Task Effect

Numerous menu selection tasks have been used in menu design studies. Card (1984) classified menu selection tasks that a user might perform: (a) Search for a known item; (b) Search for the first suitable item with a known target characterization; (c) Search the most suitable item with a known target characterization; and (d) Browsing among the items.

Some researchers showed that a user's task and the menu ordering were correlated. McDonald et al. (1983) found that categorical menu ordering was better than alphabetical ordering, when the task is one of finding definitions as opposed to that of finding an explicit word. If the user's task involves finding the correct term either from definition or from memory, categorical organization has been shown to be better (Hollands & Merikle, 1987). This is also supported by the fact that the categorized menu is more effective than the alphabetical menu when the task is finding the synonym and iconic targets (Mehlenbacher et al., 1989).

Jacko et al. (1995) showed that task complexity, when driven by the short-term memory requirements of the task, played a critical role in determining performance on menus. This is because perceived task complexity is affected by increased depth of a menu, and menu structure has an influence on performance (Jacko & Salvendy, 1996).

### 3.5. Chunking

There have been some studies on chunking principles. Gobet et al. (2001) introduced two forms of chunking principle. The first one is deliberate, under strategic control, and goal-oriented. The second is automatic, continuous, and linked to perceptual processes. These principles are similar to designer-oriented and customer-centered principle considering characteristics. They showed that perceptual chunking was better in many areas, such as verbal learning and problem solving. This explains well that customer-based menu design needs to be implemented. Tidwell (2006) also described principles of menu groupings as follows: (a) lists of objects (e.g., an inbox of e-mail messages), (b) lists of actions or tasks (e.g., browse or register), (c) lists of subject categories (e.g., science or technology), and (d) lists of tools (e.g. calendar, address book).

Some researchers focused on the importance of menu chunking. Paap and Roske-Hofstrand (1986) stressed the importance of meaningfully organized menus showing that randomly ordered menus should have only a few options, whereas meaningfully organized menus may contain many options. K. L. Norman (1991) also showed that menus grouped into collections of similar items improved selection time. This is due to reductions in working memory demands that can be attributable to meaningful chunking of information (Drager et al., 2004).

Finding the best natural categories based on the users' conceptual structures might be more important than finding the optimal menu structure because the advantage for menu breadth will be effective only when the information is well organized (Sisson, Parkinson, & Snowberry, 1983, 1986).

### 3.6. Individual Differences

Personal abilities such as vocabulary and personal characteristics differ. Several researchers have investigated whether these individual differences among users affect menu performance or not (Edwards et al., 2005; Vicente, Hayes, & Williges, 1987). Because vocabulary and spatial ability were the best predictors of task performance, accounting for 45%, redesigning the software interface to accommodate people with low spatial ability could be needed (Vicente et al., 1987). In addition to this study, Edwards et al. (2005) showed that visual characteristics and personal characteristics were the dominant factors affecting performance on a basic menu selection task.

Consideration of the role of expertise is another important aspect of designing menus. When the target item is unfamiliar, as in case of novices, the overall response time increases (Somberg & Picardi, 1983). In this manner, differences exist in the abilities of experts to process information when compared to their novice counterparts. One reason for differences may be explained by the fact that experts are more efficient at chunking meaningful information into memory. Therefore, the cognitive menu structure employed by the expert should not be employed by the novice (Snyder, Happ, Malcus, Paap, & Lewis, 1985). Sometimes menu structures developed by experts can be problematic for novice users (Lee, Whalen, McEwen, & Latremouille, 1984). Therefore, menu design considering target users should be implemented.

### 3.7. Menu Type

Menu type falls into two classifications: hierarchical menus and fisheye menus (Hornbaek & Hertzum, 2007). Hierarchical menus are further classified into three types of menu layout conditions: categorical index menus, horizontal cascading menus, and vertical cascading menus (Bernard & Hamblin, 2003). Fisheye menus are a menu display method that shows a region of the menu at high magnification, whereas items before and after that region are shown at gradually reduced sizes. Thus, fisheye interfaces have an advantage in that they can accommodate many menu items in a limited amount of screen space by showing part of an information space at high magnification, whereas other parts are shown at low magnification to provide context.

Some studies have compared menu types. Bernard and Hamblin (2003) compared two cascading menus and an indexed menu. Search time differences between the three menu layouts were detected, and the results strongly favored the index menu. One possible reason for this result is that the items in the index menus are closer together physically. Another is that the index menus are centrally located on the screen and thus have been easier to see and acquire. The index menus are able to be seen as broader menus considering easiness to see and acquire. Therefore, this is consistent with the results of menu structure studies. Meanwhile, Hornbaek and Hertzum (2007) compared hierarchical menus with fisheye menus and showed that, for finding known items, hierarchical menus were more accurate and faster than fisheye menus because mental demands of the hierarchical menu were lower. Also, participants rated hierarchical menus as more satisfying than fisheye menus. In summary, the index menus, which are able to provide the overview, are preferable in a computer setting.

### 3.8. Help Fields

Many researchers have recognized the important role of help fields, which can improve performance (Billingsley, 1982; Jacko et al., 2005; Lee, MacGregor, Lam, & Chao, 1986; Parkinson, Hill, Sisson, & Viera, 1988; Snowberry, Parkinson, & Sisson, 1985). Help fields can be a menu map, keyword index, and information about upcoming options. First, a map of menu organization such as a sitemap for the website facilitates the development of a mental model of the structure. As a result, it showed that the use of a menu map could improve information retrieval performance across time (Billingsley, 1982). A study conducted by Snowberry et al. (1985) concerning the effect of upcoming selection menus demonstrated that information about upcoming options improved performance substantially at the first two levels of the menu and provided high levels of satisfaction. Parkinson et al. (1988) also drew the conclusion that upcoming selections menu showed higher accuracy. The reason for this result is that it can reduce processing time for what to choose.

