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RESEARCH ARTICLE

Responsive List Width for Portable Devices With Different Widths of Screen

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ABSTRACT With the increasing use of large-screen portable devices and the prevalence of list-based user interfaces, it has become critically important to design list interfaces that are visually appealing and user-friendly across various devices and screen sizes. The rules for adapting list-based user interfaces on large screens warrant investigation. Thus, the present study aimed to determine the responsive list width that can enhance visual search efficiency and improve user experience on portable devices with different widths of screen. Two experiments were conducted, in which we manipulated the width of single-column and parent-child lists on portable devices with medium- (Experiment 1; N = 80) and large-width screens (Experiment 2; N = 41), varying the range of list width from very narrow to very wide. Results show that for the single-column lists on a medium-width screen, users demonstrated the highest level of preference and gave the highest ratings for satisfaction and visual aesthetics when the lists were moderately wide. For the single-column lists on a large-width screen, users preferred both the moderately-narrow and moderately-wide lists. However, for parent-child lists, the results show that both the moderately-wide and very-wide lists were favored on both the medium-width and large-width screens. These findings may be attributed to users' preference for the appropriate white space on different screens, thereby providing useful guidelines for the responsive design of lists on portable devices.

INDEX TERMS Foldable mobile phone, list width, responsive UI design, tablet, user experience.

I. INTRODUCTION

Portable devices have become an essential part of our daily lives, providing a range of functions beyond just communication, such as email, photography, shopping, gaming, and entertainment [1]. Users tend to prefer larger screens on portable devices as they enhance the emotional experience [2]. However, displaying a large amount of information on a limited screen can be a challenge, leading to reduced interaction efficiency [3]. Foldable or expandable phones, which were first introduced by Polymer Vision in 2006, are one of the latest trends. Foldable phones use flexible display technology to switch between regular-sized and jumbo-sized screens up to 8 inches [4]. In addition, touchscreen tablets with 10-inch screens are also popular, providing an immersive and entertaining interactive experience. Nevertheless, many applications and interfaces optimized for regular mobile phones struggle to adapt to larger screens, resulting in disproportionate scaling of UI elements [5]. A study has showed that using two different web map layouts on a smartphone and a large display led to longer search times for a button and reduced map effectiveness compared to using a well-adapted

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layout for both screens [6]. Hence, it is worth exploring rules for adapting user interfaces from typical phones to different large-screen devices.

Cross-device interface design should be consistent and adaptive, meaning that UI across devices should provide users with a consistent experience regarding core features across the ecosystem [7], while UI elements should also be adaptive to different devices [8]. On a regular mobile phone with a limited screen, information such as texts, labels, and controls are usually laid out to their maximum, leaving a small margin on both sides of the screen. However, it is unclear whether this type of presentation can be directly applied to portable devices with medium- and large-width screens.

Several empirical studies have been conducted on how to display information effectively on large-screen devices. The presentation style of information is critical to users' interactive experience on large-screen devices due to the significant amount of information displayed. For instance, Johnson [9] compared two different music software products' dialog boxes, one with a hierarchical design featuring well-organized function labels and control buttons, while the other lacked proper hierarchy. The results indicated that the hierarchical dialog boxes, with features like function grouping and organized texts and controls, could be scanned more efficiently than the dialog boxes with poor hierarchy.

Additionally, Rello et al. [10] explored how line spacing impacts website readability and comprehension on large displays. Their findings revealed that comprehension of text was impaired when line spacing was either too small or too large, while readability was not affected by line spacing. Moreover, the number of lists presented also affects users' performance on large screens. For example, in an item search task where users were asked to identify a movie similar to one they had recently watched from a movie-recommendation list, multi-list interfaces were found to result in slower decision-making times compared to single-list interfaces. [11].

Indeed, lists (e.g., contact books, settings) are frequently used on portable devices. However, few studies have examined how the width of lists should be displayed on large screens. Since lists are typically one or more columns comprised mostly of text and buttons, the following review focuses on studies that investigate the line length or width of textual information.

II. RELATED WORK

Previous studies have explored the influence of line length/width on task performance and user experience by manipulating the number of characters per line (CPL) displayed on PC monitors [12], [13], [14], [15], [16], or on paper [17]. However, these studies have not consistently concluded the impact of line length. Some research suggested that longer line length led to worse visual search performance, impaired comprehension, and poorer subjective experience, compared to a shorter line length [13], [15]. For example, Dyson and Haselgrove [13] reported that users had a worse comprehension of documents with a line length of 100 CPL than 55 CPL. Researchers proposed that longer lines of text might interrupt the reading, leading to difficulties in saccadic eye movements during reading and impairing text comprehension. Conversely, other studies showed that longer lines of text were associated with better comprehension [17], increased typo detection rate, and less scrolling compared to shorter lines [12]. It has been reported that less frequent scrolling resulted in lower levels of fatigue and a better emotional experience, further improving perceived usability [18]. Moreover, Zhang et al. [19] conducted an eye-tracking study to examine the effect of list formats on search performance and subjective satisfaction in e-commerce listing pages. The results showed that list formats with longer length and greater compactness received less search time, fewer fixation counts, and were more preferred than block list formats with shorter line length. Besides the above findings, there were also studies reporting no effect of line length on overall text comprehension [14], [16].

Previous research has yielded inconsistent findings regarding the impact of line length on PC screens, and few studies have examined the effect of line length on portable devices. One such study focused on the effect of the length of menu text on search performance using portable devices [20]. In this study, participants were required to search for a target sentence from a drop-down menu on a 9.7-inch tablet, while the line length of the menus was manipulated varying between 2 and 18 CPL. Hsiao and colleagues [20] found that both long lines (more than 14 CPL) and short lines (less than 6 CPL) resulted in longer search time and higher error rates. Thus, they recommended a medium line length of 9-14 CPL for different age groups. However, the width of other UI elements in lists on portable devices and the width of portable devices themselves have not been explored, thus limiting guidance on how to adjust the width of the list across different screen sizes.

The UI design guidelines of prominent portable device manufacturers such as Apple, Huawei, and Google utilize "grid systems" that divide a page into columns or modules [21], [22], [23]. This approach aims to help UI designers create a responsive and adaptive layout based on the size of the screen. For example, the Huawei HarmonyOS system suggests 8 evenly distributed grids for the regular phones and tablets in portrait, with lists occupying 4-6 grids. Moreover, the system suggests using 12 grids for tablets in landscape, but it does not specify the number of grids that should be applied to a list [22]. The iOS mobile operating system recommends restricting the width of list content for optimal readability and ensuring an adaptable interface on various devices [21]. However, it does not explicitly advise the number of grids that different types of list interfaces should occupy.

