Menu Design in Cell Phones: Use of 3D Menus

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Abstract. The number of mobile phone users has been steadily increasing due to the development of microtechnology and human needs for ubiquitous communication. Menu design features play a significant role in cell phone design from the perspective of customer satisfaction. Moreover, small screens of the type used on mobile phones are limited in the amount of available space. Therefore, it is important to obtain good menu design. Review of previous menu design studies for human-computer interaction suggests that design guidelines for mobile phones need to be reappraised, especially 3D display features. We propose a conceptual model for cell phone menu design with 3D displays. The three main factors included in the model are: the number of items, task complexity, and task type.

Keywords: cell phones, menu design, 3D menu, task complexity, task type.

1 Introduction

The number of mobile phone users has been steadily increasing due to the development of microtechnology and human needs for ubiquitous communication. People use mobile phones to communicate with their friends, family, and business partners, and also to obtain information through the mobile Internet. Moreover, people use embedded mobile phone features such as games, cameras and wireless Internet for various purposes of entertainment and shopping. Due to increasing features, mental workload of using cell phones has increased. Ling et al. [1] prioritized the design features and aspects of cell phones based on users' feedback to optimize customers' satisfaction. Although physical appearance and body color of cell phones had considerable influence on overall user satisfaction, menu design features also played a significant role. Therefore, obtaining a good menu design in cell phones is an important issue.

There has been a lot of research about menu design for computers. When it comes to menu dimensions, many researchers have concluded that performance time and errors increase as the hierarchical levels of the menu structure increase [2, 3]. With

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regard to menu type, hierarchical menus are more accurate and faster than fisheye menus [4]. Three-dimensional (3D) displays show many items of a menu at the same time, so they may give the same effect as a broader menu [5]. With regard to adaptability, computer menus that can be customized by users have been shown to be better than ones that adapt automatically [6].

Research on cell phone menu design is relatively recent. Geven, Sefelin, and Tscheligi [7] concluded that narrow hierarchies performed better than broader hierarchies in mobile devices, contrary to menu design in computers. With respect to menu type, Gutwin and Fedak [8] found that people were able to carry out a web navigation task better with the fisheye view than with alternatives. For adaptability, results have been similar to those for computer displays. Customized menus produced better performance and evaluation than the traditional static menu [9]. But, a lack of studies about 3D display for cell phones was found, and in this paper 3D design research is investigated in more detail.

At this point, there are no standard interaction devices or interfaces used in 3D environments, and there is a lack of specific best practice guidelines to develop these 3D designs. 3D design is able to convey more information than text or two-dimensional (2D) images, and it enhances the usability of the limited screen on a typical wireless device. Interactive 3D can therefore be used to remove some of the complexity and clutter present on menu systems of today's handsets. 3D icons can be animated to show activity or changes in status, and the depth dimension can be utilized to show urgency or relative importance [10]. Therefore, new standards should be developed to allow personal digital assistants (PDAs) and mobile devices to render 3D applications.

Review of previous menu design studies for human-computer interaction suggests that design guidelines for mobile phones need to be reappraised, especially 3D display features. To this end, the main objective of this paper is to propose an overall framework to develop mobile phone menu design guidelines regarding 3D displays. We review menu design components for computers in section 2 and investigate menu design factors for cell phones in section 3. Strengths and weaknesses of 3D design factors are considered in section 4. We compare menu design factors in section 5 and conclude after explaining a model of cell phone menu design in section 6.

2 Menu Design in Computers

2.1 Menu Dimension

Many of the early studies of menu design for computers focused on the cognitive factors of a menu's hierarchical structure and the structure's impact on end users' behaviors and performance in retrieving information. Out of this research, studies about whether it is better to have a broad or deep design have been conducted. Jacko et al. [2] suggested three components of hierarchical menu design: menu dimension, task complexity, and user knowledge structure. The results about the menu dimension supported that both performance time and errors increased as the levels of the menu structure increased. That is, depth in an information structure increases the likelihood of navigational errors and also increases performance time [11].