On the other hand, Lee et al. (1986) showed that the addition of a small keyword index improved user performance and satisfaction substantially compared to menu-only methods because keywords enable the user to avoid the error-prone upper levels of the menu and reduce the number of pages accessed. Last, the Microsoft Windows accessibility settings with bigger font size and strong contrast have been shown to have a significant positive impact on the performance of menu selection tasks for participants with Diabetic Retinopathy (Jacko et al., 2005). Therefore, a proper use of help fields is recommended in terms of performance and satisfaction.

## 4. 2D MENU DESIGN FEATURES IN CELL PHONES

### 4.1. Menu Structure

The advantage of depth is that it encourages funneling; the disadvantage is that it induces errors and increases the number of page transactions. On the other hand, the advantage of breadth is that it reduces navigation errors and the number of page transactions; the disadvantage is that it leads to crowding. In this manner, menu structures have trade-offs.

As in the study of menu structures in computers, there have been many menu design studies in cell phones. Some studies supported the superiority of deeper menus. First of all, Geven, Sefelin, and Tscheligi (2006) reported that narrow hierarchies performed better than broader hierarchies on a small screen. As opposed to computers, where many options can be presented at once, cell phones are better off with a layered design. Second, Huang (2006) showed that users preferred a less broad menu structure on a small-screen device. This result supported the suggestion of not having an extensive menu structure on a small screen (Ziefle, 2002). However, for deeper menus in cell phones, two factors should be considered: font size and screen size. Because small font size has a negative effect on performance for deep menus compared to broad menus, moderate font sizes should be considered for deep menus in cell phones (Babaria, Giacoppo, & Kuter, 2001). The depth of information structures should be adapted to anticipate screen size, because screen size affects the navigation behavior and perceptions of mobile phone users (Chae & Kim, 2004).

Meanwhile, findings have consistently suggested an advantage to employing a broader menu structure to achieve better user performance and accuracy, even in cell phones. Menu depth should be minimized and menu breadth should be maximized for the most efficient location of an item during a search task in a Pocket PC (Babaria et al., 2001). Huang (2006) and Dawkins (2007) also suggested that filling the screen as much as possible without requiring scrolling determined the ideal breadth of a menu.

### *4.2. Adaptation*

With computers, users can create folders, reorder the layout, and make shortcuts. But cell phones have limited screen size and a small region for input. Moreover, telecommunication carriers want the buttons to be used for their wireless Internet service. So they are reluctant to offer many customization functions to users. Therefore, cell phones do not provide enough adaptation functions currently. However, customers seem to want more customization functions in their cell phones, from the perspective of their satisfaction. Dawkins (2007) investigated the effectiveness of adaptation and concluded that customizable menus yielded better performance and satisfaction than the traditional static menu. More consideration about openness of adaptation function by telecommunication carriers is likely to be needed considering customer-centered menu design concept.

### *4.3. Task Effect*

Gutwin and Fedak (2004) compared three menu techniques with different tasks to find out the interrelationship between task type and menu type. It was shown that the fisheye view was faster than the others on a web navigation task. For an editing task, the fisheye and two-level zoom menu were faster than a panning menu. The two-level zoom menu was better than the other two menus for a monitoring task. Because the fisheye and two-level zoom menus provide overview and focus simultaneously, they are useful for the editing or monitoring task. In this manner, task type influences the selection of proper menu types, thus affecting menu performance.

### 4.4. Chunking and Labeling

Huang (2006) investigated factors of category classification and item labeling influencing user performance in menu selection. He suggested that proper modifications in category grouping and item labeling could enhance a system's usability and performance. He also found that end-users' perspectives could be different from the designer's presumptions because companies are usually under strategic control and goal oriented. Therefore, the designer should consider end-users' perspective to attract more customers and satisfy them.

### 4.5. Individual Differences

Ziefle and Bay (2004) studied the interrelationship of a user's mental model of a cellular phone menu and a user's age. It was shown that the better the mental model of the menu, the better a user's performance using the device. Therefore, cell phone designers should make the menu structure more transparent to get a clear mental model of the menu through helping information on the display or in the manual. They also found out that younger and older users' mental models differ and that older users have relatively worse mental model for the phone menu. Hence, it is important for older users to encounter intuitive labeling and be provided with submenus to minimize the memory load to perform a task. In addition to a user's mental model, user experience affected significantly the search performance even in cell phones (Han & Kwahk, 1994).

### 4.6. Menu Type

Fisheye menus, enabling a user to see important objects in detail and the overview displayed at once, are introduced on small screens (Hakala, Lehikoinen, & Aaltonen, 2005). Displaying the overview and the detail at the same time has also been found to be more beneficial than the traditional menu because the global context can allow faster navigation. Gutwin and Fedak (2004) compared three techniques for using large interfaces on small screens: a panning system, a two-level zoom system, and a fisheye view. As a result, most people preferred two-level zoom menus overall, and people were able to carry out a web navigation task better with the fisheye menu. In summary, the menus that can provide overview and detail at the same time are recommended.