Given few evidence and guidelines on designing list width for portable devices, the present study aimed to identify the responsive list width that can improve visual search efficiency and enhance user experience. Specifically, two experiments were conducted to manipulate list width (from very narrow to very wide) for portable devices with medium- (Experiment 1) and large-width screens (Experiment 2).

III. EXPERIMENT 1 METHODS

A. USERS

A total of 80 users were recruited for Experiment 1. They were selected at random from the general population aged between 18 and 45 years old, through both online and verbal communication. Of the users, 40 (16 males, 18-44 years old) were randomly assigned to complete the test with foldable mobile phones, while the other 40 (14 males, 18-39 years old) completed the test with tablets in portrait orientation. All users reported having normal or corrected-to-normal vision and using portable devices, such as mobile phones and tablets), for at least one hour daily (Appendix A). The study was approved by the Ethics Committee of Human Experimentation at the Institute of Psychology, Chinese Academy of Sciences. All users provided written informed consent prior to the study and received a cash reward of ¥70 (approximately $10) upon completion of the study.

B. APPARATUS AND MATERIALS

Experiment 1 had a target search task alongside subjective evaluations, paired comparison task, and list preference task, aiming to evaluate the user experience of different list widths. Users were instructed to perform the target search task and rate their subjective experience (e.g., perceived emotion, levels of fatigue, and satisfaction) on one of the two portable devices: an OPPO Find N foldable mobile phone with a 7.1-inch screen while unfolded (1920 × 1792 pixels), or an OPPO Pad tablet with an 11-inch screen (2560 × 1600 pixels), both running ColorOS 12.0 based on Android 11. The foldable mobile phone (unfolded; screen width of 698 dp) and tablet in portrait mode (screen width of 711 dp) were both categorized as medium-width screens [24].

To perform the target search task, we developed a Chinese language application that simulates the actual interaction with the UI interface of lists, enabling users to scroll through two types of lists: single-column lists and parent-child lists. These lists are commonly used in real-world interactions. The single-column lists displayed information in a single column, centered on the screen. The parent-child lists, on the other hand, presented information in two columns, left to right, representing the parent and child dimensions, respectively (Figure 1A). For the parent-child lists, this study specifically focused on varying and evaluating the list width of the child dimension, while keeping the parent dimension's width fixed. We manipulated the list width of both types of lists into four levels, ranging from very narrow to very wide. In the case of single-column lists, a "very narrow" list occupied approximately half of the screen width, while a "very wide" list spanned the entire screen width with small margins on both sides. As for parent-child lists, a "very wide" list occupied the entire display area of the child dimension, while maintaining a small margin on both sides same as the parent dimension.

The paired comparison task was programmed using Psychtoolbox 3 in MATLAB 2021b [25]. The stimuli for this task consisted of screenshots of the list interface developed in the target search task. These screenshots were presented on a 21-inch computer monitor with a resolution of 1920 × 1080 pixels. For the list preference task, screenshots of the list interface were printed on A4 papers. The size of the screenshots presented on the computer monitor and those printed on paper were both identical to the physical screen size of the two portable devices, ensuring the reliability of the results.

C. TASKS AND PROCEDURES

1) PAIRED COMPARISON TASK

Users completed the paired comparison task while sitting in front of the computer screen with a viewing distance of approximately 50 cm. The task involved two types of lists (single-column, parent-child), each with four levels of list widths (very narrow, moderately narrow, moderately wide, and very wide). Each trial began with a '+' fixation presented at the center of the screen for 1-2s and before disappearing, after which users were asked to indicate their relative preference between a pair of screenshots differing only in the list width, presented side-by-side. Users had to press the "F" key if they preferred the left screenshot or the "J" key if they preferred the right one without time constraints. After making their preference selection, a blank screen was presented for 500 ms before the next trial, which displayed a different pair of screenshots.

2) TARGET SEARCH TASK AND SUBJECTIVE EVALUATIONS

Users were instructed to hold the device with their left hand while using their right thumb (for the foldable mobile phone) or right index finger (for the tablet in portrait) to locate target words. The task began with several practice trials where the two list types and four width levels were randomly intermixed. The practice session was repeated until users fully understood the task instructions. Following the practice, users were asked to report their perceived level of fatigue and emotions at present, which served as the baseline (see Appendix B).

There were eight experimental blocks, each consisting of 288 trials. In each block, a specific type of list and level of list width were tested in 36 trials. As illustrated in Figure 1B, each trial started with an instruction indicating the required target words. Once the user pressed the 'Ready' button, a list interface immediately appeared with the target name (highlighted in red) remaining present at the top edge of the interface as a reminder. Target words consisted of 2-6 Chinese characters, and users were required to search for the target word by scrolling through the list and clicking on the corresponding line. The users were only able to scroll and click on the list area while the margins surrounding the list were

