Interface Design for Children's Searching and Browsing

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ABSTRACT

Elementary-age children are among the largest user groups of computers and the Internet, so it is important to design searching and browsing tools that support them. However, many interfaces for children do not consider their skills and preferences. Children are capable of doing Boolean searches, but have difficulty with the sequential presentation of hierarchical structures used in many category browsers. Based on previous research, we believed a simultaneous presentation of a flat category structure might better support children. We conducted two studies of searching and browsing with these two types of category browsers. Our results suggest that a flat, simultaneous interface provides advantages for both Boolean searching and casual browsing. These results add to the understanding of children's searching and browsing skills and preferences and suggest guidelines for other interface designers.

Author Keywords

Children, search, browse, category browser, digital library, user study, empirical evaluation.

ACM Classification Keywords

H.5.2 User Interfaces; H.3.3 Information Search and Retrieval; H.3.7 Digital Libraries

MOTIVATION

One of the largest groups of computer and Internet users is elementary-age children. In 2002, 83% of U.S. homes with children owned a computer and 78% accessed the Internet [3]. In 2003, 42% of U.S. children age 5-9 and 67% of children age 10-13 used the Internet [17]. Children use the Internet for schoolwork, and search engines and digital libraries are popular ways that they can find information. Children also use computers to play games and communicate, often requiring searching and browsing [3].

Web sites such as Yahooligans! (*yahooligans.yahoo.com*) and Ask Jeeves Kids (*www.ajkids.com*) are examples of portals that children can use to find age-appropriate content. Project Gutenberg (*www.promo.net/pg*) and the Rosetta Project (*www.childrensbooksonline.org*) are examples of large digital libraries with books for children. However, these and other web sites often have interfaces with one or more of three problems. First, they do not take into account the information processing and motor skills of children, specifically their difficulties selecting small objects with a mouse. Second, they do not consider children's searching and browsing skills, specifically their difficulties with spelling, typing, navigating, and composing queries. Third, they do not consider how children prefer to search, presenting search criteria appropriate for adults, but not for children. The ability to select content such as reading material on their own is a powerful motivator for children [10], and many websites prevent children from doing so.

BACKGROUND

Recent work in our lab has focused on designing category browsers for digital libraries that support young children's abilities to search and browse. The QueryKids interface allowed children to find information about animals in a zooming user interface [4]. This interface included large, easily clickable icons rather than a keyword search box that required typing; incremental and clearly visible results to show search progress; and a built-in Boolean protocol to prevent children from having to mentally construct Boolean queries. Search categories were based on how children liked to search for animals, such as what they ate or where they lived. Revelle et al. [21] found that second and third grade children were able to use this interface to conduct both simple and Boolean directed searches 85% of the time.

Based on the success of the QueryKids interface, we built the International Children's Digital Library (ICDL, *www.icdlbooks.org*) using a similar interface with the addition of a hierarchical category browser to allow children to find and read books online [5]. This first version of the ICDL also consisted of large, easily clickable buttons; automatically-constructed Boolean searches; and search categories based on how children like to look for books. Reuter and Druin [20] found that children in grades one through five were able to navigate the category structure to find books in open-ended browsing, but they did not generally use the Boolean capability on their own.

Based on this study and after observing the use of the ICDL, we believed that the structure and presentation of the category browser discouraged children from creating Boolean searches when browsing. While Boolean search is known to be difficult for both children and adults, children are capable of using it [18,21]. The ICDL category browser was structured using *faceted metadata* [28], a collection of independent classifiers such as shape, color, and genre, each of which was hierarchical in structure. The categories were presented using *sequential menus* [7], in which only one facet at a time could be explored. Creating a Boolean search using categories from different facets required navigating to the leaves of one facet to make a selection, backtracking to the top of the hierarchy, and then navigating to the leaves of another facet. In addition, some of the facets at the top-level were rather abstract and potentially confusing (e.g. Format and Genre).

We believed these problems could be fixed with two changes. For structure, we believed that collapsing the depth of the facet hierarchies would make them easier for children to navigate, as has been found for adults [15]. We believed the benefit would be even greater for elementary-age children, who are still learning hierarchical categorization [26], don't always navigate hierarchies efficiently [14], and may have trouble understanding abstract, top-level categories [22]. For presentation, we believed that using *simultaneous menus* [7], in which each facet or branch in a category structure can be explored in parallel, might also be faster for children. For adults, this design was found to be faster than sequential presentation when creating multi-item Boolean searches [7].

