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An Empirical Study on the Breadth and Depth Tradeoffs in Very Small Screens: Focusing on Mobile Internet Phones

Minhee Chae
Yonsei University

Jinwoo Kim
Yonsei University

AN EMPIRICAL STUDY ON THE BREADTH AND DEPTH TRADEOFFS IN VERY SMALL SCREENS: FOCUSING ON MOBILE INTERNET PHONES

Minhee Chae
Yonsei University
minheechae@yahoo.comkr

Jinwoo Kim
Yonsei University
jinwoo@yonsei.ac.kr

Abstract

Recently many people can retrieve information anywhere and anytime using handheld mobile Internet devices. Although there has been much progress in mobile Internet technologies, small size of mobile Internet screen remains as a fundamental limitation causing poor usability. One way to work within this constraint is to organize an information structure with efficient depth/breadth design. This study investigated the impacts of screen size and horizontal depth, a new concept proposed by this paper for mobile Internet, on user's behaviors and perceptions. Results of a lab experiment showed that horizontal depth and screen size significantly affect the navigation behaviors and perceptions of mobile Internet users.

Keywords: Mobile Internet, breadth/depth, screen size

Introduction

Recent years witness much excitement and hype in relation to the promised era of the *mobile Internet*, defined as the wireless access to the digitized contents of the Internet via handheld devices [7]. Many forecasters, basing their predictions on the uptake of standard mobile Internet phones, suggest that in the near future most Internet access will take place using small wireless devices, equipped with a browser and wireless connection, providing 'anywhere and anytime' Internet access [3].

Despite the forecasts that mobile Internet is the next "Killer App," the reactions of real users are quite negative in terms of its usability [16]. Such poor experiences in the mobile Internet result from the limitations that distinguish the mobile Internet from the conventional desktop PC-base Internet [4]. Mobile Internet devices, especially Internet-enabled phones, have much inferior resources compared to traditional Internet: small displays screens, limited storages, and cumbersome input facilities.

Even though future generations of mobile Internet will alleviate these limitations gradually, small display is not likely to change very much as far as portability requirement will continue to constrain the size of screen. Consequently, most mobile Internet devices have very small display. This is especially true for mobile Internet phones, which are dominant devices for accessing the mobile Internet in Japan, Korea, and Hong Kong, where the usage rate of the mobile Internet is much higher than in U.S. [13]. Therefore, only a small amount of information can be shown on the mobile Internet phones at a time; there are typically 1~8 lines vertically and less than 10 characters within a line on typical mobile Internet phones (e.g., Kyocera 3035 or Nokia 6310). Therefore, most of time mobile Internet users cannot be shown complete lists of possible options within the screen display area. Users have to scroll though the menu list, select an option, scroll through a sub-menu and so on repeatedly, which leads the user to having to make a large number of key presses and commit numerous navigation errors [1].

One way to overcome usability problems caused by small displays is to develop efficient information structure considering small screen size. However, information on a mobile screen is presented to users mostly in the form of a hierarchy. In comparison with the conventional menus in the traditional Internet systems, which provide users with multiple paths to reach a target page, most mobile browsers only allow one-path interaction. Mobile users are not allowed to directly jump from page to page but required to follow all the paths or links sequentially. Such a stepwise path-following interaction has been known to cause more Internet users to suffer from this kind of problem more severely [13, 16].

Therefore, the very portability itself of mobile Internet phones poses a formidable design challenge: How do we present information effectively on small screens with limited navigation facilities but for accomplishing complex tasks? The main goal of this study is to investigate how the characteristics of information structure and screen size impact on mobile user's behavior and performance.

Literature Review

Hierarchical Menu Structure

Most information on the mobile Internet is organized into a hierarchical tree, in which each node (menu panel) in the hierarchy can be reached only from a single superordinated node that lies directly above it in the hierarchy. One of most critical characteristics that must be considered in the hierarchical menu design is the trade-off between depth and breadth of menu structure [10]. Depth (d) is defined as the number of levels in the hierarchy. Breadth (b) is defined as the number of options per menu panel [17].

Miller's [15] study indicated well the trade-off between depth and breadth in designing menu structure. In his study, he hypothesized that the structure of menu hierarchy affects the speed and accuracy of target acquisition. He tested four different structures with the same 64 bottom level nodes: 2^6, 4^3, 8^2, and 64^1. The result indicated that increased breadth was beneficial but only with the expense of displaying crowding. In fact, he suggested that the 8^2 structure allowed the fastest acquisition and fewer errors among the four structures. These prior studies support that tradeoffs between depth and breadth of hierarchical menu systems influence the performance and behavior of user navigation.