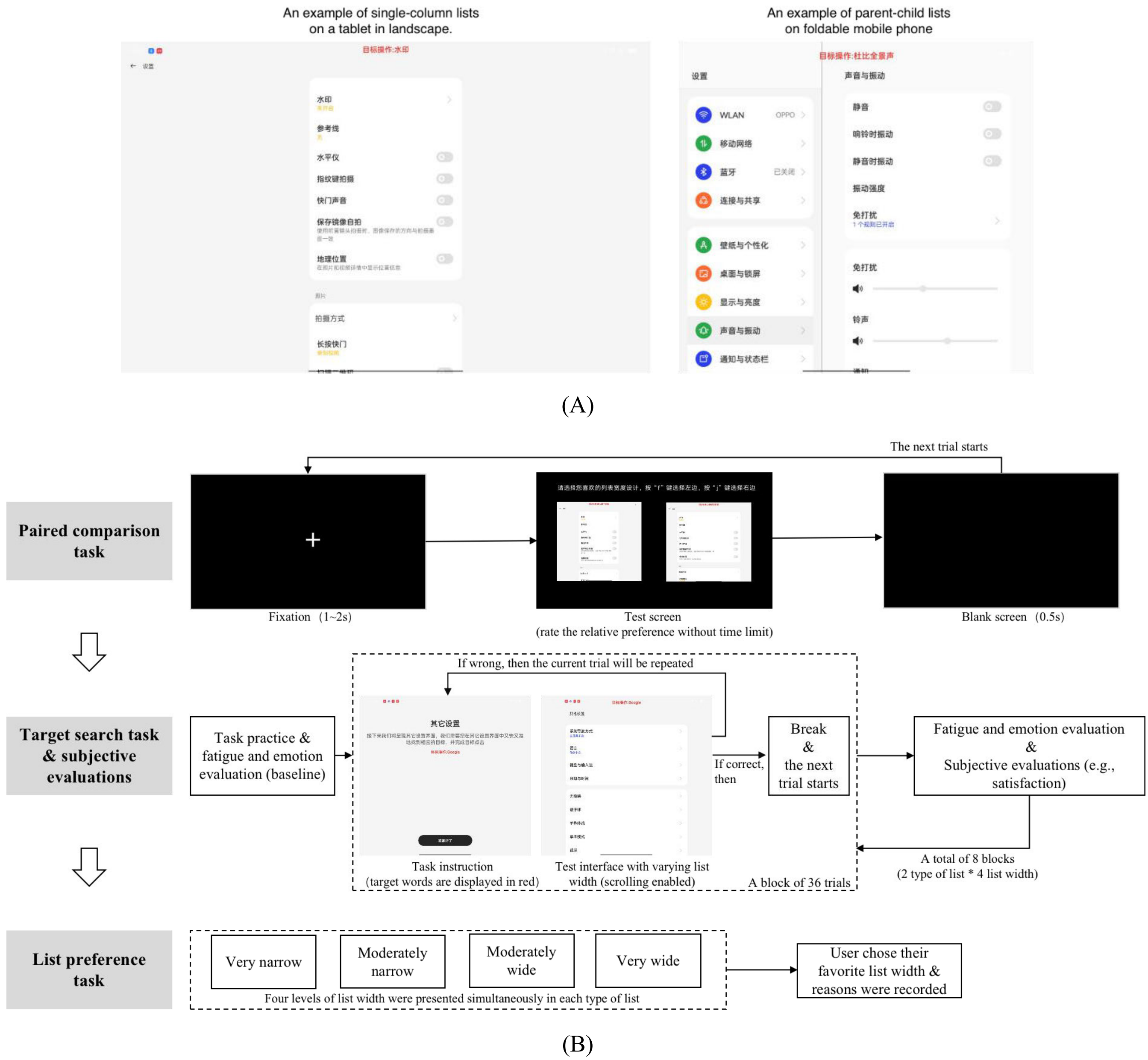

FIGURE 1. Examples of single-column lists (A-left, take a very-narrow list interface of the tablet in landscape orientation as an example) and parent-child lists (A-right, take a very-narrow list interface of the foldable phone as an example), and diagram of study procedures for both experiments (B).

not operable during the task. If an error was made, a "×" feedback appeared for 500 ms, and the trial was repeated until the target word was successfully located. The next trial began following a break of 3s. It is important to note that the aim of this experiment was to vary the width of the entire list, and the text length and spacing within each line were adjusted to fit the available list width. Moreover, the target words can appear at varying locations within the list, including both near- and far-reaching spaces, in order to simulate real-world information search processes. After each block, users reported their current emotional experience and level of fatigue, as well as subjective evaluations of the search process (i.e., perceived efficiency, comfort, satisfaction, and visual aesthetics; see Appendix C). The next block began following a break of 10s. The order of the experimental blocks was randomized across individuals.

3) LIST PREFERENCE TASK

Users were required to choose their favorite interface/list width from the screenshots printed on A4 papers and provide a brief explanation of their choice.

Users completed the tasks in the laboratory in the following order: paired comparison task, target search task with subjective evaluations alongside, and finally the list preference task (Figure 1B and Appendix D). The entire experiment session lasted approximately 70 minutes.

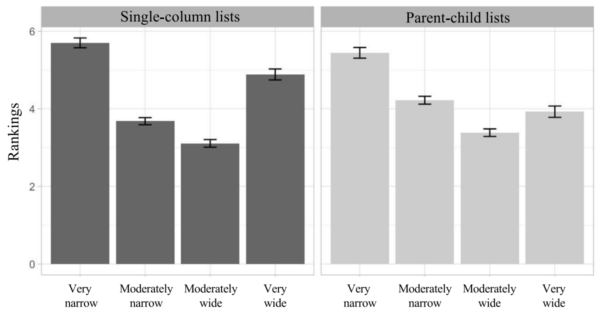

FIGURE 2. **Rankings of different list widths for the single-column (left) and parent-child lists (right) on the medium-width screen. Error bars indicate ± 1 SEM. Note. The lower the ranking value, the more times the users chose that list width in the paired comparison task.**

D. DESIGN

Experiment 1 employed a mixed design, with list width (very narrow, moderately narrow, moderately wide, very wide), type of list (single-column, parent-child), and target position (near, far) as the within-subject variables, and type of device (foldable mobile phone, tablet in portrait) as the between-subject variable. The primary dependent variables were the rankings of list widths in the paired comparison task, task completion time and response accuracy in the target search task, and subjective rating scores on perceived emotion and fatigue, perceived efficiency, perceived comfort, satisfaction, and visual aesthetics. In addition, the selection proportion of every list width was computed in the list preference task. Note that the effect of target position was only manipulated and studied in the target search task.

IV. EXPERIMENT 1 RESULTS

Data were analyzed using R version 3.6.2 [26].

A. PAIRED COMPARISON RANKING

Since there were large differences in the characteristics of the single-column lists and parent-child lists, two separate 4 (list width) × 2 (type of device) mixed-model ANOVAs were conducted to analyze the rankings of the different list widths. For the single-column lists, the main effect of list width was significant ($F(3, 234) = 3.13$, $p < .001$, $\eta_p^2 = 0.29$). Post-hoc analysis (Holm correction) showed that the moderately-wide list received the highest ranking (all $p < .01$), followed by the moderately-narrow and very-wide lists. The very-narrow list was ranked last (all $p < .001$; Figure 2 left). The main effect of type of device did not reach the significance level ($F < 1$), nor did the interaction between list width and type of device ($F < 1$).

For the parent-child lists, the main effect of list width was significant ($F(3, 234) = 1.70$, $p < .001$, $\eta_p^2 = 0.18$). Post-hoc analysis showed that the moderately-wide list was ranked the highest (all $p < .05$), followed by the very-wide and moderately-narrow lists. The very-narrow list was in the last place (all $p < .001$; Figure 2 right). The main effect of the type of device ($F < 1$) and the interaction between list width and type of device ($F < 1$) were not significant.

B. TARGET SEARCH PERFORMACE

1) TASK COMPLETION TIME

Trials in which users made an error were excluded. Then, task completion times beyond 3 standard deviations of the mean in each condition were also removed from the analysis. Two separate 4 (list width) × 2 (target position) × 2 (type of device) mixed-model ANOVAs were conducted to analyze the task completion time in the single-column lists and parent-child lists. The mean and standard error of the task completion time under different conditions are shown in Appendix E.