However, these two changes yield a design with many more categories on the same page, which may be visually overwhelming for children, whose information processing skills are slower than adults [10]. Additionally, not all the categories may fit on the screen at once because of the need to use large, easily clickable category icons [8], necessitating paging or scrolling. Despite these reservations, we still believed that this design would be superior, and replaced the hierarchical sequential browser in the ICDL with a flat simultaneous design in October 2004.

To evaluate our decision, we formally explored the tradeoffs for children completing searching and browsing tasks using a hierarchical structure presented sequentially and a flattened structure presented simultaneously with two studies. Until now, no studies have looked systematically at how children of different ages are able to use hierarchical and flat category structures, simultaneous and sequential menu presentations, and Boolean logic. This research describes two studies designed to help fill this void.

RELATED WORK

Our interface design decisions for the ICDL category browser were based on related work in three areas: information processing and motor skills; searching and browsing skills; and selection criteria.

First, young children process information more slowly than adults, and this affects their motor skills [10,25]. For motor skills that involve a mouse, children are slower to acquire a target than adults and require larger targets [8]. Children have difficulty holding down a mouse button for extended periods of time, coordinating dragging and clicking, double-clicking, and using multi-button mice [8,9,24].

Second, children have difficulty with many common searching and browsing tools. Keyword searches are problematic because children have difficulty spelling, typing, and composing queries [6,16]. Sequential category hierarchies are problematic because children do not always navigate them efficiently [14], may not think hierarchically [26], and may have difficulty understanding abstract, top-level categories [22]. Children are capable of completing Boolean searches in sequential category browsers [21], but do not seem to create them spontaneously when browsing [20]. For adults, a simultaneous category browser facilitates faster creation of Boolean searches than a sequential browser, though the sequential presentation was found to be faster for single-item searches [7]. Simultaneous category browsers presenting faceted metadata were also faster and preferred to keyword searches for adults using the Flamenco image browser [28].

Finally, children look for books differently than adults. In physical libraries, early elementary children choose books based on the appearance of the cover and illustrations [12,16]. Older children focus on textual summary information in book jackets, covers, and indices [27]. Younger children tend not to make a distinction between fiction and non-fiction books, and prefer books about certain genres like fantasy to fiction or learning books [13]. Older children focus on particular genres that interest them, such as sports and animals [13,27]. Recommendations by peers and teachers also have an important influence on children's book selections [12]. Many of these trends are also true in digital libraries [20]. The categories in the ICDL category browser were chosen to reflect these trends.

Several digital library systems for children have attempted to address these issues [e.g. 1,2,19]. These systems included child-appropriate categories and large buttons, but were generally based around a sequential, hierarchical category browser using the Dewey Decimal Classification system. While these systems were improvements over keyword search interfaces, they were not publicly accessible digital libraries and did not look carefully enough at children's searching and browsing skills. Project Gutenberg and the Rosetta Project are current examples of public digital libraries with children's books, but these have adult-oriented interfaces. A number of digital library catalogs for children with more appropriate interfaces exist [e.g. 11,23], but don't provide access to book scans. The ICDL provides free access to children's books from all over the world and is exploring children's searching and browsing skills more deeply.

USER STUDIES

We conducted two studies to evaluate our design choices for the new ICDL category browser. Both compared a flat category structure presented simultaneously to a hierarchical category structure presented sequentially. The first design (*simultaneous*) required paging to reach half of the categories. The second design (*sequential*) required hierarchical navigation to reach all of the categories. In the first study (*simple*), children searched for a single item. In the second study (*Boolean*), children did two-item searches. Children also completed free browsing tasks in each study.

Hypotheses

We had the following hypotheses for our studies:

H1. The simultaneous interface would be faster for simple tasks that did not require paging.

H2. The simultaneous interface would be faster, easier, and preferred for all Boolean tasks, regardless of paging.

H3. Boolean tasks would be harder for younger children to complete than for older children.

H4. The simultaneous interface would better support creation of Boolean tasks.

H5. The simultaneous interface would better support understanding of Boolean tasks.

Study Designs

Participants

The participants were 72 first grade (age 6-7), third grade (age 8-9) and fifth grade (age 10-11) children. In each study, 36 children participated, 12 in each grade, equally split between boys and girls. Children came from 4 suburban Maryland elementary schools. All were familiar with computers; none had previously used the ICDL.

Materials

Participants used a Dell laptop with a 12 inch display, 1024x768 screen resolution, an Intel Pentium 3 Mobile CPU, Windows XP, and a Kensington single-button mouse. The software was an adapted version of the ICDL running locally and instrumented to record the time of each mouse click. Participants used the Microsoft Internet Explorer 6 browser in full screen mode with the task bars hidden.