Usability of Small Screens

There is a considerable amount of research on the usability of small screens [2, 6, 9, 12, 19]. However, there still exist inconsistencies among results of those studies. Some suggested that even though users' performance in terms of time to select an option worsened as the display size decreased, the impact was not dramatic [9, 19]. On the contrary, a recent study of the impact of display size on web interaction showed that small screen size reduced user effectiveness by up to 50% for the tasks being observed [12].

The inconsistencies among those prior studies might result from three reasons. First, typical displays explored in those studies were in the range of a quarter to half size of VGA dimensions (1024x768), while typical mobile displays are much smaller especially for mobile Internet phones. Real problems may only occur when the display is so small that only a small number of options (1-3 lines) could be displayed at a time. Therefore those prior results may not be directly applied to the 'very small' displays of current mobile Internet phones. Second, the interest of many previous studies was motivated by the desire to use miniature displays on devices such as typewriters and photocopiers [2]. Such early office automation devices allowed users to select functions by choosing options from a list of a few choices presented on a small LCD screen. However, information structures lying in those devices are much simpler in comparison with the mobile Internet, which provides a great amount of information organized into complex structures. Mobile Internet users would not struggle if only a simple list of choices was presented to them on current small screens. Third, even though several previous studies have been conducted to design effective mobile menu systems, there has been little research on the relation between small screen and hierarchical menu structure of mobile Internet. Although the characteristic of menu structure influences on users' behavior and on cognitive process of users, previous studies failed to consider the impact of hierarchical menu structure and screen size together [6, 12]. For these reasons, the impact of small screens is worth being revisited in the 'new' context of the mobile Internet.

Interaction Design for Mobile Internet

Breadth and Horizontal Depth

Small screen constraint differentiates mobile Internet from other conventional desktop-based Internet in terms of information structure. In order to explicate the difference, let's consider a simple example of finding traffic information ('*Target*' as represented in the figure 1).

The user starts searching information from the top level (*a*: home as shown in the figure 1) and moves down to sub-level (*b*) until encountering a list of street names. If there are *n* street names on the list, there may be several ways to present the whole list on the screen, such as providing *n* street names within one page(*b-b'*: in the figure 1a) or divide the lists into several pages (*b-b'*: 5 pages in the figure 1b). In the former case, the user has to search a certain street ('list *k*') by scrolling down the long list. In the latter case, the user has to move from the first page to the third page containing '*list k*' (*b*➔*b1*➔*b2*), then in the page *b2*, h/she keeps going down to *c* and to the '*Target*' information. In summary, the user moves down 3 vertical depths (*a* ➔ *b* ➔ *c* ➔ *Target*) in both cases. However, there is a difference in terms of *horizontal depth*. The user, in the case (a), only has to scroll down at the level *b*, while the user in case (b) has to move two more horizontal depths (*b* ➔ *b1*➔ *b2*) to reach the page where the *list k* is. As shown in the figure 1, we refers the depth, which is existing between multiple divided pages, as the '*Horizontal depth'* (b-b1-b2-b3-b4-b5'), distinguishing it from the '*Vertical depth'* (a-b-c-d). Therefore, the *horizontal depth* is defined as the number of pages dividing a unit of content into multiple sequential links, as opposed to having it as a unit on a single page. Because less information per page (breadth) leads to more pages, which lead to more levels in the hierarchy (horizontal depth), there may exist a similar trade-off between horizontal depth and breadth with the well-known trade-off between depth and breadth on the menu design, which was dealt in the prior section [8, 11,15].

Previous studies on paging (dividing information into multiple pages) have shown that paging results in more errors [8]. Such prior studies imply that error rates may be increased as horizontal depth increases [10]. Moreover, increasing horizontal depth may also increase perceived complexity of users, because users with more horizontal depths at the same level of hierarchy might perceive that they have explored deeper structure. As perceived complexity increases, users may have more difficulty in forming correct mental models or structural frameworks in mind [18]. This becomes more problematic in case of mobile Internet because relatively deep information structure has to be used in order to make a large amount of information fit into a limited screen space.