For the single-column lists, the main effect of target position was significant ($F(1, 78) = 186.91$, $p < .001$, $\eta_p^2 = 0.13$). Users completed the task faster for near-reaching targets (1.862s) compared to far-reaching targets (2.371s). The main effect of type of device was significant ($F(1, 78) = 22.85$, $p < .001$, $\eta_p^2 = 0.13$), with task completion time being shorter with the tablet in portrait (1.862s) compared to the foldable mobile phone (2.371s). However, the main effect of list width was not statistically significant ($F < 1$). As the primary aim of the present study was to determine the responsive list width on portable devices, a planned post-hoc test was performed to examine potential differences across list widths. However, the pairwise contrasts revealed no significant differences across list widths (all $p > .100$). Additionally, there was a significant interaction between target position and type of device ($F(1, 78) = 79.55$, $p < .001$, $\eta_p^2 = 0.06$), which was beyond the interest of the present study. Interactions involving list width were not significant.

For the parent-child lists, the main effect of the target position was significant ($F(1, 78) = 15.31$, $p < .001$, $\eta_p^2 = 0.09$), with task completion time being shorter for near-reaching targets (2.335s) compared to the far-reaching targets (2.499s). The main effect of the type of device was also significant ($F(1, 78) = 6.62$, $p = .012$, $\eta_p^2 = 0.01$), with task completion time being shorter with the tablet in portrait (2.136s) compared to the foldable mobile phone (2.698s). However, the main effect of the list width was not significant ($F(3,234) = 1.21$, $p = .308$, $\eta_p^2 = 0.004$). Post-hoc pairwise contrasts revealed no significant differences across list widths (all $p > .100$). None of the interactions reached the significance level.

2) ACCURACY

The accuracy analysis was based on the users' first attempt in each trial condition. The procedure for the analysis of accuracy was similar to that of task completion time. The mean and standard error of response accuracy across different conditions are shown in Appendix E. For the single-column lists, the main effect of list width was marginally significant ($F(3, 234) = 2.58$, $p = .054$, $\eta_p^2 = 0.01$). However, the post-hoc test did not reveal any statistically significant differences across list widths (all $p > 0.05$). The main effects of

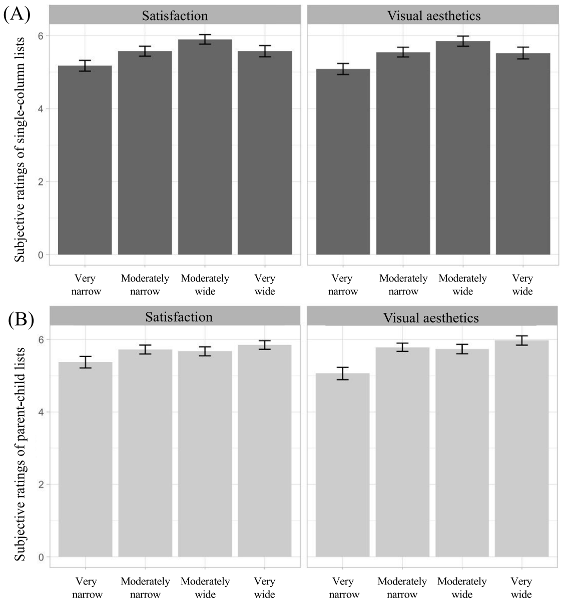

FIGURE 3. **Subjective evaluations for different list widths in the single-column (A) and parent-child lists (B) on the medium-width screen. Error bars indicate ± 1 SE.**

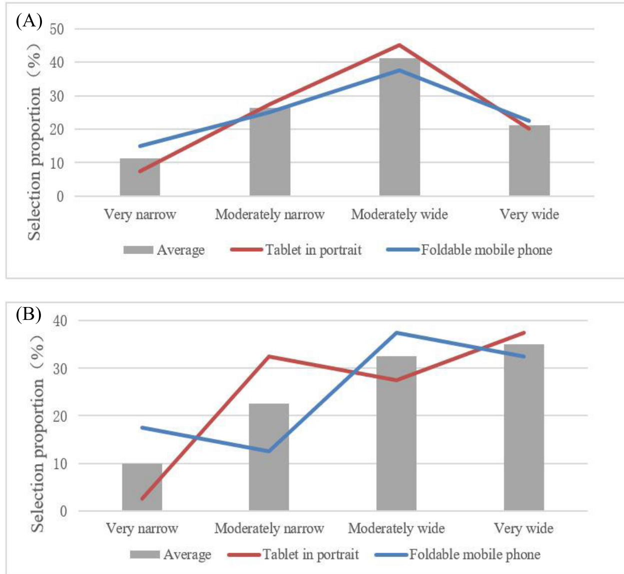

FIGURE 4. **Selection proportions of different list widths for the single-column (A) and parent-child lists (B) on medium-width screens.**

type of device ($F < 1$) and target location ($F(1, 78) = 2.72$, $p = .103$, $\eta_p^2 = 0.01$) were not statistically significant. Furthermore, none of the interactions reached the significance level.

For the parent-child lists, the main effect of target position was significant ($F(1, 78) = 8.39$, $p = .005$, $\eta_p^2 = 0.01$). The accuracy was higher for far-reaching targets (98.46%) compared to near-reaching targets (97.57%). However, the main effects of list width ($F < 1$) and type of device ($F < 1$) were not significant. Planned pairwise contrasts conducted to compare different levels of list widths revealed no significant differences (all $p > .100$). None of the interactions reached the significance level.

C. SUBJECTIVE EVALUATIONS

The scores for emotion and fatigue after each block were compared to their respective baseline scores, resulting in a difference in the score between the two time points. Then, two separate 4 (list width) × 2 (type of device) mixed-model ANOVAs were conducted for every subjective measure. For the single-column lists, the main effect of list width was significant for satisfaction ($F(3, 234) = 6.03$, $p < .001$, $\eta_p^2 = 0.04$) and visual aesthetics ($F(3, 234) = 6.08$, $p < .001$, $\eta_p^2 = 0.04$; Figure 3A). Post-hoc analyses revealed that the moderately-wide list received the highest subjective rating scores, while the very-narrow list received the lowest scores. No other effects reached significance.

For the parent-child lists, the main effects of list width on satisfaction ($F(3, 234) = 4.05$, $p = .008$, $\eta_p^2 = 0.02$) and visual aesthetics ($F(3, 234) = 14.00$, $p < .001$, $\eta_p^2 = 0.08$) were all significant. Post-hoc results showed that the very-narrow lists received the lowest scores, while no significant difference was found in other contrasts (Figure 3B). No other effects reached significance.

D. SELECTION PROPORTION

The selection proportions of different list widths for every type of list and device are shown in Figure 4. For the single-column lists, the moderately-wide list had the highest selection proportion (41.25%). Notably, this list width received the highest preference for both the tablet in portrait mode (45%) and the foldable mobile phone (37.5%).

For the parent-child lists on a medium-width screen, the selection proportion of the very-wide list was the highest (35%), closely followed by the moderately-wide list (32.5%). Specifically, a large proportion of users showed a preference for the very-wide list on the tablet in portrait (37.5%), while they preferred the moderately-wide list on foldable mobile phones (37.5%). Users noted that both the moderately-wide and very-wide lists improved the visual balance and aesthetics of the entire interface, which was consistent with their interactive experience.