Seppala and Salvendy [3] also drew the conclusion that a broader mode of data presentation is more effective than a deeper one. Because searching back and forth through the menu system decreases the speed and accuracy of performance, the broader menu has better performance in the case of a personal computer. This is because increased depth involves additional visual search and decision-making, and greater uncertainty as to the location of target items due to the increased number of menu frames [12]. In other words, as the depth increases and the number of responses needed while going through a menu tree increases, more time for decision making and responding is required [3].

2.2 Menu Type

Menu structure can be classified as hierarchical and fisheye [4]. Fisheye is a menu display method that shows a region of the menu at high magnification, while items before and after that region are shown at gradually reduced sizes. Hornbaek and Hertzum [4] provided evidence that, for finding known items, conventional hierarchical menus were more accurate and faster than fisheye menus. Also, participants rated hierarchical menus as more satisfying than fisheye menus. For browsing tasks, the menus did not differ with respect to accuracy or selection time.

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, while other parts are shown at low magnification to provide context. However, performance remained worse with fisheye menus than with hierarchical menus because the latter impose lower mental demands on users [4].

Within a hierarchical menu, cascading and indexed menus can be compared [13]. Participants searched three types of menu layouts: categorical index; horizontal cascading; vertical cascading. Search time differences between the three menu layouts were detected that strongly favored the index menu. One possible reason for this result is that the items in the index menus were in closer proximity. Another is that the index menus were centrally located on the screen, and thus would have been easier to see and acquire.

2.3 Adaptability

Some commercial applications now have adaptable interfaces. For example, the Start Menu in Microsoft Windows XP™ has an adaptive function that provides automatically generated shortcuts to frequently used applications. Microsoft Office also provides Smart Menus, which are an adaptive mechanism where infrequently used menu items are hidden from view.

Understanding these interfaces through strong empirical and theoretical studies is particularly important, because adaptive interfaces are now being introduced into productivity software and used by an increasing number of people [14]. Mitchell and Shneiderman [15] compared dynamic vs. static menus using a menu-driven computer program. Subjects who used adaptive dynamic menus for the first set of tasks were significantly slower than those who used static menus. Moreover, 81% of the subjects preferred working with static menus to working with dynamic menus. This preference likely is because dynamic menus can slow down first-time users, at least until they become accustomed to this interaction style.

Findlater and McGrenere [6] compared the measured and perceived efficiency of three menu conditions: static, adaptable and adaptive. They found that users generally preferred the customizable version to the adaptive menus. In terms of performance, adaptive menus were not faster than either of the other conditions. User-driven customization is a more viable approach for personalizing user interfaces than system-driven adaptation. The static menu was found to be significantly faster than the adaptive menu, and the adaptable menu was found to be significantly faster than adaptive menu under certain conditions. But, in terms of accuracy, there were no differences. However, the majority of users preferred the adaptable menu overall and ranked it first for perceived efficiency. Therefore, this study suggests that system-driven adaptation is not helpful.

3 Menu Design in Cell Phones

3.1 Menu Dimension

As screens become smaller, the information they display changes more extensively with each scrolling action, making it more difficult to refocus on the page. In this way, screen size affects the navigation behavior and perceptions of mobile phone users [11]. Therefore, the breadth of information structures should be adapted to anticipated screen size.

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. Therefore, a user encountering greater depth has fewer options to process on a single page. Thus, the cognitive load on the user is reduced.

Findings consistently have suggested an advantage of employing a deeper menu structure to achieve better user performance and accuracy. Geven et al. [7] showed that people perform better with narrow hierarchies than with broader hierarchies on small screens. Contrary to computers, where many options are usually presented at once, it is better to use a layered design in cell phones.