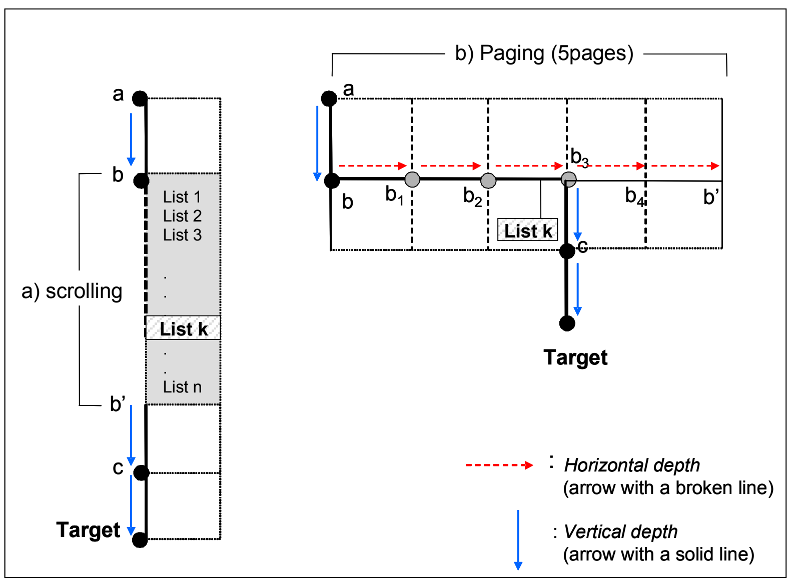


Figure 1. Horizontal Depth and Vertical Depth

However, we also need to consider the side effect of more breadth in mobile Internet systems. There exists a difference in a method of processing information options per display page between mobile Internet system and conventional Internet system. For a conventional Internet system, users only need to visually scan options listed on a screen in order to encode options on a screen and to decide whether to terminate search or continue to examine more of options [15, 17]. In case of mobile menu system, however, to view options hidden beyond visible area of screen requires a user to scroll line by line because only small number of lines can be displayed simultaneously. Whenever a user presses *scroll down* button, entire information seen on the visible area of screen moves down line by line and changes very fast. For example, if a user scrolls down once on a 4-line mobile phone screen, three quarters of existing information all move up one line and a quarter of existing information at the top of screen is replaced by the other new 1/4 information at the bottom. Whenever moving down the list of items by scrolling, the user must refocus on the correct part of the text, which is newly updated [14]. Consequently, processing time of mobile users includes not only time it takes to visually scan options displayed on a visible area but also time it takes to scroll down line by line in order to view the rest of the list on the page and to refocus on it. Creating more horizontal depth and less breadth of mobile Internet system might reduce perceived complexity in serial information searching [11]. Therefore, there exist tradeoffs between horizontal depth and breadth, just as there are tradeoffs between vertical depth and breadth.

Screen Size and Horizontal Depth

One interesting aspect of screen size in terms of horizontal depth is the information changing rate by scrolling the menu structure line by line. In order to make the aspect more clear, let's consider an example with two screen sizes as shown in the figure 2. There are two sizes of small screens in figure 2: 6 line and 9 line screen. Each screen size includes 2 lines of icons and 1 line of heading, which cannot be used to display contents. In other words, the 9 line-screen has six lines of content area [Fig 2-(a)], while the 6 line-screen has three lines [Fig 2-(b)]. The main difference in terms of navigation process resulting from these two screen sizes lies in the information change rate by scrolling line by line. If a user, for example, scrolls down line by line on a 6-line mobile screen (with three lines of contents), 1/3 of the entire existing information changes per a scroll. However, if he/she scrolls down on a 9-line screen (with six lines of contents), only 1/6 of existing information changes per a scroll. The smaller the screen, the more radical information changes user experience, and consequently the users experience more cognitive load to relocate their current states.