V. SUMMARY OF EXPERIMENT 1

Experiment 1, which utilized portable devices with a medium-width screen, demonstrated that list width significantly impacted user preferences and subjective evaluation scores. Specifically, for single-column lists, the moderately-wide list was the most preferred, obtaining the highest ranking order and receiving the highest satisfaction and visual aesthetic scores. For parent-child lists, both the moderately-wide and very-wide lists were preferred, receiving higher rating scores and larger selection proportions than other list widths, though the moderately-wide list was ranked the highest in the paired comparison task. According to users' oral reports, usability, visual aesthetics/balance as well as the interaction experience were all considered by users when evaluating the preferred list width. However, the effect of list width on target search performance did not reach a significant level for any list type or device.

VI. EXPERIMENT 2 METHODS

A. USERS

A total of 41 users (20 males, aged 20-44) were recruited for Experiment 2. They were selected at random from the general population aged between 18 and 45 years old, through both online and verbal communication. All users reported having normal or corrected-to-normal vision and using portable devices for at least one hour daily (Appendix A). Prior to the study, all users provided written informed consent. Upon completion of the study, all users received a cash reward of ¥70 (approximately equivalent to $10).

B. TASKS, APPARATUS, MATERIALS

In Experiment 2, the tasks, apparatus, and materials for stimulus presentation and response collection were the same as those used in Experiment1, with the exception that the tablet used in Experiment 2 was in landscape mode (screen width of 1138 dp), which was classified as a large-width screen [24]. The list width was manipulated in four levels ranging from very narrow to very wide, similar to Experiment 1. However, for single-column lists, the 'very narrow' list occupied about one-third of the screen width, which was different from Experiment 1.

C. PROCEDURE

The procedure used was identical to that of Experiment 1.

D. DESIGN

In Experiment 2, a within-subject design was employed, with list width (very narrow, moderately narrow, moderately wide, very wide), type of interface (single-column lists, parent-child lists), and target position (near-reaching, far-reaching) as within-subject variables. The primary dependent variables were the rankings of list width in the paired comparison task, task completion time and response accuracy in the target search task, as well as subjective ratings on perceived emotion and fatigue, perceived efficiency, perceived comfort, perceived satisfaction, and visual aesthetics. In addition, the selection proportion of every list width was computed in the list preference task. The effect of target position was only manipulated and studied in the target search task.

VII. EXPERIMENT 2 RESULTS

A. PAIRED COMPARISON RANKINGS

The rankings of the different list widths for the two types of lists were analyzed separately using two one-way (list width) repeated measures ANOVAs. For the single-column lists, the main effect of the list width was significant ($F(3, 120) = 4.43$, $p = .005$, $\eta_p^2 = 0.10$). Post-hoc analysis showed that the moderately-narrow and moderately-wide lists were ranked the highest (all $p < .050$), while there was no significant differences between the ranking order of the moderately-wide and moderately-narrow lists ($p = .323$). The very-narrow list received the lowest ranking score (all $p < .05$; Figure 5 left).

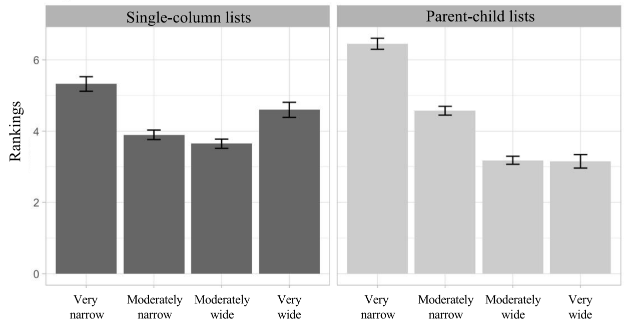

FIGURE 5. Rankings of different list widths for the single-column (left) and parent-child lists (right) on a large-width screen. Error bars indicate ± 1 SEM. Note. The lower the ranking value, the more times the users chose that list width in the paired comparison task.

For the parent-child lists, the main effect of the list width was significant ($F(3, 120) = 37.20$, $p < .001$, $\eta_p^2 = 0.48$). Post-hoc analysis showed the moderately-wide and very-wide lists were ranked highest (all $p < .001$), whereas there were no significant differences between the moderately-wide and very-wide lists ($p = .797$). The very narrow list was ranked last (all $p < .001$; Figure 5 right).

B. TARGET SEARCH PERFORMANCE

1) TASK COMPLETION TIME

As in Experiment 1, trials with errors and task completion times beyond 3 standard deviations of the mean in each condition were excluded from analysis. Two separate 4 (list width) × 2 (target position) repeated measures ANOVAs were conducted to examine task completion time for single-column lists and parent-child lists. Mean task completion time and standard error for each condition are provided in Appendix F. For the single-column lists, the main effect of target location was significant ($F(1, 40) = 178.32$, $p < .001$, $\eta_p^2 = 0.30$), with shorter task completion time for near-reaching targets (1.972s) compared to far-reaching targets (2.892s). However, neither the main effect of list width nor the interaction effect was significant (all $F < 1$). Planned pairwise comparisons indicated no significant differences in task completion time across list widths (all $p > .100$).

For the parent-child lists, the main effect of target location was significant ($F(1, 40) = 27.80$, $p < .001$, $\eta_p^2 = 0.08$), with shorter task completion time for near-reaching targets (2.481s) compared to far-reaching targets (2.959s). Additionally, we observed a marginally significant main effect of list width ($F(3, 120) = 2.52$, $p = .061$, $\eta_p^2 = 0.01$). Users completed the task faster for the moderately-wide list (2.587s) than for the very-narrow list (2.847s; $p = .004$), but no significant differences were observed for other list widths

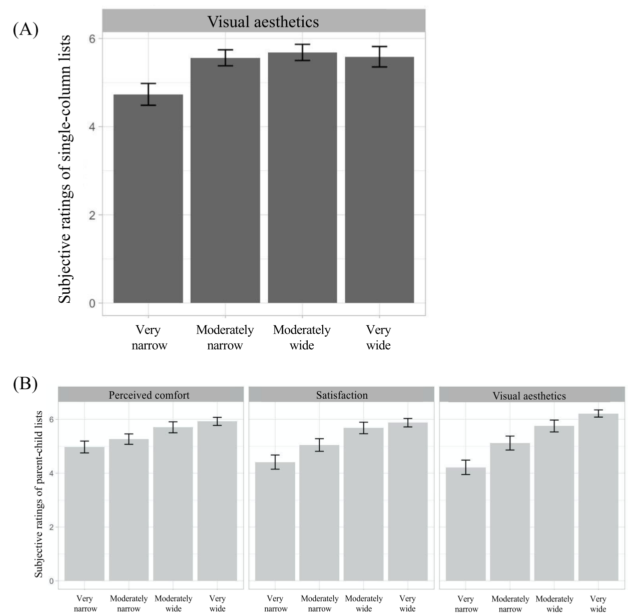

FIGURE 6. Subjective evaluations for different list widths in the single-column (A) and parent-child lists (B) on the large-width screen. Error bars indicate ± 1 SEM.