### 4.7. Help Fields

Submenu windows present child-level menu items along with their upper-level menus. The help fields such as a submenu window, feedback, a sitemap, and visual momentum might be useful for cell phones with small screens. According to the studies conducted by several researchers, navigation aids such as feedback, visual momentum, and a map of the menu structure promotes learning of the user interface and improves performance (Han & Kwahk, 1994; Tang, 2001). Furthermore, Beck, Han, and Park (2006) concluded that submenu windows could reduce trial and error and improve user satisfaction when presented properly, and the separate submenu windows with no delay were recommended. But in real situations, a submenu with no display is hard to implement because all information including child-level items should be called up whenever their upper-level menu is shown. Nevertheless, the submenu window is helpful to the users, especially when the association between the parent menu item and its children is not clear.

## 5. 2D MENU DESIGN COMPARISON

In spite of differences in screen size and modes of input, there are many similarities when comparing menu design guidelines for cell phones and personal computers.

Many factors such as adaptation, task type, chunking, individual differences, and help fields showed similar results. Adaptation was effective in both cases (Dawkins, 2007; Gajos et al., 2006; Greenberg & Witten, 1985). Task effect exists in both cases as well (Chae & Kim, 2004; Jacko et al., 1995). Chunking was an important feature influencing menu performance (Huang, 2006; K. L. Norman, 1991). Individual differences, especially expertise effect, existed in computers, and a user's mental model had an effect on performance on menus in cell phones (Hollands & Merikle, 1987; Ziefle & Bay, 2004). Help fields were shown to improve performance as well (Beck et al., 2006; Jacko et al., 2005; Lee et al., 1986).

On the other hand, in computers, a broad menu design is more efficient than a deep menu, whereas it is better to use a layered design for mobile use (Geven et al., 2006; Huang, 2006; Kiger, 1984; Miller, 1981). Hierarchical indexed menus are more accurate and faster than fisheye menus in computers (Hornbaek & Hertzum, 2007), but the menus that can display overview and detail at the same time are preferable in cell phones (Gutwin & Fedak, 2004). Comparisons between computers and cell phones for 2D menu design features are summarized in Table 1.

## 6. 3D MENU DESIGN

### 6.1. 3D Menu Design in Computers

Compared to 2D menu studies, relevant 3D menu studies have not proliferated because 3D menus are common in virtual reality settings, but our focus is on the computers and cell phones. However, there have been several studies about the spatial benefits of 3D menus. Because our brains have evolved to recognize and interact with 3D, there are some advantages of a 3D environment, which are better use of space and spatial relations perceived at low cognitive load, and so on, and 3D user interfaces enable a more natural and intuitive style of interaction (Molina, Gonzalez, Lozano, Montero, & Lopez-Jaquero, 2003). Further, 3D design space is self-evidently richer than the 2D design space, because a 2D space is a part of 3D

**Table 1: 2D Menu Design Comparison**

| *Factors* | *Computer* | *Cell Phone* | *Implications* |
|---|---|---|---|
| Menu structure | Broad menu design is more efficient than deep menu. But a crowded display should be avoided. | In general, the narrow hierarchies perform better than the broader hierarchies but filling the screen is needed. | Filling the screen is recommended. |
| Adaptation | Once users understand the value of customization, the adaptable menu is very useful. | The customizable menu has better performance and higher evaluation. | — |
| Menu ordering | Categorical menus are useful when menu categories can give a clue to target items | N/A | — |
| Task effect | Task has an important role in determining performance on menus. | Task effect on user performance exists. | — |
| Chunking | Menu chunking might be more important than menu structure. | Category classification and labeling influence user performance. | — |
| Individual differences | Individual differences among users affect menu performance | A user's mental model and user experience have an effect on performance on menus. | — |
| Menu type | Hierarchical indexed menus are accurate and fast. | Displaying the overview and the detail at the same time is preferred. | Overview and detail menu such as fisheye or two-level zoom menu is applicable in cell phones. |
| Helping fields | Helping fields can improve performance. | The submenu reduces error and improves user satisfaction. | — |

The data were not reported for the factors which are irrelevant to characteristics of 3D menus.

space. Hence, it is always possible to flatten out part of a 3D display and represent it in 2D (Ware, 2004).

However, there is lack of empirical research into the benefits that are produced by moving from two to three dimensions. Ware and Franck (1996) conducted research that concerns the benefits of presenting abstract data in 3D. The experiment was designed to provide quantitative measurements of how much more (or less) can be understood in 3D than in 2D. Results showed that the 2D interface was reliably outperformed by 3D interfaces. These results provide strong reasons for using advanced 3D graphics for interacting with a large variety of information structures.

The effect of 3D is to make the screen space effectively more dense in the sense that the same amount of screen can hold more objects, which the user can zoom into or animate into view in a short time (Robertson, Card, & Mackinlay, 1993). The 3D interfaces make it possible to display more information without incurring additional load because of preattentive processing of perspective views with a smaller size that shows spatial relations at a distance. A preattentive ability based on simple 3D depth cues makes it possible to use less screen space and understand their spatial relations without thinking about it (Robertson et al., 1998). This might be a desirable feature for small screens that have a restricted screen resolution and size (Rekimoto, 1996).

Although 3D menus have some positive aspects, 3D interfaces still remain among the greatest challenges. People often find it difficult to understand 3D spaces because sometimes 3D applications tend to have greater visual complexity than 2D applications (van Dam, 1997). Moreover, creating a 3D visualization environment is considerably more difficult than creating a 2D system with similar capabilities.