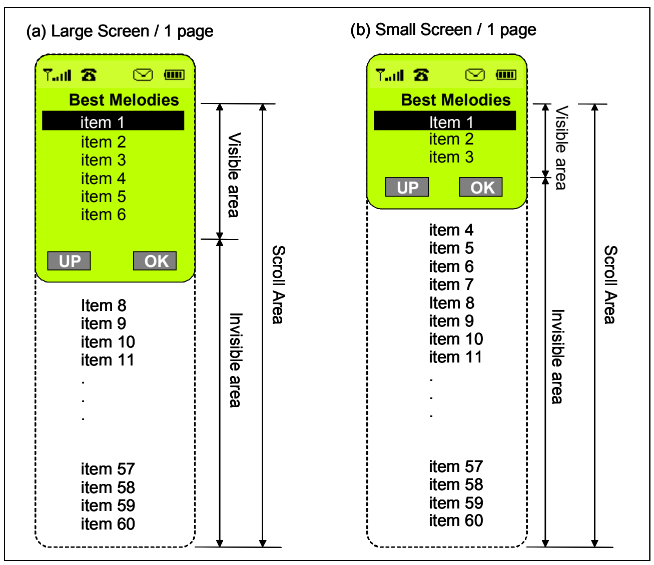


Figure 2. Two Screen Sizes Used in the Experiment

Research Model and Hypothesis

Research model consists of two independent variables and two groups of dependent variables. The two independent variables are horizontal depth and screen size. The two groups of dependent variables are objective performance and subjective perception. Dependent variables for *objective performance* were measured in terms of *Between-Page Navigation* (BPN) and *Within-Page Navigation* (WPN). First, BPN represents the number of 'paging backwards and forwards'. It is known that users may have done BPN in an attempt to originate themselves or to provide context as they progress through the text [6]. BPN is supposed to be closely related to the screen size and horizontal depth, because deeper horizontal depth and smaller screen size are expected to create more BPN. Second, WPN refers to as scrolling activities within a single page. According to the study of Jones, et al. [12], additional scrolling compromised the user's ability to accomplish the task. Therefore, the amount of scrolling reflects cognitive loads users get, and therefore, WPN is also supposed to be closely related to screen size and horizontal depth. Since there is not enough space to provide contextual cues or navigational aids, users will continue to scroll much more to make sense of the pages for smaller screen [6]. On the other hand, deeper horizontal depth will decrease WPN because relatively few items will be presented in a single page with deeper horizontal depths.

Dependent variables for *subjective perception* consist of perceived depth and user satisfaction. First, *Perceived depth* was introduced to measure the user's perception of the depth of specific information in an information structure [11]. The horizontal depth existing between many divided pages may increase 'perceived depth'. Therefore, we were interested in identifying whether 'horizontal depth' is perceived as a real 'depth', increasing the level of perceived depth. Second, *User satisfaction* measures how users are satisfied with the given Internet systems in terms of navigation and structure [5]. We are interested in investigating whether subjective satisfaction of users corresponds with perceived depth.

Based on the research model, research hypotheses are presented below:

> H_1: *Horizontal depth is a significant factor influencing objective performance and subjective perception.*
> H_{1a}: *Deeper horizontal depth will increase BPN.*
> H_{1b}: *Deeper horizontal depth will decrease WPN.*
> H_{1c}: *Deeper horizontal depth will increase perceived depth.*
> H_{1d}: *Deeper horizontal depth will decrease user satisfaction.*
> H_2: *Screen size is a significant factor influencing objective performance and subjective perception.*
> H_{2a}: *Smaller screen will increase BPN.*
> H_{2b}: *Smaller screen will increase WPN.*
> H_{2c}: *Smaller screen will increase perceived depth.*
> H_{2d}: *Smaller screen will decrease user satisfaction.*

Experiment

The experiment was conducted in Korea with Korean mobile Internet users.

Experimental Mobile Internet Site

We designed experimental sites as 3 x 3 x 3 x 3 (four vertical depths and three breadths). Each of 81 menu items at the bottom level was linked with 60 selective items. For example, if a subject is given a task to find information of when a fan club meeting of Britney Spears will be held, he/she will navigate along with the path (1st level: For Fun > 2nd level: Communities > 3rd level: Fan Clubs > 4th level: Movie Stars), and then he/she will encounter a list of sixty movie stars, each of which contains specific information. Then we developed a standard navigation system for the experimental site based on industry guidelines for mobile Internet phone [20]. Experimental sites were built on a Game Virtual Machine (GVM) programmed in Mobile C, a language optimized in Mobile environment using the base of ANSI C. Then, we executed the experimental sites on GVM installed mobile Internet phone, which is featured with WAP protocol and 256-color LCD.

Participants

Ninety participants in total were selected based on their demographics, average amount of usage, and familiarity with mobile Internet: 45 males and 45 females. Their ages represented the range from teenager to thirties, which are main customer groups for mobile Internet phones. They were recruited by advertisement at web sites related to mobile Internet with monetary compensation.

Experimental Design

We selected a 2 x 3 factorial design with two between-subject independent variables: screen size and horizontal depth. Screen size has two levels: small (6 lines) and large screen (9 lines). Horizontal depth has three levels: deep (6 levels), medium (4 levels), and shallow (1 level).

First, we operationalized the horizontal depth by dividing a content list with sixty items into one, four or six pages, respectively. If 60 items on a list (e.g. 60 movie starts or 60 titles of incoming emails) are divided into four pages, 15 items (lines of contents) are presented per page at a time. In this case, the horizontal depth (HD) is 4 depth and the breadth (B) per display is 15

(4HD/15B). Likewise, if we divide 60 options into 6 pages, each page would have 10 items (6HD/10B). This study fixed the vertical depth (4 depths) and total number of items (60) across all treatments.

Second, we selected two sizes of screen with 6 lines and 9 lines. As we have already seen in Figure 2, each screen includes 2 lines of icons and 1 line of heading. Therefore, the large screen has six content lines out of nine total lines, whereas the small screen has three content lines. Each line can display at most 8 Korean characters. We selected these two sizes of screens because the 6 line screen is the most typical size of mobile Internet phones, and the 12 line screen is the largest display available at the time of research.