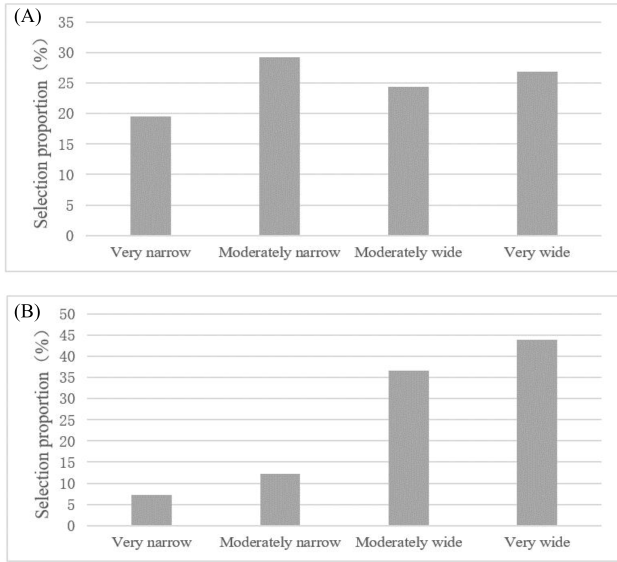

FIGURE 7. Selection proportions of different list widths for the single-column (A) and parent-child lists (B) on the large-width screen.

(all $p > .100$). The interaction between list width and target location was not significant ($F(3, 120) = 1.77$, $p = .156$, $\eta_p^2 = 0.004$).

2) ACCURACY

The accuracy analysis was conducted based on the users' first attempt in each trial condition. The procedure for the analysis of accuracy was similar to that of task completion time. The mean and standard error of response accuracy under different conditions are shown in Appendix F. For the single-column lists, the main effect of the target position was significant ($F(1, 40) = 5.40$, $p = .025$, $\eta_p^2 = 0.02$). Accuracy was higher for far-reaching targets (98.84%) than for near-reaching targets (98.04%). The main effect of the list width was marginally significant ($F(3, 120) = 2.41$, $p = .071$, $\eta_p^2 = 0.02$). Post-hoc tests indicated no significant differences across list widths (all $p > .100$).

For the parent-child lists, no significant main effects or interactions were found (all $F < 1$). Post-hoc pairwise comparisons revealed no significant differences across list widths (all $p > .100$).

C. SUBJECTIVE EVALUATION

Two separate one-way (list width) repeated measures ANOVAs were conducted for every subjective measure. For the single-column lists, a significant main effect of list width was found for perceived visual aesthetics ($F(3, 120) = 4.86$, $p = .003$, $\eta_p^2 = 0.07$). Post-hoc analysis showed that the very-narrow list received the lowest score (all $p < .010$; very-wide vs. very-narrow, $p = .053$), with no significant differences between the other width levels (all $p > .100$; Figure 6A). For the parent-child lists, significant main effects of list width were found for ratings of perceived comfort ($F(3, 120) = 7.80$, $p < .001$, $\eta_p^2 = 0.08$), satisfaction ($F(3, 120) = 12.17$, $p < .001$, $\eta_p^2 = 0.15$), and visual aesthetics ($F(3, 120) = 20.81$, $p < .001$, $\eta_p^2 = 0.22$). Post-hoc analysis showed that the moderately-wide and vary-wide lists received the highest scores (all $p < .050$), with no significant differences between them (all $p > .050$). The very-narrow list received the lowest score in the ratings of satisfaction and perceived visual aesthetics (all $p < .050$; Figure 6B). Other main effects or interactions were not significant.

D. SELECTION PROPORTION

The selection proportions of different list widths for every type of list are shown in Figure 7. For the single-column lists, the moderately-narrow list was the most frequently chosen (29.27%). For the parent-child lists, the very-wide list was the most popular (43.90%), closely followed by the moderately-wide list (36.59%). Consistent with Experiment 1, users took both usability and visual experience into account when determining their preferred list width.

VIII. SUMMARY OF EXPERIMENT 2

By employing a portable device with a large-width screen, the results of Experiment 2 showed that for the single-column lists, both moderately-narrow and moderately-wide lists were preferred, receiving the highest rankings in the paired comparison task and high scores of visual aesthetics. For the parent-child lists, both moderately-wide and very-wide lists were preferred, receiving the highest rating scores for perceived comfort, satisfaction, and visual aesthetics. Additionally, users completed tasks faster when the list was moderately wide compared to when it was very narrow. Consistent with Experiment 1, users considered both usability and visual experiences when evaluating their preferred list width.

IX. DISCUSSION

the present study aimed to determine the responsive list width that can enhance visual search efficiency and improve user experience on portable devices with medium- (Experiment 1) and large-width screens (Experiment 2). We found that, for single-column lists on a medium-width screen users preferred the moderately-wide list width. Additionally, for single-column lists on a large-width screen users preferred both the moderately-narrow and moderately-wide lists. For the parent-child lists, both the moderately-wide and very-wide list widths were favored by users on both medium-width and large-width screens.

The finding that users preferred medium width for single-column lists is consistent with previous studies demonstrating better visual search performance and higher comprehension scores when line length is neither too long nor too short [13], [20]. It has been suggested that long lines of information may interfere with normal eye movements, making it difficult for readers to locate the beginning of new lines [13], [20]. However, it should be noted that our study focused on the effect of list width i.e., the width of the entire list including texts, labels, and the space between them, rather than the effect of text length on search performance and subjective experience. In the present study, very-wide lists were associated with excessive white space within each line of a list, whereas the text length remained unchanged, which did not affect target search efficiency but led to lower preference ranking orders and subjective evaluation scores compared to a narrower list.

However, a very-short line length can also be detrimental and lead to a slower speed of reading, because a large amount of white space next to the information display area may distract attention [14]. In UI design, white space can be used to help users easily find the information they are looking for, add aesthetic value, and may improve the perceived quality of a product [27]. However, increasing the proportion of white space beyond 50% of an interface does not further improve the visual aesthetics and the perceived usability, rather, it can decrease satisfaction scores [28]. Researchers and designers suggest proper use of white space in graphics and UI interfaces to create a feeling of clarity and balance [28], [29], [30], which are important factors influencing the evaluation of interface aesthetics [31].