Huang [16] showed that users prefer a less extensive menu structure on a small-screen device. This result supports the recommendation of not having a broad menu structure on a small screen. With less space to display information, designers of cell phones tend to chunk menu items of a broader menu into several pages or screens. This chunking requires end-users to employ more scrolling operations, maintain more information in working memory, and engage in more searching and navigation behaviors. The consequence is to reduce the speed and accuracy in use of the menus. The following describes the two suggestions that Huang [16] developed:

(1) Reduce both breadth and depth of the menu.
(2) Instead of displaying only a limited number of items on one screen, include more menu items and options in one page.

Dawkins [9] also suggests that filling the screen as much as possible without requiring scrolling should be the ideal breadth of the menu.

3.2 Menu Type and Adaptability

Many of the current visualization methods aimed at small screens rely on distorting the view. The viewpoint information is manipulated in a way that enables seeing important objects in detail, and the whole information space can be displayed at once with very low amount of detail [17]. The rubber sheet is one of view distortion techniques that allow the user to choose areas on the screen to be enlarged. Zooming and zoomable user interfaces (ZUI) are another way of presenting large information spaces even on a small screen. Combs and Bederson [18] studied image browsers and found that their system, based on a ZUI method (as well as 2D thumbnail grid), outperformed 3D browsers in terms of retrieval time and error rate.

Displaying the overview and the detail at the same time is also more beneficial than the traditional linear format because the global context allows faster navigation [8]. Gutwin and Fedak [8] found that people were able to carry out a web navigation task better with the fisheye view. Some phones are already being designed with a fisheye display for selected items to be salient and clear. Therefore, a fisheye menu may be better than a 2D hierarchical menu.

In computers, users can create folders, reorder the layout, and make shortcuts. But a mobile phone has limited screen size and a small input device. Moreover, telecommunication carriers want the buttons to be used for their wireless Internet service. They are therefore reluctant to offer many customization functions to users. In other words, mobile phones do not provide enough adaptation functions.

Dawkins [9] evaluated personalized menus alongside a traditional static menu structure based on user preference and performance. He concluded that customized menus had better performance and evaluation than the traditional static menu. Therefore, customers seem to want more customization functions in their cell phones from the perspectives of performance and satisfaction.

4 3D Design

4.1 Benefits of 3D Design

Human information-processing has evolved to recognize and interact with a 3D world. And the 3D design space is richer than the 2D design space, because a 2D space is part of 3D space. It is always possible to flatten out part of a 3D display and represent it in 2D [19]. Therefore, it is unsurprising that 2D interfaces have performed relatively poorly. For example, Ware and Franck [20] conducted an experiment that was designed to provide quantitative measurements of how much more (or less) can be understood in 3D than 2D. Results showed that the 2D interface was outperformed by 3D interfaces. These results provide strong reasons for using advanced 3D graphics for interacting with a large variety of information structures [20].

The 3D interfaces make it possible to display more information without incurring additional cognitive load, because of pre-attentive processing of perspective views (e.g., smaller size indicates spatial relations at a distance). An ability to recognize spatial relations based on 3D depth cues makes it possible to place pages at a distance (thereby using less screen space) and understand their spatial relations without effort [21]. As described before, there are many 3D depth cues that can be provided to facilitate spatial cognition. The most obvious of these are perspective view and occlusion. Using these cues, the user gets the advantages of a 3D environment (better use of space, spatial relations perceived at low cognitive overhead, etc.). 3D allows larger menu items than the screen size. This would be a desirable feature for small screens that have a restricted screen resolution and size [22].

The effect of 3D is to increase the effective density of the screen space 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. It seems reasonable that 3D can be used to maximize effective use of screen space [23], especially in cell phones for which the screens are small screens.

The use of 3D models on the Internet is gaining popularity, and the number of 3D model databases is increasing rapidly because 3D interfaces enable a more natural and intuitive style of interaction [24]. Since the use of 3D models is becoming more common on various cellular phone web sites, development of algorithms that retrieve similar information will be important in cell phone menu design [25].