Interfaces

Both interfaces allowed children to search for books using category buttons (e.g. cover colors, age ranges, genres) that could be selected and unselected to include or exclude them from the search. Categories were arranged around the perimeter of the screen and books were presented in the middle in sets of 8. The simultaneous interface used a single-level category structure (Figure 1,2). The sequential interface used a two-level category structure (Figures 3,4). The simultaneous interface presented 44 leaf-level categories over two pages. It required less navigation to select multiple categories, but showed more categories per page and required paging by use of "More Choices" arrows at the top and bottom of the screen. The sequential interface organized the 44 leaves into 9 facets, each with 2-12 leaves. To select leaves from different facets, users had to backtrack using a large "Up Arrow". In both interfaces, 3 featured books were shown if no categories were selected.

Figure 1. Page 1 of the simultaneous interface

Figure 2. Page 2 of the simultaneous interface

Figure 3. The top level of the sequential interface

Figure 4. The color leaf level of the sequential interface

Procedure

In each study, participants, whose parents had signed consent forms, worked with a researcher one at a time. The researcher explained the project and had the children sign assent forms. Participants completed tasks with one interface, then the other. Each participant used both interfaces, so we created two different but structurally and cognitively similar sets of tasks for each study. For example, children might be asked to find Red books in one set and Orange books in the other. These category buttons were located near each other in both interfaces and involved the same concept. Interface order and task set use were counterbalanced and the order of the searching tasks in each task set was randomized for each child.

Tasks

In both studies, the first task was a free browsing task to observe how participants used an interface without instruction. After the children explored for two or three minutes, the researcher demonstrated the interface. This included instruction on how to select a single category, how to unselect categories and start over, how to use the results paging arrows, and how to use the More Choices or Up Arrow buttons. It did not include instruction on how to create a Boolean search, since one of our study goals was to observe whether children understood this feature. Participants then completed six timed, randomized search tasks. Each search task was a question of the form "How many X books are there?", where X was one category in the simple study and two categories from different facets in the Boolean study. In the simultaneous interface, half of these tasks required using the second page (two-page tasks) and half did not (one-page tasks).

In the Boolean study, children completed two additional tasks in which they were asked to select two category buttons and then questioned about what kinds of books were found. One task was completed before the six search tasks and one was done immediately after. These two questions were designed to elicit whether participants understood that they were creating a conjunctive Boolean search when they selected two category buttons.

After completing the tasks in the first interface, participants answered two questions about the difficulty and likeability of the interface and then repeated the same protocol with the second interface. Finally, participants were asked which interface they liked better. The entire process took 15-30 minutes. University rules required that the studies take no more than 30 minutes per child, which pilot testing showed would require giving some children hints or enforcing time limits. We chose to give hints so that we would have complete time data, and because we wanted to talk with children as they were having problems. We recorded and report on the number of hints given. One of the authors conducted all of the experiments. The experimenter attempted to give hints in a consistent way based on expected problems identified in pilot testing to reduce the potential for bias toward either interface.

Analysis

For search tasks, each child completed three one-page tasks and three two-page tasks with each interface. These tasks were averaged by grade and task type for analysis. All time data was analyzed using repeated measures analysis of variance (ANOVA) and is graphed with 95% confidence intervals. Preliminary analysis indicated no effect by task set, so this factor was excluded. Post-hoc analyses were done with Tukey tests to explore significant results in factors with more than two levels. For subjective questions (e.g. likeability) and counts (e.g. hints) for which assumptions of normality may not hold, non-parametric statistical tests were used. All analyses were performed overall and by grade. Some non-significant results by grade may be due to lack of power with only 12 participants.

Results: Simple Study - Searching

Overall

Search times for all 36 children were submitted to a 3 (grade) x 2 (interface) x 2 (task type – one-page/two-page) ANOVA. Results of this analysis indicated a significant difference by grade $F(2,33)=23.99$, $p<.01$ (Figure 5) and a significant interaction effect between interface and task type, $F(1,33)=26.64$, $p<.01$ (Figure 6). Tukey post-hoc tests on grade indicated that fifth graders were faster than first graders, and third graders were faster than first graders.