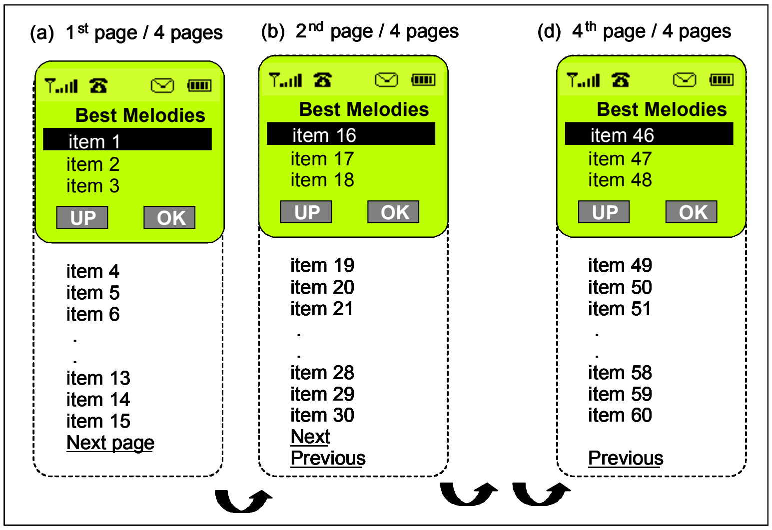


Figure 3. Sample Screen Used in this Experiment

Experimental Procedure

Each participant was assigned four different tasks in a random order. Participants were asked to perform the given tasks one by one in 10 minutes per task based on the results from the pilot test. Navigation behaviors of each participant were recorded in system log files, which were transferred from mobile Internet phone to desktop PC through serial cable real-time as shown in Figure 4. BPN and WPN were measured using the data from system log file and video data captured by a small camera mounted on the mobile Internet phone as shown in Figure 4.

After completing each task, subjects were asked to answer to the 'perceived depth' question, asking "Please check V where you think the information you have just found is located in depth?" Following this question, subjects were given a vertical line, which is divided into equal pieces. The topmost node represents 'Home' – starting point. Subjects have to indicate one node where information is relatively located from the 'Home'. A set of post-task questionnaire consisting of 7 items was administered to assess subjects' subjective satisfaction in terms of usability.

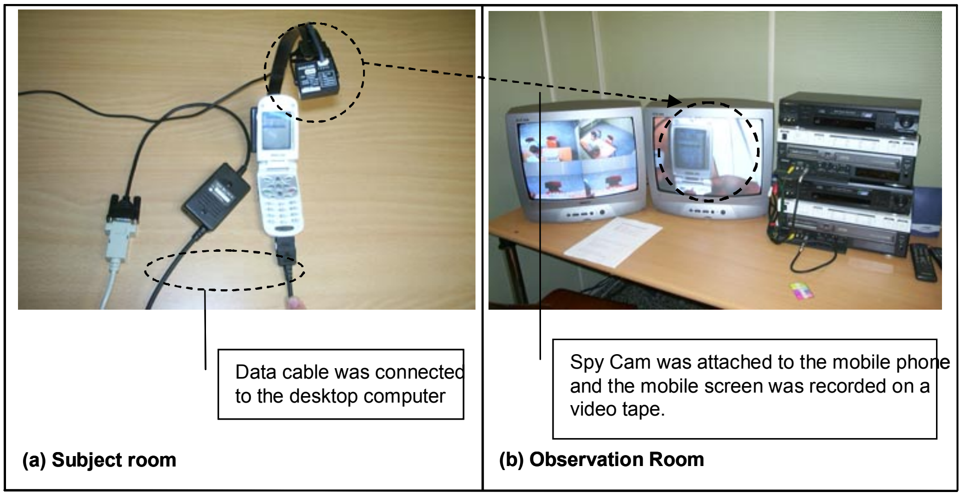


Figure 4. Experimental System

Results

Objective Performance Results of Site Navigation

Between Page Navigation (BPN)

Two-way ANOVA result revealed that there are statistically significant interaction effect between screen size and horizontal depth ($F(2, 83)=3.96$, $p< .05$) as shown in Figure 5. The BPN increased faster in the small screen than in the large screen as horizontal depth increased from one to six. There were also main effects of screen size ($F(1, 83) = 15.85$, $p< .01$) and horizontal depth ($F(2, 83) = 11.60$, $p<.01$).