Several researchers showed that 3D methods were slower (Cockburn & McKenzie, 2000, 2001; Ware, 2004). Cockburn and McKenzie (2000) compared subjects' efficiency in locating files when using Cone Tree and when using a normal tree menu. Results showed that the subjects took longer to complete their tasks when using the cone interface and that they rated the cone interface more poorly than the normal menu for seeing and interacting with the data structure. Moreover, Cockburn and McKenzie (2001) showed that 2D menus were faster, although there were no significant differences. Even if somewhat more information can be shown in 3D, the rate of information access may be slower.

Therefore, we should not automatically assume that 3D provides more readily accessible information. Deciding whether to use a 3D interface must involve considering conditions for which 3D is clearly beneficial. Under the circumstance that the use of 3D models is gaining wide popularity on the Internet and the number of 3D model databases is increasing rapidly, studies of conditions for which 3D is beneficial are necessary.

### *6.2. 3D Menu Design in Cell Phones*

The design space for small screens is rather limited in terms of both information visualization and interaction. Because the physical size of the screen is small, either the resulting images are very small or only a few can be displayed simultaneously. Therefore, information visualization techniques that are suitable for small screens might be different from the ones for computers. Meanwhile, 3D interfaces can be considered suitable tools for small screens. This is because 3D systems can be used to remove some complexity and clutter present on menu systems displayed on handsets and because users have reported (Cockburn & McKenzie, 2001) that 3D interfaces feel more natural and are preferable to a 2D interface. Moreover, because the real world we live in is 3D in nature, it may be easier for us to think in terms of 3D than in 2D (Hakala et al., 2005).

3D is no longer limited to PCs. 3D standards are being developed for mobile devices (Molina et al., 2003). The use of 3D models is becoming more common on cell phone websites, and the number of 3D model databases is increasing rapidly (Suzuki, Yaginuma, & Sugimoto, 2003). Interactive 3D technology by Beardow (2004) is one example of 3D model popularity. Because the use of 3D models is becoming more common on various cellular phone websites, the 3D interfaces will play an important role in cell phone menu design (Suzuki et al., 2003). Recently, 3D menus have been introduced into cell phone interfaces to attract consumers (e.g., Samsung Omnia 2, LG Arena). These cell phones provide a cube-shaped menu for users to navigate it with enjoyment at a fast speed.

Under these circumstances, there are several 3D menu studies conducted to investigate the presentation of large information spaces on a small screen. Fitzmaurice, Zhai, and Chignell (1993) presented a study about whether 3D can be used on small terminals and showed that depth perception in a palmtop display is about as good as the corresponding depth perception on a larger display. Furthermore, Hakala et al. (2005) investigated a 3D interface that can be used to display more information at once. As a result, the proposed spatial layout made the folder locations easier to remember, and it was possible to see more folders on the screen than with a regular tree map. In summary, 3D menus have been introduced and might be effective in cell phones.

### 6.3. 3D Menu Types

Dachselt and Hubner (2007) surveyed existing 3D menus from the literature and classified them according to various criteria. For use in a computer and cell phone, 3D menus in desktop virtual reality settings are investigated. Five menu types can be applied even to cell phones, which have a small screen size, and poor input devices are explained.

***Cone tree.*** Robertson, Mackinlay, and Card (1991) described an information visualization technique, called the Cone Tree. The tree was presented in 3D to maximize effective use of available screen space and enable visualization of the whole structure. A 2D layout of the same structure would not fit on the screen. The body of each cone is shown transparently, so that the cone does not block the view of cones behind it and it is thus possible to display many items.

The inventors of the Cone Tree claim that about 1,000 nodes may be displayable without visual disorder using cone trees, which is visually more than could be contained in a 2D environment. However, 3D Cone Trees require more complex user interactions to access some of the information than are necessary for 2D layouts (Robertson et al., 1991; Ware, 2004). Even though 3D Cone Tree has this issue, it has been used as an organizational structure browser. Other potential applications include software module management and document management (Robertson et al., 1993).

***Data mountain.*** Data Mountain is a new user interface for document management designed specifically to take advantage of human spatial memory. It allows users to arrange thumbnail images of documents on an inclined 3D plane. It uses a manual layout to exploit spatial memory for long-term use and is designed to work in computers (Robertson et al., 1998). It supports a larger number of items by preventing overlap. As a result, Robertson et al. (1998) showed that Data Mountain has advantages over the current Microsoft Internet Explorer Favorites mechanism for document management.

***Collapsible cylindrical trees.*** The collapsible cylindrical trees (CCT) technique uses rotating cylinders to display menu items, which is very much like a telescope. The property of collapsibility allows for compressing or temporarily hiding a menu without removing it. Child nodes are mapped on rotating cylinders, which will be dynamically displayed or hidden to achieve a balance of detail and context. Whereas with long lists of items, long vertical movements are needed in conventional menus, CCT solves this problem by mapping many different labels on a cylinder. Therefore, when vertical space is limited or too many menu items are presented at once, CCT is very useful (Dachselt & Ebert, 2001). In this manner, the idea of CCT is not to display an entire menu hierarchy at the same time but only to display the first two levels of a menu plus the selected path down the hierarchy (Dachselt & Ebert, 2001). Thus, information overload is avoided and a quick overview is guaranteed.

***3D carousel view.*** 3D carousel view is a kind of 3D ring menu. Document icons are arranged on a ring. This carousel is typically used to select one item or option from a small set of items, but it could be used with larger numbers of items. Wang, Porturalski, and Vronay (2005) elaborated 3D carousel view to hold an arbitrary number of items in an efficient manner. All extra bins are hidden or compressed in the clipping area. In this way, the carousel can support any number of bins.