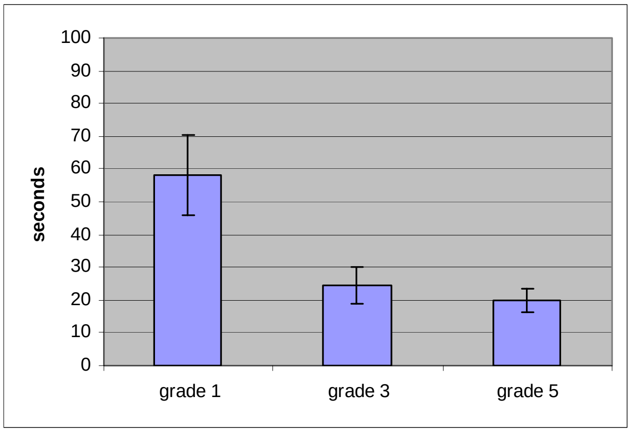

Figure 5. Mean time by grade for simple tasks

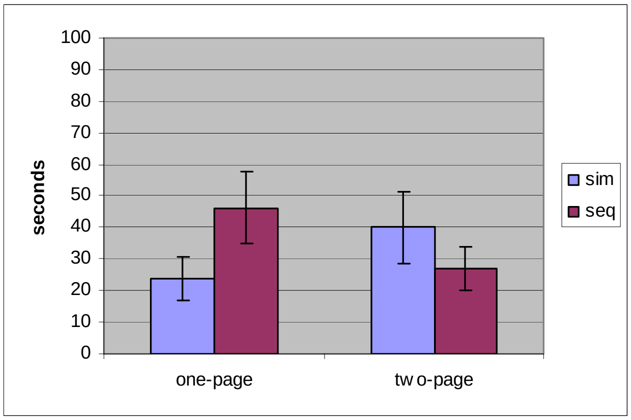

Figure 6. Mean time by interface and task for simple tasks

Tukey post-hoc tests on the interaction between interface and task type indicate that one-page tasks in the simultaneous interface were faster than one-page tasks in the sequential interface and two-page tasks in the simultaneous interface. Two-page tasks in the sequential interface were also faster than one-page tasks in the sequential interface. We expected to find no difference between one-page and two-page tasks in the sequential interface since they were structurally equivalent. However, the one-page task sets each contained a task that involved the Format category, a relatively abstract term. Children took more than twice as long and required more than twice as many hints to complete the task with this category in the sequential interface compared to the averages of the other tasks done with the sequential interface.

For interface difficulty and likeability, children were given three choices to choose from: hard, medium, easy and not much, a little, a lot. We assigned these choices values from 1-3 and conducted Wilcoxon signed rank tests to compare their answers. The results of these tests were not significant for either difficulty or likeability, indicating no difference between the two interfaces. For interface preference, children chose whether they liked either interface better or both the same. Of the children, 11 preferred the simultaneous interface, 5 preferred the sequential, and 20 liked both equally. We ordered these choices with "both" as the median value and performed a one-sample median test. The results of this test were not significant, indicating neither interface was strongly preferred.

In the simultaneous interface, children needed 79 total hints, compared to 84 in the sequential. To analyze whether there was a difference by interface, we conducted a Wilcoxon signed rank test. The results of this test were not significant, indicating that there was no difference between the two interfaces. Combining both interfaces and looking at the data by grade, first graders needed an average of 10.1 hints, third graders an average of 2.25, and fifth graders an average of 1.25. To analyze whether there was a difference in the number of hints by grade, we conducted a Kruskal Wallis test. This test was significant ($p<.01$), indicating that younger children needed more hints.

Looking at the hints in the simultaneous interface by task type (one-page vs. two-page), a Wilcoxon signed rank test was not significant, indicating that two-page tasks did not require more hints than one-page tasks. The same was also true for hints in the simultaneous interface for each grade.

First Grade

Search times for all 12 children were submitted to a 2 (interface) x 2 (task type) ANOVA. Results indicated a significant interaction effect between interface and task type, $F(1,11)=11.85$, $p<.01$. Tukey post-hoc tests indicate that one-page tasks in the simultaneous interface were faster than one-page tasks in the sequential. For interface difficulty, likeability, preference, and hints, there were no significant differences between the two interfaces.

Third Grade

Search times for all 12 children were submitted to a 2 (interface) x 2 (task type) ANOVA. Results indicated a significant interaction effect between interface and task type, $F(1,11)=6.37$, $p=.03$. Tukey post-hoc tests indicate that none of the comparisons between interface and task type were significant, but in the simultaneous interface, one-page tasks interface were marginally faster than two-page tasks, $p=.08$. For interface difficulty, likeability, preference, and hints, there were no significant differences between the two interfaces.

Fifth Grade

Search times for all 12 children were submitted to a 2 (interface) x 2 (task type) ANOVA. Results indicated a significant interaction effect between interface and task type, $F(1,11)=17.83$, $p<.01$. Tukey post-hoc tests indicate that one-page tasks in the simultaneous interface were faster than one-page tasks in the sequential interface and two-page tasks in the simultaneous interface. For interface difficulty, likeability, preference, and hints, there were no significant differences between the two interfaces.