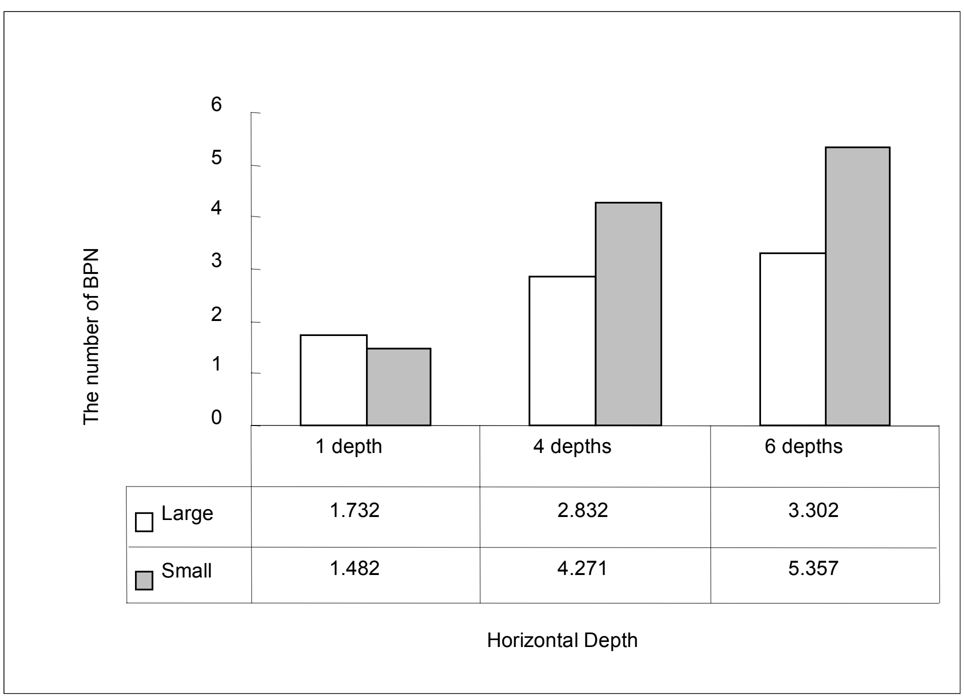
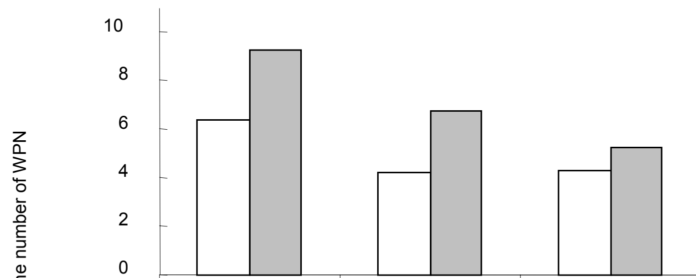


Figure 5. Between-Page Navigation Activities

Within-Page Navigation (WPN)

The result, as shown in figure 6, indicated significant main effects both of the horizontal depth ($F(2, 82) = 13.21$, $p<.01$) and screen size ($F(1, 82) = 45.28$, $p<.01$). Subjects with small screen carried out more WPN actions than their large screen counterparts.



	1 depth	4 depths	6 depths
Large	6.372	4.253	4.303
Small	9.285	6.839	5.293

Horizontal Depth

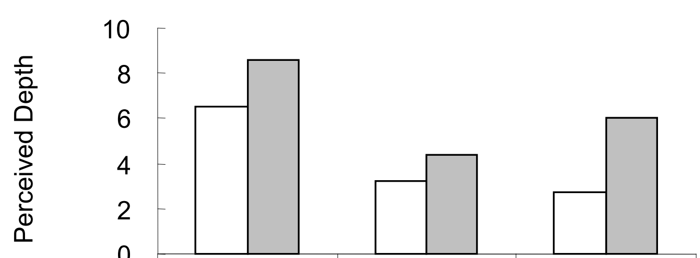
Figure 6. Within-Page Navigation Activities

For horizontal depth, subjects made more WPN as the horizontal depth gets shallower. No significant interaction effect of the two independent variables was found ($F(2, 82) = .86$, ns).

Subject Perception of Depth and Satisfaction

Perceived Depth

Results showed that there was a significant interaction effect of screen size and horizontal depth on the perceived depth ($F(2, 84) = 7.61$, $p<.01$) as shown in Figure 7.