The carousel has been identified as a method of hierarchical information visualization UI since the 3D ring menu, which used 3D objects instead of 2D flat items was easy to use (Kim, Kim, Park, Lee, & Lim, 2000). As a result, many video games use carousels to display menus. However, the carousel was not as efficient for users as a list view. Wang et al. (2005) performed usability tests emulating a small device, and the results showed that 2D view had significant advantages. In spite of relatively poor performance, the carousel does have other advantages (Wang et al., 2005): (a) it supports a straightforward and aesthetical layout, (b) it is easy to understand, (c) the focus + context effect is easily achieved by 3D perspective, and (d) the animated rotation of the bins provides a fun user experience.

***Revolving stage menu.*** Revolving Stage Menu is an improved ring menu that was able to display multiple 2D menus arranged in a circular way. Therefore, this menu is more familiar to users and still provides detail and overview at the same time. The stage can be rotated until the desired menu item is selected (Dachselt, 1999). A cube-shaped menu provided in the Samsung Omnia 2 and LG Arena is a kind of revolving stage menu.

**Table 2: Important Factors for 3D Menu Design**

| *Factors* | *Results* | *Implications* |
|---|---|---|
| No. of items (Menu breadth) | • To make a meaningful estimate of the relative advantages of 3D over 2D, many nodes were needed in the 3D condition (Ware & Franck, 1996).<br>• As many as 1,000 nodes may be displayable without visual disorder using Cone Tree (Robertson et al., 1991).<br>• The effect of 3D is to make the screen space denser, which is better use of space.<br>• Data Mountain makes it possible to increase the amount of information on the screen.<br>• When vertical space is limited or too many menu items are presented at once, CCT is very useful menu (Dachselt & Ebert, 2001). | 3D menus are beneficial in broader menus. |
| Menu type | • 3D Carousel View can support any number of items.<br>• CCT is a useful menu when many menu items are shown.<br>• Revolving Stage Menu is familiar with users and provides focus and overview. | There will be suitable menus for cell phones. |

### 6.4. Summary for 3D Menu Design

From 3D menu design studies, two important factors for 3D menu design were extracted. Two factors found to be important are the number of items and menu type. Even though 3D menus are not superior to 2D ones all the time, 3D menus have several advantages: a better use of space and a natural and intuitive interface. Moreover, according to the results in Table 2, 3D menus are likely to be more beneficial in broader menus. Out of suitable 3D menus for computers and cell phones, 3D menus falling in with purposes and target users should be implemented. The result and implications of important factors for 3D menu design are summarized in Table 2.

## 7. REAPPRAISAL

### 7.1. Guidelines for 2D Menu Design

The following 2D menu design guidelines for computers and cell phones have been extracted from the comprehensive literature review reported in this article. When designing menus, designers should follow these guidelines. Although cell phones have small screens and challenging input modes, the guidelines are fairly consistent. Menu design guidelines for computers include the following:

1. Broader menu structure should be considered. But excessive breadth, which can lead to crowding, should be avoided.
2. Even though adaptable interface cannot be useful at first, eventually the adaptable menu is useful.
3. Menu chunking principles should follow not the designers' mental models but the mental models that users have.

4. A menu system should be able to be flexible because individual differences can affect menu performance.
5. Hierarchical indexed menus are preferred in terms of selection time.

2D menu guidelines for cell phones include the following:

1. In general, narrow hierarchies should be designed, but filling the screen as much as possible without scrolling is needed.
2. The adaptable menu that users are able to personalize should be considered.
3. The menu should be designed considering primary tasks for applications, as task types can influence menu performance.
4. The interface that is able to display the overview and the detail at the same time is preferred.
5. The submenu window with no delay is recommended.

### 7.2. Guidelines for 3D Menu Design

Many features covered in 2D menu design studies were not investigated in 3D menu studies. From implications about menu structure and menu type, the following 3D menu design guidelines are drawn. These guidelines are applied to computers and cell phones:

1. Overall, a broader menu structure should be considered because 3D menus can display more items. 3D menus might be more useful in cell phones with broader menus because cell phones have a smaller screen size.
2. The menu should be chosen and designed considering purposes and target users.
   a. 3D Cone Tree: organization structure browser (purpose)
   b. Data Mountain: thumbnail document management (purpose)
   c. Collapsible Cylindrical Trees, 3D Carousel View, and Revolving Stage Menu: young generation pursuing fun (target users)
3. Revolving stage menu could be implemented in cell phones. The reasons are as follows: (a) It has 2D menus that users are familiar with, (b) it has the focus + context effect, and (c) it provides the broader menu effect.

### 7.3. Models for Cell Phone Menu Design: Use of 3D Menu

From literature about 2D and 3D menu design studies, models for cell phone menu design are proposed. Because cell phones with small screens are likely to benefit more from 3D menus, this model is investigated.

This model takes advantage of 3D menu design guidelines for cell phone menu interfaces. Three main factors for cell phone menu design are included in the proposed model: presentation type (3D vs. 2D), the number of items (breadth), and menu type.

The presentation type influences perception, cognition, and motor response time. The reasons are as follows. First, 3D menus give us different perception from the one of 2D menus, as 3D menus are natural and intuitive. Second, 3D menus make it possible to use spatial cognition. Last, 3D menus provide better use of space by displaying more data without causing additional load, and users are able to figure out overview and focus of the menu items at the same time. Thus, the presentation type influences short-term memory requirement. As a result, the presentation type involving 2D and 3D menus would impact performances, perceived space use, and user satisfaction in cell phone menus.