Results: Simple Study - Browsing

Overall

During the browsing tasks, we counted the number of Boolean searches a child created in each interface. Although the search tasks in the simple study were all one-item searches, there was nothing to prevent children from creating multi-item Boolean queries while browsing. A Boolean search was defined as having at least two leaf-level categories selected. Children created 183 Boolean searches in the simultaneous interface and 79 in the sequential. To analyze whether there was a difference by interface, we conducted a Wilcoxon signed rank test. The results of this test were significant ($p<.01$), indicating that significantly more Boolean searches were created in the simultaneous interface. Combining both interfaces and looking at the data by grade, first graders created an average of 5.8 Boolean searches, third graders an average of 6.7, and fifth graders an average of 9.3. To analyze whether there was a difference by grade, we conducted a Kruskal Wallis test. The results of this test were not significant.

We also counted the number of children who used the navigation buttons on their own in each interface. In the simultaneous interface, 9 children used the More Choices buttons and 27 did not. To see if these values differed from the null hypothesis that half the children would use the buttons, we conducted a binomial test. The results of this test were significant ($p<.01$), indicating that significantly more children did not find this button than did find it. In the sequential interface, 21 children used the Up Arrow and 15 did not. The results of a binomial test were not significant. Combining both interfaces and looking at the data by grade, there were 4 uses of any navigation tool in first grade, and 13 each in the third and fifth grades. To analyze this data, we conducted a Fisher exact test. This difference was significant (p<.01), indicating that significantly more children in the third and fifth grades used the navigation tools on their own than first grade children.

First Grade

First graders created 47 Boolean searches in the simultaneous interface and 23 in the sequential. The results of a Wilcoxon signed rank test were significant (p=.02). No child used the More Choices buttons in the simultaneous interface. The results of a binomial test were significant (p<.01). In the sequential interface, 4 children used the Up Arrow and 8 did not. This difference was not significant.

Third Grade

Third graders created 59 Boolean searches in the simultaneous interface and 21 in the sequential. The results of a Wilcoxon signed rank test were significant (p=.02). In the simultaneous interface, 5 children used the More Choices buttons and 7 did not. In the sequential interface, 8 children used the Up Arrow and 4 did. These differences were not significant in either interface.

Fifth Grade

Fifth graders created 77 Boolean searches in the simultaneous interface and 35 in the sequential. The results of a Wilcoxon signed rank test were significant (p=.02). In the simultaneous interface, 4 children used the More Choices buttons and 8 did not. This difference was not significant. In the sequential interface, 9 children used the Up Arrow and 3 did not. The results of a binomial test were significant (p=.04).

Results: Boolean Study - Searching

Overall

Search times for all 36 children were submitted to a 3 (grade) x 2 (interface) x 2 (task type) ANOVA. Results of this analysis indicated significant differences by grade $F(2,33)=19.96$, $p<.01$ (Figure 7) and interface $F(1,33)=53.25$, $p<.01$, and a significant interaction effect between interface and task type, $F(1,33)=18.71$, $p<.01$ (Figure 8). For the interface effect, the simultaneous interface was faster than the sequential.

Tukey post-hoc tests on grade indicated that there were significant differences between all three grades, with fifth graders faster than both third and first graders, and third graders faster than first graders. Tukey post-hoc tests on the interaction between interface and task type indicate that one-page tasks in the simultaneous interface were faster than one-page tasks in the sequential interface, and two-page tasks in both interfaces. Two-page tasks in the simultaneous interface were faster than both one-page and two-page tasks in the sequential interface.

For interface difficulty and likeability, we conducted Wilcoxon signed rank tests to compare the responses for each interface. The results of both of these tests were significant, indicating that the simultaneous interface was considered easier and was better liked than the sequential interface. For overall interface preference, 19 children preferred the simultaneous interface, 4 preferred the sequential interface, and 13 liked both equally. The results of a one-sample median test were significant (p<.01), indicating that more children preferred the simultaneous.

In the simultaneous interface, children needed 116 total hints, compared to 221 in the sequential interface. To analyze whether there was a difference by interface, we conducted a Wilcoxon signed rank test. This test was significant (p<.01), indicating that significantly more hints were required in the sequential interface.

Combining both interfaces and looking at the data by grade, first graders needed an average of 18.2 hints, third graders an average of 7.4, and fifth graders an average of 2.5. To analyze whether there was a difference in the number of hints by grade, we conducted a Kruskal Wallis test. This test was significant (p<.01), indicating that younger children needed more hints than older children.

Looking at the hints in the simultaneous interface by task type (one-page vs. two-page), a Wilcoxon signed rank test was not significant, indicating that two-page tasks did not require more hints than one-page tasks. The same was also true for hints in the simultaneous interface for each grade.