4.2 Weaknesses of 3D Design

Creating a 3D visualization environment is considerably more difficult than creating a 2D system with similar capabilities. As the study of Cockburn and McKenzie [26] suggests, one should not assume that use of 3D provides more readily accessible information. In determining whether to implement a 3D display, designers should decide whether there are enough subtasks that would benefit from 3D representations. The complexity and the consistency of the user interface for the whole application must also be weighed in the decision. In the study of Ware [19], 3D navigation methods took considerably longer than 2D alternatives. Even if somewhat more information can be shown in 3D than in 2D, the rate of information access may be slower, and 3D applications may have greater visual complexity than 2D applications [27].

People often find it difficult to understand 3D spaces and to perform actions in them. It is clear that simply adapting traditional WIMP (windows, icons, menus, and pointers) interaction styles to 3D does not provide a complete solution to this problem. Rather, novel 3D user interfaces, based on interactions with the physical world, must be developed. Jones and Dumais [28] have suggested that little significant value is provided by adding physical location information to the storage and subsequent retrieval of a document over and above simply providing a semantic label for the same purposes.

4.3 Direct Comparison between 2D and 3D

Few prior studies have directly compared 2D and 3D interactive systems. Also, there is a surprising lack of empirical research into the benefits (or costs) that are produced by moving from 2D to 3D. Cockburn and McKenzie [29] compared subject's efficiency in locating files when using Cone-Trees (a 3D technique for exploring hierarchical data structures) and when using a 'normal' folding tree interface similar to that used in Windows Explorer. Results showed that the subjects took longer to complete their tasks when using the cone interface. They rated the cone interface as poorer than the normal one for seeing and interacting with the data structure. Also, Cockburn and McKenzie [26] showed no significant difference between task performance in 2D and 3D, but a significant preference for the 3D interfaces.

Recently there has been a growth of interest in 3D interactive systems for everyday 'desktop' computing applications, such as document and file management. However, the relative value of the third visual dimension in cell phone menu design has not previously been evaluated.

5 Models for Cell Phone Menu Design

Jacko et al. [2] proposed modifications to an information-processing model developed by Salvendy and Knight [30]. In this model, three constructs of hierarchical menu retrieval were proposed: menu dimension, task complexity, and knowledge structure. Figure 1 illustrates a version of Jacko et al.'s [2] information-processing model extended to cell phone menu retrieval operation. The model takes advantage of the natural 3D human information-processing capabilities for cell phone menu interfaces, with distinctions similar to those identified by Jacko et al. The three main factors for cell phone menu design within 3D display included in the model are: the number of items, task complexity, and task type.

Cell phones support more features such as broadcasting, mobile wallet and health condition sensor, etc. This is consistent with an issue raised by Norman [31], 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 human cognitive limitations, a cell phone with too many features may overwhelm users due to its complexity [1]. 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 could influence menu dimensions, resulting in effects on perception, cognition, and motor response time. In this way, the number of items is an important characteristic of a virtual menu that will influence the item selection time. Moreover, inclusion of many menu items may decrease the usability of a 2D display solution. Therefore, deciding whether or not to use 3D design should depend on the number of items per menu screen.

Task complexity can impact performance and satisfaction of 3D menu design because in a 3D environment the spatial relationships are perceived at low cognitive overhead [22]. Thus, performing a complex task may be better in a 3D environment than in a 2D environment. On the other hand, a 3D display sometimes has greater visual complexity. Therefore, direct comparisons between 2D and 3D menus for different levels of task complexity are needed. Task type influences the perceptual information required, the cognition operations involved in using that information, and necessary motor responses. Experiments need to be conducted to validate the proposed conceptual model.