Cell phones support more features such as broadcasting, mobile wallet and health condition sensor, and so on. This is consistent with an issue raised by D. A. Norman (1988), which is "a tendency to add to the number of features that a device can do, often extending the number beyond all reasons" (p 173). With the unchanged human's cognitive limitation, a cell phone packed with too many features may overwhelm users due to its complexity (Ling et al., 2007). Under these circumstances, it is important to investigate how the number of items can influence 3D menu design in cell phones. The number of items per screen—in other words, the breadth—impacts perception, cognition, and motor response time (Jacko et al., 1995). In this manner, the number of displayed items is an important characteristic of a menu, for example, influencing the item selection time. However, many menu items might decrease significantly the usability of a solution, when conventional 2D menu is used. Therefore, the presentation type is dependent on the number of items per menu screen.

It is clear that menu types influence perception of menu items because different menus provide different settings for the menu, and thus the users' perception is different. Menu types also influence short-term memory requirements because 3D menus have various broader menu effects and 2D menus give different depth-level effects. There exist some 3D menus in computers, some of which are applicable in cell phones.

## REFERENCES

Allen, R. (1983). Cognitive factors in the use of menus and trees: An experiment. *IEEE Journal on Selected Areas in Communications*, *1*, 333–336.

Babaria, K., Giacoppo, S., & Kuter, U. (2001). *Single item search and selection in handheld devices: A pilot study on the effects of font size & menu design*. Retrieved from http://www.cs.umd.edu/class/fall2001/cmsc838s/rust.doc

Bayman, P., Civanlar, S., & Whitten, W. B. I. (1989). Usage-sensitive menu design with Huffman coding. *Proceedings of 22nd Annual Hawaii International Conference, 2*. pp. 436–437.

Beardow, P. (2004). Enabling wireless interactive 3D. *Superscape Plc*. Retrieved from http://www.superscape.com

Beck, J., Han, S. H., & Park, J. (2006). Presenting a submenu window for menu search on a cellular phone. *International Journal of Human Computer Interaction*, *20*, 233–245.

Bernard, M., & Hamblin, C. (2003). Cascading versus indexed menu design. *Usability News*, *5*(1).

Billingsley, P. A. (1982). Navigation through hierarchical menu structures: Does it help to have a map? *Proceedings of the 26th Annual Meeting of Human Factors Society*, *26*, 103–107.

Card, S. K. (1984). Visual search of computer command menus, in H. Bouma & D. G. Bouwhuis (Eds.). *Attention and Performance X: Control of Language Processes* (pp. 97–108). London: Lawrence Erlbaum.

Chae, M., & Kim, J. (2004). Do size and structure matter to mobile users? An empirical study of the effects of screen size, information structure, and task complexity on user activities with standard web phones. *Behaviour and Information Technology*, *23*, 165–181.

Cockburn, A., & McKenzie, B. (2000). *An Evaluation of Cone Trees*. Sheffield, England: People and Computers XIV: British Computer Society Conference on Human Computer Interaction 2000, 425–436.

Cockburn, A., & McKenzie, B. (2001). 3D or not 3D?: Evaluating the effect of the third dimension in a document management system. *Proceedings of the SIGCHI conference on Human factors in computing systems*, 434–441.

Dachselt, R. (1999). The challenge to build flexible user interface components for non-immersive 3D environments. *Proceedings of the 8th International Conference on Human-Computer Interaction*, *2*, 1055–1059.

Dachselt, R., & Ebert, J. (2001). Collapsible cylindrical trees: a fast hierarchical navigation technique. Proc. of *Information Visualization* 2001, 79–86.

Dachselt, R., & Hubner, A. (2007). Three-dimensional menus: A survey and taxonomy. *Computers & Graphics*, *31*(1), 53–65.

Dawkins, A. L. (2007). *Personalized hierarchical menu organization for mobile device users*. Unpublished master's thesis, North Carolina University Raleigh, North Carolina.

Drager, K. D. R., Light, J. C., Carlson, R., D'Silva, K., Larsson, B., Pitkin, L., et al. (2004). Learning of dynamic display AAC Technologies by typically developing 3-year-olds effect of different layouts and menu approaches. *Journal of Speech, Language and Hearing Research*, *47*, 1133–1148.

Dray, S. M., Ogden, W. G., & Vestewig, R. E. (1981). Measuring performance with a menu-selection human–computer interface. *Proceedings of the 25th Annual Meeting of the Human Factors Society*, 746–748.

Edwards, P. J., Barnard, L., Leonard, V. K., Yi, J. S., Moloney, K. P., Kongnakorn, T., et al. (2005). Understanding users with Diabetic Retinopathy: factors that affect performance in a menu selection task. *Behaviour & Information Technology*, *24*, 175–186.

Findlater, L., & McGrenere, J. (2004). A comparison of static, adaptive, and adaptable menus. *Proceedings of the 2004 Conference on Human Factors in Computing Systems*, 89–96.

Fitzmaurice, G. W., Zhai, S., & Chignell, M. H. (1993). Virtual reality for palmtop computers. *ACM Transactions on Information Systems (TOIS)*, *11*, 197–218.