	1 depth	4 depths	6 depths
Large	6.523	3.210	2.734
Small	8.636	4.394	6.032

Horizontal Depth

Figure 7. Perceived Depth

On a large screen, the perceived depth decreased as the level of horizontal depth decreased. On a small screen, however, the perceived depth was the highest at the 1 horizontal depth, the lowest at the 4 depths and in the middle at the 6 depths. It suggests that there exists a trade-off between horizontal depth and breadth for the small screen. Presenting information in greater horizontal depths may reduce the complexity users to a certain degree, by decreasing both the amount of scrolling per page and the number of alternative options for decision making. However, greater horizontal depth also increases the number of pages that have to be traversed. Therefore, the two conflicting effects of increased horizontal depth might lead to the 4 horizontal depths as the optimal. In addition, there are significant main effects of both screen size ($F(1, 84) = 11.44$, $p<.01$) and horizontal depth ($F(2, 84) = 7.39$, $p<.01$). As a display got smaller, participants perceived that target information was located in deeper depth, indicating that small screen size had a significant effect on the degree of perceived depth.

User Satisfaction

To measure user satisfaction, 'Perceived Usefulness and Ease of Use' (PUEU), and 'Questionnaire for User Interface Satisfaction' (QUIS) measures was adopted in this study. We averaged the seven questions of user satisfaction borrowed from prior research and then conducted two-way ANOVA with the average. The results indicated a significant interaction effect between screen size and horizontal depth ($F(2, 84) = 4.22$, $p<.05$) as shown in Figure 8. The level of satisfaction was highest at the 4 horizontal depths on the small screen, while the level of satisfaction increased as the horizontal depth increased on the large screen. This result indicates that participants in small screen groups perceived the mobile Internet system with 4 horizontal depths as more convenient for navigation than that with 1 or 6 horizontal depths. This result is in a line with that of perceived depth that participants perceived given mobile menu system shallowest when information was divided in 4 horizontal depths. The main effect of screen size was not statistically significant ($F(1, 84) = 1.49$, *ns*), while there was the main effect of the horizontal depth ($F(2, 84) = 4.10$, $p<.05$).

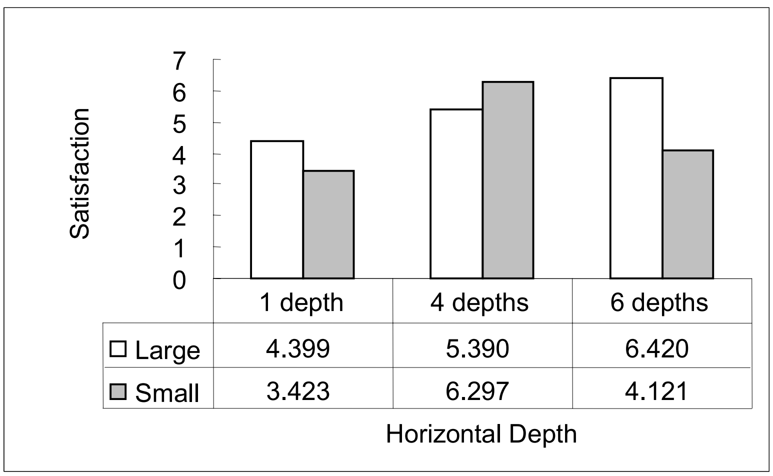


Figure 8. Overall Satisfaction

Conclusion and Discussion

One of the most consistent results across different dependent variables is the effect of screen size. The small screen was found to increase BPN, WPN, and perceived depth. This may be the reason for the inconsistency of prior research in the effect of small screen size. The research that did not observe the effect of small screen might use relatively big screens to observe the differences between its screen and computer screen [9]. The result from this study clearly indicates that there is a big difference between the size of three-line and six-line screens.

Another interesting result is the impact of horizontal depth. Our results clearly indicate the trade-offs of horizontal depth on BPN and WPN. On the one hand, the number of BPN increased as the horizontal depth was greater. This may be because the number of page transaction increased requiring more execution time between transactions as horizontal depth increased [17]. On the contrary, the amount of scrolling (WPN) decreased as the horizontal depth increased. The results may be because the number of options that had to be considered on a single page at once decreased. Consequently, these two conflicting effects were optimized at the level of the 4 horizontal depths as shown in the results of perceived depth and satisfaction. A user not only perceived a given mobile Internet site least complex but also was satisfied most with the site at the 4 horizontal depths. It is also worth noting the interaction effects between screen size and horizontal depth. The impact of horizontal depth on the navigation performance becomes more significant as screen size gets smaller. Moreover, the trade-off impacts of horizontal depth on the perceived depth and satisfaction became more explicit in a small screen rather than in a large screen.

This study has both theoretical and practical implications. From the theoretical perspective, we extended existing studies on trade-offs between depth and breadth and reinterpreted them in a new context of the mobile Internet systems. Moreover, the new concept of distinguishing the horizontal depth from the vertical depth is substantial in enhancing navigation patterns and decreasing the problems of cognitive overload, because it brings design issues regarding scrolling and paging in the context of designing the entire structure of mobile Internet systems.