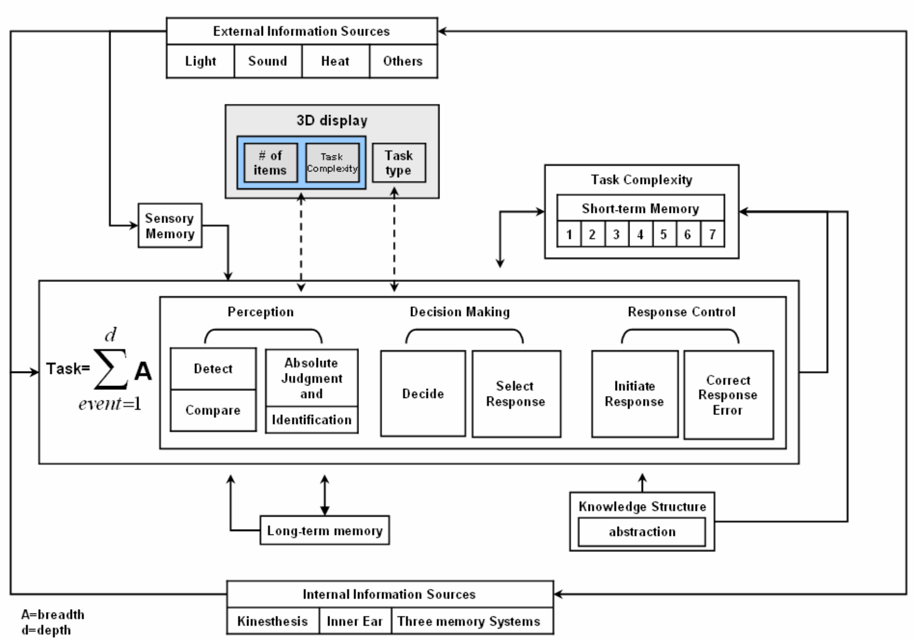

Fig. 1. Modified Information-processing Model for Cell Phone Menu Operation

6 Conclusion

The widespread use of cell phones for a variety of purposes provides evidence that they are shifting from just a communication tool to being an integral part of people's everyday life. It is important to study cell phone menu design because, though menu design plays a crucial role in cell phone usability, little work exists on developing cell phone menu design.

Three factors were identified that may influence performance of menu retrieval tasks with 2D and 3D displays in cell phones: the number of items, task complexity, and the type of tasks. These three factors are included in the proposed conceptual model for cell phone menu design with 3D displays. Research designed to validate this model should provide insights into the human information-processing requirements of various cell phone menu interfaces.

References

1. Ling, C., Hwang, W., Salvendy, G.: A survey of what customers want in a cell phone design. Behaviour & Information Technology 26, 149–163 (2007)
2. Jacko, J.A., Salvendy, G., Koubek, R.J.: Modelling of menu design in computerized work. Interacting with Computers 7, 304–330 (1995)
3. Seppala, P., Salvendy, G.: Impact of depth of menu hierarchy on performance effectiveness in a supervisory task: computerized flexible manufacturing system. Human Factors 27, 713–722 (1985)