Gajos, K. Z., Czerwinski, M., Tan, D. S., & Weld, D. S. (2006). Exploring the design space for adaptive graphical user interfaces. *Proceedings of the Working Conference on Advanced Visual Interfaces*, 201–208.

Geven, A., Sefelin, R., & Tscheligi, M. (2006). Depth and breadth away from the desktop: the optimal information hierarchy for mobile use. *Proceedings of the 8th Conference on Human–Computer Interaction With Mobile Devices and Services*, 157–164.

Gobet, F., Lane, P. C. R., Croker, S., Cheng, P. C. H., Jones, G., Oliver, I., et al. (2001). Chunking mechanisms in human learning. *Trends in Cognitive Sciences*, *5*, 236–243.

Gong, Q., & Salvendy, G. (1995). An approach to the design of a skill adaptive interface. *International Journal of Human–Computer Interaction*, *7*, 365–383.

Greenberg, S., & Witten, I. H. (1985). Adaptive personalized interfaces- question of viability. *Behaviour & Information Technology*, *4*(1), 31–45.

Gutwin, C., & Fedak, C. (2004). Interacting with big interfaces on small screens: a comparison of fisheye, zoom, and panning techniques. *Proceedings of the 2004 Conference on Graphics Interface*, 145–152.

Hakala, T., Lehikoinen, J., & Aaltonen, A. (2005). Spatial interactive visualization on small screen. *Proceedings of the 7th International Conference on Human–Computer Interaction With Mobile Devices & Services*, 137–144.

Han, S. H., & Kwahk, J. (1994). Design of a menu for small displays presenting a single item at a time. *Proceedings of Human Factors and Ergonomics Society*, *38*, 360–364.

Hollands, J. G., & Merikle, P. M. (1987). Menu organization and user expertise in information search tasks. *Human Factors*, *29*, 577–586.

Hornbaek, K., & Hertzum, M. (2007). Untangling the usability of fisheye menus. *ACM Transactions on Computer–Human Interaction*, Article 6, 1–32.

Huang, S. C. (2006). Empirical evaluation of a popular cellular phone's menu system: Theory meets practice. *Journal of Usability Studies*, *1*(2), 136–150.

Jacko, J. A., Barnard, L., Yi, J. S., Edwards, P. J., Leonard, V. K., Kongnakorn, T., et al. (2005). Empirical validation of the Windows accessibility settings and multimodal feedback for a menu selection task for users with Diabetic Retinopathy. *Behaviour & Information Technology*, *24*, 419–434.

Jacko, J. A., & Salvendy, G. (1996). Hierarchical menu design: Breadth, depth, and task complexity. *Perceptual and Motor Skills*, *82*, 1187–1201.

Jacko, J. A., Salvendy, G., & Koubek, R. J. (1995). Modelling of menu design in computerized work. *Interacting with Computers*, *7*, 304–330.

Kiger, J. I. (1984). The depth/breadth trade-off in the design of menu-driven user interfaces. *International Journal of Man–Machine Studies*, *20*, 201–213.

Kim, N., Kim, G. J., Park, C. M., Lee, I., & Lim, S. H. (2000). Multimodal Menu Presentation and Selection in Immersive Virtual Environments. *Proceedings of IEEE Virtual Reality.* pp. 281–288.

Larson, K., & Czerwinski, M. (1998). Web page design: implications of memory, structure and scent for information retrieval. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 25–32.

Lee, E., & MacGregor, J. (1985). Minimizing user search time in menu retrieval systems. *Human Factors*, *27*(2), 157–162.

Lee, E., MacGregor, J., Lam, N., & Chao, G. (1986). Keyword-menu retrieval: an effective alternative to menu indexes. *Ergonomics*, *29*(1), 115–130.

Lee, E., Whalen, T., McEwen, S., & Latremouille, S. (1984). Optimizing the design of menu pages for information retrieval. *Ergonomics*, *27*, 1051–1069.

Ling, C., Hwang, W., & Salvendy, G. (2007). A survey of what customers want in a cell phone design. *Behaviour & Information Technology*, *26*, 149–163.

MacGregor, J., Lee, E., & Lam, N. (1986). Optimizing the structure of database menu indexes: A decision model of menu search. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *28*, 387–399.

McDonald, J. E., Stone, J. D., & Liebelt, L. S. (1983). Searching for items in menus: The effects of organization and type of target. *Proceedings of the 27th Annual Meeting of the Human Factors Society*, 834–837.

Mehlenbacher, B., Duffy, T. M., & Palmer, J. (1989). Finding information on a menu: Linking menu organization to the user's goals. *Human–Computer Interaction*, *4*, 231–251.

Miller, D. P. (1981). The depth/breadth tradeoff in hierarchical computer menus. *Proceedings of the Human Factors Society*, pp. 296–300.

Mitchell, J., & Shneiderman, B. (1989). Dynamic versus static menus: an exploratory comparison. *ACM SIGCHI Bulletin*, *20*(4), 33–37.

Molina, J. P., Gonzalez, P., Lozano, M. D., Montero, F., & Lopez-Jaquero, V. (2003). Bridging the gap: Developing 2D and 3D user interfaces with the IDEAS methodology. *Proceedings of the 10th International Conference on Design, Specifications, and Verification of Interactive Systems DSV–IS 2003*, 303–315.

Norman, D. A. (1988). *The design of everyday things*. New York, NY: Basic Books.