From a practical perspective, by identifying the relationships among horizontal depth and screen size together, this study provides practical design guidelines for mobile services providers. Screen size turned out to affect users' behavior and perception significantly. More meaningful finding is that screen size has significant interaction effects with horizontal depth on users' perception. For example, users had the highest level of satisfaction at the four horizontal depths level when they were using the small screen, whereas their satisfaction was highest at the six depths with the large screen. Current network protocols can provide accurate information about the type and model number of mobile phones through which users are accessing mobile Internet. Therefore, we can provide different information structure according to the size of screen for the specific model of mobile phones shown in the protocol data. Adjusting horizontal depth according to the screen size will lead to the optimal information structure for mobile Internet systems.

Acknowledgements

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References

1. M. J. Albers, and L. Kim, User Web browsing characteristics using palm handheld for Information Retrieval, Technology & Teamwork, IEEE (2000) 125-135.
2. G..Buchanan, S. Farrant, M. Jones, Thimbleby, H., Marsden, G., and Pazzani, M. Improving Mobile Internet Usability, in: Proc. The 10th International WWW Conference (WWW10), May 1-5, Hong Kong, 2001.
3. O. Buyukkoken, H. Garcia-Molina, A. Paepcke, Focused Web searching with PDAs, Computer Networks 22 (2000) 213-230.
4. M. Chae and J. Kim, What's so different of the Mobile Internet? An Explorative Study on the Business Implications of the Mobile Internet, Forthcoming in Communications on ACM, 2002.
5. J. P. Chin, V. A. Diehl, and K. Norman, Development of an Instrument Measuring User Satisfaction of the Human Computer Interface, in: Proc. the 1998 ACM Conference on Human Factors and Computing Systems (CHI '88), Washington DC, U.S.A, May 15-19, 1988 pp. 213-218.
6. A. Dillon, J. Richardson, and C. McKnight, The effect of display size and text splitting on reading lengthy text from the screen, Behavior and Information Technology 9: 3 (1990) 215-227.
7. L. Francis, Mobile Computing, in: Proc. the 15th Annual International Conference on Computer Documentation (SIGDOC'97), Snowbird, UT, October 19-22, 1997 pp. 63-37.
8. G. Geiser, and W. Schumacher, Parallel versus serial instrumentation for multi-variable manual control in control rooms, in Monitoring behavior and supervisory control, in: T. B. Sheridan and G. Johannsen, (Ed.), Plenum, New York, 1976, pp. 405-415.
9. S. Han, and J. Kwahk, Design of a menu for small displays presenting a single item at a time, in: Proc. Human Factors and Ergonomics Society 38th Annual Meeting, vol. 1, 1994 pp. 360-364.
10. R. L. Henneman, and W. B. Rouse, Human Performance in monitoring and controlling hierarchical large-scale systems, IEEE Transactions on System, Man and Cybernetics (SMC) 14 (1984) 184-191.
11. J. Jacko and G. Salvendy, Hierarchical Menu Design: Breadth, Depth and Task Complexity. Perceptual and Motor Skill 82 (1996), pp. 1187-1201.
12. M. Jones, G. Marsden, N. Mohd-Nasir, K. Boone, and G. Buchanan, Improving Web Interaction on Small Displays, Computer Networks 31 (1999) 1129-1137.

13. H. Kim, J. Kim, Y. Lee, M. Chae, and Y. Choi, An Empirical Study of the Use Contexts and Usability Problems in Mobile Internet, in: Proc. the 35th Hawaii International Conference on Systems Sciences (HICSS'02), Hawaii, January, 2002.
14. M. Melchior, Perceptually guided scrolling for reading continuous text on small screen devices, in: Proc. HCI 2001, Lille, France, September 10-14, 2001.
15. D. P. Miller, The Depth/Breadth tradeoff in hierarchical computer menus, in: Proc. the Human Factors Society 25th Annual Meeting, Miller, GA, 1981 pp.296-300.
16. J. Nielson, WAP Usability Report, 2000.
17. K. Paap and N. Cooke, Design of Menus, Handbook of Human-Computer Interaction, in: M. Helander, T. K. Landauer, (2nd Ed.), Elsevier Science B. V., Amsterdam, Netherlands, 1997.
18. E. Schwarz, I. Beldie, and S. Pastoor, A Comparison of paging and scrolling for changing screen contents by inexperienced user, Human Factors 25 (1983) 279-282.
19. S. Swierenga, Menuing and Scrolling as alternative information access techniques for computer systems: Interfacing with the user, in: Proc. The Human Factors Society the 34th Annual Meeting, vol. 1 ,1990 pp. 356-359.
20. Telstra, Telstra WAP Design Guideline for developers of WML Application, 2001, **http://www.telstra.com**.