Furthermore, narrow lines can also have disadvantages such as frequent sentence segmentation, difficulty in understanding [17], and increased screen scrolling [12]. However, the target stimuli employed in the present study consisted of 2-6 Chinese characters, making it unlikely to cause sentence segmentation or comprehension difficulties even with a very-narrow list width. However, the supplementary texts that were task-unrelated were located below some of the critical stimuli (mimicking the real-word list interaction), and were segmented into multiple lines to fit into the very-narrow width of the list. Frequent line breaks can make the page longer and result in more scrolling, which may have contributed to the worst user experience with the very-narrow list width, as found in the present study. Therefore, in a typical list interface with limited texts or elements, it is advisable to avoid using very-wide or very-narrow lists to reduce the unnecessary negative space within and on both sides of the list and to reduce the possibility of line breaks.

In the present study, users consistently reported a better experience with moderately wide or very wide child dimensions in parent-child lists on both medium-width and large-width screens. It is worth noting that although the very-wide lists occupied the entire display area of the child dimension, the actual width was essentially equivalent to the very-narrow and moderately-narrow width of the single-column lists. Therefore, differences in user experience across list widths may not be due to preferences for an absolute width value. Instead, it is plausible that when the child dimension of the parent-child lists was very wide, the white space on both sides of the list and the space between the parent and child dimensions were symmetric, creating a visually balanced layout.

Symmetry preference has been found in various fields, such as screen design [32], [33], architecture design [34], and cross-culture research [31]. For example, Muhlenbeck et al. [35] found that participants from different cultural backgrounds all preferred symmetrical patterns, showed longer fixation durations on the symmetric patterns, and more frequently pointed to images with symmetric structures. These findings support the results of the present study, which showed a preference for symmetry in the spaces surrounding the list and dimensions. In addition, some users preferred the parent-child list with a moderately-wide width, leaving more white space on both sides of the child dimension compared to the space next to the parent dimension. This is in line with the visual hierarchy principle in interface design, which emphasizes a clear and cohesive layout by using white space to highlight different parts of the design and make the user feel less overwhelmed [36], [37]. The importance of proper white space in design has been discussed earlier.

Finally, the present study revealed that the variation in list width did not affect the target search performance on portable devices with a medium-width screen, but it significantly affected the performance on a larger-width screen. This finding suggests that in the future, when designing responsive list width for smaller screens, researchers and designers should prioritize evaluating the subjective experience. Furthermore, physiological measures such as facial electromyography (fEMG) and electrodermal responses (EDA) have been shown to effectively capture affective responses to visually appealing stimuli [38]. Therefore, future studies exploring the user experience related to list design across screens could potentially utilize these measures. However, it is important to note that the results of the present study may be limited to young individuals with normal or corrected vision, and thus, generalization to elderly individuals and those with visual impairments should be made with caution. Previous

TABLE 1. Demographic information of users in Experiment 1 and Experiment 2.

Experiment	Type of device	N	Age range	Gender	Daily use of portable devices	Experience with current portable devices
Experiment 1	Foldable mobile phone	40	18 to 24 years old ($N = 28$)	16 males and	1 to 3 hours ($N = 2$)	less than half a year ($N = 2$)
			25 to 29 years old (N = 10)	24 females	3 to 5 hours ($N = 15$)	half a year to 1 year ($N = 7$)
			30 to 34 years old ($N = 1$)		5 to 8 hours ($N = 16$)	1 to 2 years ($N = 15$)
			40 to 44 years old ($N = 1$)		8 to 10 hours ($N = 7$)	2 to 5 years ($N = 16$)
	Tablet in portrait	40	18 to 24 years old ($N = 25$)	14 males and	1 to 3 hours ($N = 1$)	less than half a year ($N = 8$)
			25 to 29 years old ($N = 13$)	26 females	3 to 5 hours ($N = 9$)	half a year to 1 year ($N = 3$)
			30 to 34 years old ($N = 1$)		5 to 8 hours ($N = 22$)	1 to 2 years ($N = 15$)
			35 to 39 years old ($N = 1$)		8 to 10 hours ($N = 7$)	2 to 5 years ($N = 13$)
					more than 10 hours ($N = 1$)	5 to 10 years ($N = 1$)
Experiment 2	Tablet in landscape	41	18 to 24 years old ($N = 12$)	20 males and	1 to 3 hours ($N = 2$)	less than half a year ($N = 6$)
			25 to 29 years old ($N = 17$)	21 females	3 to 5 hours ($N = 13$)	half a year to 1 year ($N = 5$)
			30 to 34 years old ($N = 5$)		5 to 8 hours ($N = 13$)	1 to 2 years ($N = 12$)
			35 to 39 years old ($N = 5$)		8 to 10 hours ($N = 11$)	2 to 5 years ($N = 18$)
			40 to 44 years old ($N = 2$)		more than 10 hours ($N = 2$)	

TABLE 2. Tasks and procedures for Experiment 1 and 2.

Order	Tasks	Procedures	
1	**Paired comparison task**	·A total of 8 blocks (two types of lists × four levels of list widths).	
		In each block:	
		1	Each trial started with a '+' fixation presented in the center of the screen for 1-2s and then disappeared.
		2	A pair of screenshots was shown differing only in the list width side-by-side.
		3	Users were instructed to press the "F" key if they preferred the left screenshot or the "J" key if they preferred the right one, without time constraints.
		4	A blank screen was presented for 500 ms.
		5	The next trial started; repeat 1-4.
2	**Target search task & subjective evaluations**	·A total of 8 blocks (two types of lists × four levels of list widths).	
		·Users completed several practice trials until they understood the task instructions and procedures.	
		·Perceived fatigue and emotions were recorded (serving as baseline).	
		·In each block:	
		1	Each trial started with task instruction indicating the required target words.
		2	Users clicked the 'Ready' button when they were ready.
		3	A list interface appeared with the target name (in red) remaining present at the top edge of the interface as a reminder.
		4	Users located the target word by scrolling through the list and selecting the corresponding line.
		5.1	If an error was made, then a "×" feedback would show up for 500 ms, and the trial was repeated until the target word was identified.
		5.2	If correct, then the next trial started following a break of 3s; repeat 1-4
		·After each block, users were asked to rate their current emotional experience, levels of fatigue, and subjective evaluations of the search process.	
3	**List preference task**	·Users selected their preferred interface/list width from a collection of interface screenshots printed on A4 papers and provided a brief explanation for their choice.	

research has highlighted that elderly and visually impaired users require design features such as enlarged buttons, simplified interfaces, and tactile and audible feedback upon button activation [39], [40], [41]. Accordingly, further investigation is warranted to determine the appropriate design guidelines for lists, which are not limited to list width, for these populations.