4. Hornbaek, K., Hertzum, M.: Untangling the usability of fisheye menus. ACM Trans. on Computer-Human Interaction, Article 6, 1–32 (2007)
5. Dachselt, R., Ebert, J.: Collapsible cylindrical trees: a fast hierarchical navigation technique. In: Information Visualization, INFOVIS 2001, pp. 79–86 (2001)
6. Findlater, L., McGrenere, J.: A comparison of static, adaptive, and adaptable menus. In: Proceedings of the 2004 conference on Human Factors in Computing Systems, pp. 89–96 (2004)
7. Geven, A., Sefelin, R., Tscheligi, M.: Depth and breadth away from the desktop: the optimal information hierarchy for mobile use. In: Proceedings of the 8th conference on Human-Computer Interaction with Mobile Devices and Services, pp. 157–164 (2006)
8. Gutwin, C., Fedak, C.: Interacting with big interfaces on small screens: a comparison of fisheye, zoom, and panning techniques. In: Proceedings of the 2004 conference on Graphics Interface, pp. 145–152 (2004)
9. Dawkins, A.L.: Personalized Hierarchical Menu Organization for Mobile Device Users. Vol. Master. North Carolina (2007)
10. Beardow, P.: Enabling Wireless Interactive 3D. article retrieved from the Superscape Plc (June 2004), `http://www.superscape.comin`
11. Chae, M., Kim, J.: 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 (2004)
12. Jacko, J.A., Salvendy, G.: Hierarchical menu design: Breadth, depth, and task complexity. Perceptual and Motor Skills 82, 1187–1201 (1996)
13. Bernard, M., Hamblin, C.: Cascading versus Indexed Menu Design. Usability News 5 (2003)
14. Gajos, K.Z., Czerwinski, M., Tan, D.S., Weld, D.S.: Exploring the design space for adaptive graphical user interfaces. In: Proceedings of the working conference on Advanced Visual Interfaces, pp. 201–208 (2006)
15. Mitchell, J., Shneiderman, B.: Dynamic versus static menus: an exploratory comparison. ACM SIGCHI Bulletin 20, 33–37 (1989)
16. Huang, S.C.: Empirical Evaluation of a Popular Cellular Phone's Menu System: Theory Meets Practice. Journal of Usability Studies, 136–150 (2006)
17. Hakala, T., Lehikoinen, J., Aaltonen, A.: Spatial interactive visualization on small screen. In: Proceedings of the 7th international conference on Human Computer Interaction with Mobile Devices & Services, pp. 137–144 (2005)
18. Combs, T.T.A., Bederson, B.B.: Does Zooming Improve Image Browsing? In: Proceedings of the fourth ACM Conference on Digital Libraries, pp. 130–137 (1999)
19. Ware, C.: Information Visualization: Perception for Design. Morgan Kaufmann, San Francisco (2004)
20. Ware, C., Franck, G.: Evaluating stereo and motion cues for visualizing information nets in three dimensions. ACM Transactions on Graphics 15, 121–140 (1996)
21. Robertson, C.M., Larson, K., Robbins, D.C., Thiel, D., van Dantzich, M.: Data mountain: using spatial memory for document management. In: Proceedings of the 11th annual ACM Symposium on User Interface Software and Technology, pp. 153–162 (1998)
22. Rekimoto, J.: Tilting operations for small screen interfaces. In: Proceedings of the 9th annual ACM Symposium on User Interface Software and Technology, pp. 167–168 (1996)
23. Robertson, C.S.K., Mackinlay, J.D.: Information visualization using 3D interactive animation. Communications of the ACM 36, 57–71 (1993)

24. Molina, J.P., Gonzalez, P., Lozano, M.D., Montero, F., Lopez-Jaquero, V.: Bridging the Gap: Developing 2D and 3D User Interfaces with the IDEAS Methodology. In: Jorge, J.A., Jardim Nunes, N., Falcão e Cunha, J. (eds.) DSV-IS 2003. LNCS, vol. 2844, pp. 303–315. Springer, Heidelberg (2003)
25. Suzuki, M.T., Yaginuma, Y., Sugimoto, Y.Y.: A 3D model retrieval system for cellular phones. In: IEEE International Conference on Systems, Man and Cybernetics, vol. 4, pp. 3846–3851 (2003)
26. Cockburn, A., McKenzie, B.: 3D or not 3D?: evaluating the effect of the third dimension in a document management system. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, pp. 434–441 (2001)
27. van Dam, A.: Post-WIMP user interfaces. Communications of the ACM 40, 63–67 (1997)
28. Jones, W.P., Dumais, S.T.: The spatial metaphor for user interfaces: experimental tests of reference by location versus name. ACM Transactions on Information Systems 4, 42–63 (1986)
29. Cockburn, A., McKenzie, B.: An Evaluation of Cone Trees. People and Computers XIV-Usability Or Else! 425–434 (2000)
30. Salvendy, G., Knight, J.: Psychomotor work capabilities. In: Salvendy, G. (ed.) Handbook of Industrial Engineering, pp. 1–5 (1982)
31. Norman, D.A.: The Psychology of Everyday Things. Basic Books, New York (1988)