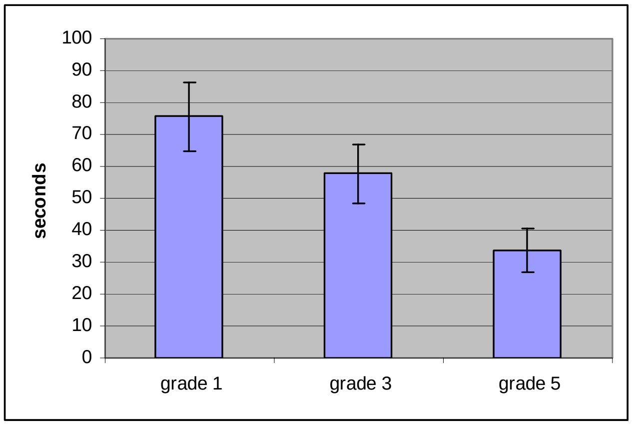

Figure 7. Mean time by grade for Boolean tasks

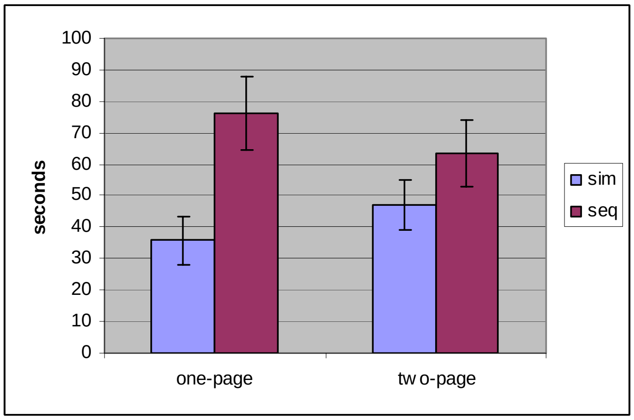

Figure 8. Mean time by interface and task for Boolean tasks

First Grade

Search times for all 12 children were submitted to a 2 (interface) x 2 (task type) ANOVA. Results indicated a significant difference by interface, $F(1,11)=31.08$, $p<.01$, and a significant interaction effect between interface and task type, $F(1,11)=6.48$, $p=.03$. For the interface effect, the simultaneous interface was faster than the sequential. Tukey post-hoc tests on the interaction effect indicate that one-page tasks in the simultaneous interface were faster than both one-page and two-page tasks in the sequential, and that two-page tasks in the simultaneous interface were faster than one-page tasks in the sequential.

For interface difficulty, likeability, and preference, there were no significant differences between the two interfaces. Children in this grade needed 76 total hints in the simultaneous interface, compared with 142 in the sequential. The results of a Wilcoxon signed rank test were significant ($p=.01$).

Third Grade

Search times for all 12 children were submitted to a 2 (interface) x 2 (task type) ANOVA. Results indicated a significant difference by interface, $F(1,11)=8.27$, $p=.02$, and a significant interaction effect between interface and task type, $F(1,11)=6.75$, $p=.02$. For the interface effect, the simultaneous interface was faster than the sequential. Tukey post-hoc tests on the interaction effect indicate that one-page tasks in the simultaneous interface were faster than one-page tasks in the sequential.

For interface difficulty and likeability, there were no differences between the two interfaces, though for difficulty, the simultaneous interface was borderline easier ($p=.06$). A one sample-median test on interface preference was significant ($p<.01$), indicating that more children preferred the simultaneous interface. Children in this grade needed 31 total hints in the simultaneous interface and 58 in the sequential. This difference was not significant.

Fifth Grade

Search times for all 12 children were submitted to a 2 (interface) x 2 (task type) ANOVA. Results indicated a significant difference by interface, $F(1,11)=34.17$, $p<.01$, and a significant interaction effect between interface and task type, $F(1,11)=5.98$, $p=.03$. For the interface effect, the simultaneous interface was faster than the sequential. Tukey post-hoc tests on the interaction effect indicate that one-page tasks in the simultaneous interface were faster than one-page and two-page tasks in the sequential and two-page tasks in the simultaneous, and that two-page tasks in the simultaneous interface were faster than one-page tasks in the sequential.

For interface difficulty, likeability, and preference, there were no significant differences between the two interfaces. Children in this grade needed 9 total hints in the simultaneous interface and 21 in the sequential. This difference was not significant.