X. CONCLUSION

This study aimed to determine the responsive list width that can facilitate visual search efficiency and improve user experience on portable devices. The results indicated that for the single-column lists on a medium-width screen, users showed the highest preference and rating scores of satisfaction and visual aesthetics when the lists were moderately

TABLE 3. Mean (in seconds) and standard error of the mean for task completion time and response accuracy, as a function of the type of device, type of list, target position, and list width for the medium-width screen.

Type of device	Type of list	Target position	List width	Task completion time		Accuracy	
				Mean	*SE*	*Mean*	*SE*
Foldable mobile phone	Single-column lists	Near	Very narrow	1.984	0.125	0.988	0.004
			Moderately narrow	1.960	0.097	0.992	0.004
			Moderately wide	1.922	0.088	0.989	0.005
			Very wide	1.938	0.118	0.968	0.009
		Far	Very narrow	2.827	0.116	0.985	0.005
			Moderately narrow	2.864	0.143	0.994	0.003
			Moderately wide	2.734	0.099	0.986	0.005
			Very wide	2.744	0.115	0.992	0.004
		Average	**Very narrow**	2.405	0.097	0.986	0.003
			Moderately narrow	2.412	0.100	0.993	0.002
			Moderately wide	2.328	0.080	0.988	0.003
			Very wide	2.341	0.093	0.980	0.005
	Parent-child lists	Near	Very narrow	2.616	0.167	0.967	0.010
			Moderately narrow	2.552	0.146	0.975	0.007
			Moderately wide	2.961	0.302	0.986	0.006
			Very wide	2.548	0.150	0.983	0.007
		Far	Very narrow	2.646	0.138	0.982	0.004
			Moderately narrow	2.742	0.152	0.990	0.003
			Moderately wide	2.857	0.174	0.988	0.003
			Very wide	2.659	0.133	0.981	0.004
		Average	**Very narrow**	2.631	0.108	0.975	0.005
			Moderately narrow	2.647	0.105	0.982	0.004
			Moderately wide	2.909	0.173	0.987	0.003
			Very wide	2.604	0.100	0.982	0.004
Tablet in portrait	Single-column lists	Near	Very narrow	1.757	0.091	0.986	0.005
			Moderately narrow	1.728	0.066	0.990	0.003
			Moderately wide	1.717	0.089	0.985	0.004
			Very wide	1.891	0.119	0.983	0.005
		Far	Very narrow	1.962	0.094	0.996	0.002
			Moderately narrow	1.966	0.093	0.985	0.005
			Moderately wide	1.895	0.091	0.990	0.003
			Very wide	1.977	0.099	0.985	0.005
		Average	**Very narrow**	1.859	0.066	0.991	0.003
			Moderately narrow	1.847	0.058	0.988	0.003
			Moderately wide	1.806	0.064	0.988	0.003
			Very wide	1.934	0.077	0.984	0.003
	Parent-child lists	Near	Very narrow	2.079	0.126	0.983	0.006
			Moderately narrow	1.992	0.092	0.972	0.010
			Moderately wide	2.010	0.100	0.972	0.010
			Very wide	1.921	0.103	0.967	0.010
		Far	Very narrow	2.269	0.091	0.986	0.003
			Moderately narrow	2.252	0.080	0.984	0.004
			Moderately wide	2.250	0.105	0.981	0.005
			Very wide	2.317	0.095	0.984	0.003
		Average	**Very narrow**	2.174	0.078	0.985	0.004
			Moderately narrow	2.122	0.062	0.978	0.005
			Moderately wide	2.130	0.073	0.976	0.006
			Very wide	2.119	0.073	0.975	0.005

TABLE 4. Mean (in seconds) and standard error of the mean for task completion time and response accuracy, as a function of the type of list, target position, and list width for the large-width screen.

Type of list	Target position	List width	Task completion time		Accuracy	
			Mean	*SE*	*Mean*	*SE*
Single-column lists	Near	Very narrow	1.964	0.093	0.976	0.005
		Moderately narrow	1.910	0.088	0.988	0.004
		Moderately wide	1.981	0.116	0.985	0.004
		Very wide	2.031	0.103	0.973	0.006
	Far	Very narrow	2.897	0.118	0.991	0.003
		Moderately narrow	2.815	0.124	0.991	0.004
		Moderately wide	2.894	0.110	0.989	0.004
		Very wide	2.964	0.138	0.984	0.005
	Average	**Very narrow**	2.431	0.091	0.983	0.003
		Moderately narrow	2.363	0.091	0.989	0.003
		Moderately wide	2.438	0.094	0.987	0.003
		Very wide	2.497	0.100	0.978	0.004
Parent-child lists	Near	Very narrow	2.645	0.156	0.973	0.009
		Moderately narrow	2.491	0.103	0.978	0.008
		Moderately wide	2.263	0.115	0.981	0.008
		Very wide	2.527	0.138	0.981	0.007
	Far	Very narrow	3.049	0.137	0.981	0.004
		Moderately narrow	2.981	0.131	0.981	0.005
		Moderately wide	2.912	0.125	0.975	0.005
		Very wide	2.896	0.131	0.985	0.003
	Average	**Very narrow**	2.847	0.105	0.977	0.005
		Moderately narrow	2.736	0.087	0.980	0.005
		Moderately wide	2.587	0.092	0.978	0.004
		Very wide	2.711	0.097	0.983	0.004

wide. In addition, for the single-column lists on a large-width screen, users preferred both the moderately-narrow and moderately-wide list widths. In the case of parent-child lists, both moderately-wide and very-wide lists were favored on medium-width and large-width screens. These findings may be due to users' preference for the proper white space on various screens, thus providing useful guidelines for the responsive design of list on portable devices.

APPENDIX A
DEMOGRAPHIC INFORMATION

See Table 1.

APPENDIX B
EMOTION AND FATIGUE EVALUATIONS

A. EMOTION EVALUATION

1. How pleasant are you feeling now? Please rate on a scale from 1 (very unpleasant) to 9 (very pleasant).

2. How active are you feeling now? Please rate on a scale from 1 (very calm) to 9 (very excited).

B. FATIGUE EVALUATION

1. Please choose a number from 0 (no fatigue) to 10 (severe fatigue) that best describes your current level of fatigue.

APPENDIX C
SUBJECTIVE EVALUATOINS

Please rate the degree to which you agree with each of the following statements according to your experience when performing the target search task in the list, on a scale from 1 - 7 with 1 being strongly disagree and 7 being strongly agree.

1. I think the target search task was completed efficiently with the list.
2. The list is visually comfortable.
3. I am satisfied with the list.
4. The list looks beautiful.

APPENDIX D
TASKS AND PROCEDURES
See Table 2.

APPENDIX E
TARGET SEARCH PERFORMANCE IN EXPERIMENT 1
See Table 3.

APPENDIX F
TARGET SEARCH PERFORMANCE IN EXPERIMENT 2
See Table 4.

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