Norman, K. L. (1991). *The psychology of menu selection: Designing cognitive control at the human/computer interface*: Northvale, NJ: Ablex.
Norman, K. L., & Chin, J. P. (1988). The effect of tree structure on search in a hierarchical menu selection system. *Behaviour and Information Technology*, *7*(1), 51–65.
Paap, K., & Roske-Hofstrand, R. (1986). The optimal number of menu options per panel. *Human Factors*, *28*, 377–385.
Parkinson, S. R., Hill, M. D., Sisson, N., & Viera, C. (1988). Effects of breadth, depth and number of responses on computer menu search performance. *International Journal of Man–Machine Studies*, *28*, 683–692.
Rekimoto, J. (1996). Tilting operations for small screen interfaces. *Proceedings of the 9th Annual ACM Symposium on User Interface Software and Technology*, 167–168.
Ro, Y. J., Choi, H. J., Lee, D. H., & Ko, I. Y. (2008). Dynamic pull-down menu organization in run-time by analyzing menu selection behaviors. *Proceedings of the 8th IEEE International Conference*, 730–735.
Robertson, G., Card, S. K., & Mackinlay, J. D. (1993). Information visualization using 3D interactive animation. *Communications of the ACM*, *36*(4), 57–71.
Robertson, G., Czerwinski, M., Larson, K., Robbins, D. C., Thiel, D., & van Dantzich, M. (1998). Data mountain: Using spatial memory for document management. *Proceedings of the 11th Annual ACM Symposium on User Interface Software and Technology*, 153–162.
Robertson, G., Mackinlay, J. D., & Card, S. K. (1991). Cone Trees: animated 3D visualizations of hierarchical information. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 189–194.
Schultz, E. E., & Curran, P. S. (1986). Menu structure and ordering of menu selection: independent of interactive effects? *ACM SIGCHI Bulletin*, *18*(2), 69–71.
Sears, A., & Shneiderman, B. (1994). Split menus: effectively using selection frequency to organize menus. *ACM Transactions on Computer–Human Interaction*, *1*(1), 27–51.
Seppala, P., & Salvendy, G. (1985). Impact of depth of menu hierarchy on performance effectiveness in a supervisory task: computerized flexible manufacturing system. *Human Factors*, *27*, 713–722.
Sisson, N., Parkinson, S., & Snowberry, K. (1983). Design methodology for menu structures. *Proceedings of the 2nd Annual Phoenix Conference on Computers and Communications*, 557–560.
Sisson, N., Parkinson, S. R., & Snowberry, K. (1986). Considerations of menu structure and communication rate for the design of computer menu displays. *International Journal of Man–Machine Studies*, *25*, 489.
Snowberry, K., Parkinson, S. R., & Sisson, N. (1983). Computer display menus. *Ergonomics*, *26*, 699–712.
Snowberry, K., Parkinson, S., & Sisson, N. (1985). Effects of help fields on navigating through hierarchical menu structures. *International Journal of Man–Machine Studies*, *22*, 479–491.
Snyder, K. M., Happ, A. J., Malcus, L., Paap, K. R., & Lewis, J. R. (1985). Using cognitive models to create menus. *Proceedings of the 29th Annual Meeting of Human Factors Society*, 655–658.
Somberg, B. L., & Picardi, M. C. (1983). Locus of the information familiarity effect in the search of computer menus. *Proceedings of the 27th Annual Meeting of Human Factors Society*, 826–830.
Suzuki, M. T., Yaginuma, Y., & Sugimoto, Y. Y. (2003). A 3D model retrieval system for cellular phones. *Proceedings of Systems, Man and Cybernetics*, *4*, 3846–3851.

Tang, K. H. E. (2001). Menu design with visual momentum for compact smart products. *Human Factors*, *43*, 267.

Tidwell, J. (2006). *Designing interfaces*. Sebastopol, CA: O'Reilly.

Troiano, L., Birtolo, C., Armenise, R., & Cirillo, G. (2008). Optimization of menu layouts by means of genetic algorithms. *Lecture Notes in Computer Science*, *4972*, 242.

Tullis, T. S. (1985). Designing a menu-based interface to an operating system. *ACM SIGCHI Bulletin*, *16*(4), 84.

van Dam, A. (1997). Post-WIMP user interfaces. *Communications of the ACM*, *40*(2), 63–67.

Vicente, K. J., Hayes, B. C., & Williges, R. C. (1987). Assaying and isolating individual differences in searching a hierarchical file system. *Human Factors*, *29*, 349–359.

Wallace, D. F., Anderson, N. S., & Shneiderman, B. (1987). Time stress effects on two menu selection systems. *Proceedings of the 31st Annual Meeting of Human Factors Society*, *31*, 727–732.

Wang, S., Poturalski, M., & Vronay, D. (2005). Designing a generalized 3D carousel view. *Conference on Human Factors in Computing Systems*, 2017–2020.

Ware, C. (2004). *Information visualization: Perception for design*. San Francisco, CA: Morgan Kaufmann.

Ware, C., & Franck, G. (1996). Evaluating stereo and motion cues for visualizing information nets in three dimensions. *ACM Transactions on Graphics*, *15*, 121–140.

Worldwide mobile subscriptions to reach 5.6 billion by 2013. (2008). *Cellular-news*. Retrieved from http://www.cellular-news.com/story/32073.php

Ziefle, M. (2002). The influence of user expertise and phone complexity on performance, ease of use and learnability of different mobile phones. *Behaviour & Information Technology*, *21*, 303–311.

Ziefle, M., & Bay, S. (2004). Mental models of a cellular phone menu. Comparing older and younger novice users. *Lecture Notes in Computer Science*, 25–37.