Results: Boolean Study - Browsing

Overall

While browsing, children created 224 Boolean searches in the simultaneous interface and 104 in the sequential interface. The results of a Wilcoxon signed rank test were significant ($p<.01$), indicating that significantly more Boolean searches were created in the simultaneous interface. Combining both interfaces and looking at the data by grade, first graders created an average of 7.9 Boolean searches, third graders an average of 7.3, and fifth graders an average of 12.2. These differences were not significant.

We also counted the number of children who used navigation buttons on their own. In the simultaneous interface, 12 children used the More Choices buttons, while 24 did not. The results of a binomial test were significant ($p<.01$), indicating that significantly more children did not find this button than did find it. In the sequential interface, 23 children used the Up Arrow and 13 did not. The results of a binomial test were significant ($p=.05$), indicating that significantly more children found this button than did not find it. Combining both interfaces and looking at the data by grade, there were 10 uses of a navigation tool in first grade, 8 in third grade, and 17 in fifth grade. To analyze this data, we conducted a Fisher exact test. This test was significant ($p=.03$), indicating that significantly more children in fifth grade used the navigation tools on their own than third and first grade children.

First Grade

First graders created 60 Boolean searches in the simultaneous interface and 34 in the sequential. This difference was not significant. In the simultaneous interface, 1 child used the More Choices buttons and 11 did not. The results of a binomial test were significant ($p<.01$). In the sequential interface, 9 children used the Up Arrow and 3 did not. The results of a binomial test were significant ($p=.04$).

Third Grade

Third graders created 62 Boolean searches in the simultaneous interface and 26 in the sequential. The results of a Wilcoxon signed rank test were borderline significant ($p=.06$). In the simultaneous interface, 4 children used the More Choices buttons and 8 did not. In the sequential interface, 4 children used the Up Arrow and 8 did not. Binomial tests were not significant for either interface.

Fifth Grade

Fifth graders created 102 Boolean searches in the simultaneous interface and 44 in the sequential. The results of a Wilcoxon signed rank test were significant ($p=.02$). In the simultaneous interface, 7 children used the More Choices buttons and 5 did not. This difference was not significant. In the sequential interface, 10 children used the Up Arrow and 2 did not. The results of a binomial test were significant ($p=.01$).

Results: Boolean Study - Comprehension

Overall

In the Boolean study, children completed two additional tasks where they were asked to select two category buttons and then to explain what kinds of books they had found. For the second of these tasks, asked after the children had completed the timed searching tasks, 22 children understood they were doing conjunctive Boolean tasks in the simultaneous interface, compared with 14 who did not. The results of a binomial test were not significant, indicating that children were as likely to understand as not. In the sequential interface 18 children understood what type of task they were doing and 18 did not, indicating that children were as likely to understand as not.

To see if there was a difference in understanding by grade, we combined both interfaces together and conducted a Fisher exact test. There were 10 instances of understanding in either interface in first grade, 7 in third grade, and 23 in fifth grade. This test was significant ($p<.01$), indicating that fifth graders understood they were creating conjunctive Boolean queries more often than first and third graders.

First Grade

In the simultaneous interface, half the children understood they were creating conjunctive Boolean searches. In the sequential interface, 4 children understood and 8 did not. These differences were not significant for either interface.

Third Grade

In the simultaneous interface, 4 children understood that they were creating a conjunctive Boolean query and 8 did not. This difference was not significant. For the sequential interface, 3 children understood and 9 did not. The results of a binomial test were significant ($p=.04$).

Fifth Grade

For the simultaneous interface, all 12 children understood that they were creating a conjunctive Boolean query. For the sequential, 11 of 12 children understood. The results of binomial tests for both were significant.

Discussion

Simple Searches

The simple study results indicate that younger children require more time and more hints than older children to find a single category in a directed searching task, regardless of the interface presentation. The results also indicate that neither the simultaneous nor the sequential interface is faster, requires more hints, and is liked more, easier to use, or preferred, either overall or within any of the three grades. However, our hypothesis (H1) that one-page tasks would be faster in the simultaneous interface than in the sequential interface was supported overall and within first and fifth grade. One-page tasks were faster than two-page tasks in the simultaneous interface overall, and within fifth grade, though there was no difference in the number of hints required to complete one-page vs. two-page tasks. One-page and two-page tasks in the sequential interface were structurally equivalent, but two-page tasks were faster because a one-page task involved the Format category.

Boolean Searches

The Boolean study results indicate that younger children require more time and more hints than older children to find two categories in different category facets, regardless of the interface. The results also indicate that the simultaneous interface is faster, requires fewer hints, and is liked more, easier to use, and preferred overall. Of all the interactions between interface and task type, only the difference between one-page and two-page tasks in the sequential interface was not significant overall. This supported our hypothesis (H2) that the simultaneous interface would be faster, easier, and preferred for both one-page and two-page tasks compared to the sequential interface.

In addition to being faster and requiring fewer hints, older children understood that they were creating a conjunctive Boolean query more often than younger children, supporting our hypothesis (H3). However, neither interface was more likely to support this understanding than not. Our hypothesis (H5) that the simultaneous interface would better support this understanding was not supported.

For all grades, the simultaneous interface was faster than the sequential interface, but only first graders needed more hints in the sequential interface. First and fifth graders did not like either interface more than the other, consider either one easier to use, or prefer one to the other. Third graders did not like either interface more or consider either one easier to use, but preferred the simultaneous interface. However, many of the counts in the individual grades leaned toward an advantage for the simultaneous interface, but with only 12 subjects per grade, we may not have had enough power to detect differences within each grade.

Browsing

In both the simple and Boolean studies, the browsing tasks seemed to favor the simultaneous interface with regard to children's ability to create Boolean searches, supporting our hypothesis (H4). During browsing, children created significantly more Boolean searches using the simultaneous interface than the sequential interface, both overall and within some of the grades. We did not record whether or not children understood that they were creating a Boolean search at that time, but these results suggest that creating a Boolean search was easier in the simultaneous interface.

In both studies, children were more likely than not to find the Up Arrow button in the sequential presentation, and less likely to find the More Choices buttons in the simultaneous presentation. Children did not have any problem understanding or using the More Choices buttons once they found them or the researcher pointed them out. It is likely that some combination of more icons on the screen, the small size of the More Choices buttons, and the placement of the More Choices buttons made them hard to find. This was a significant usability problem for children who did not receive prior instruction.

DESIGN GUIDELINES

The results of these studies suggest several guidelines that we believe will be useful for other designers of searching and browsing interfaces for elementary-age children.

1. *Both flat, simultaneous and hierarchical, sequential designs are useful for single-item searches.* Our research confirms that children are able to use category browsers to search for information, so these tools continue to be a reasonable way to support children's searching and browsing. For interfaces that only support selecting a single category, both a two-level sequential presentation of a hierarchical structure and a two-page simultaneous presentation of a flat structure are appropriate. However, if all of the categories fit on a single page, the simultaneous presentation is likely to be faster.

2. *Flat, simultaneous designs better support conjunctive Boolean searching and browsing*. We suggest that if Boolean search is supported, a simultaneous presentation of a flat structure is preferable to a sequential presentation of a hierarchy, at least for conjunctive searches between facets. In directed searches, children were faster and preferred creating conjunctive Boolean searches in the simultaneous interface. During free browsing tasks, children also spontaneously created more conjunctive Boolean searches in the simultaneous interface.

3. *Boolean search must be implemented with care.* Not all elementary-age children, particularly those in first and third grades, understand Boolean functionality, so the interface needs to work regardless of whether children understand the logic. Features such as automatic creation of Boolean searches, the constant presence of items to choose from in a results section on the same screen, and the prevention of no-hit searches by graying out useless categories, can all make the interaction easy even if a child does not understand the underlying Boolean logic.

4. *Navigation tools must be large and prominent.* Finally, our research suggests that young children are comfortable navigating a two-level hierarchy, provided they have a large, conspicuously placed navigation arrow. On the other hand, smaller, less obviously placed buttons for paging in a simultaneous presentation may be too small and/or get lost among other buttons. As a result, we recommend larger, more prominently placed paging buttons, or avoiding paging altogether by decreasing the number of categories.

CONCLUSIONS AND FUTURE WORK

We presented the results of two studies designed to improve the understanding of elementary-age children's searching and browsing skills using two common category browser interfaces in a children's digital library. Our results indicate that a flat category structure presented simultaneously has a number of advantages over a hierarchical category structure presented sequentially, particularly for conjunctive Boolean searches. We believe these results will be applicable to other searching and browsing interfaces for children, such as digital libraries and search engines, and we presented design guidelines for designers of such tools.

In the future, we would like to see research undertaken to explore four other areas. First, our research compared only two of the three possible structure/presentation combinations in a category browser. We compared a flat, simultaneous interface to a hierarchical, sequential interface. We did not look at a hierarchical, simultaneous design. A flat, sequential design is not possible. As a result, we were not able to determine if either structure or presentation had more of an impact on performance and preference. Our hypothesis is that a hierarchical, simultaneous design, such as is implemented in Microsoft Windows Explorer, would be more difficult for children to use than either of the other two designs because it would have many items on screen and require a lot of navigation. Future studies might explore this question, and whether changes to structure or presentation have a greater effect.

Second, our research evaluated only conjunctive Boolean search between facets. We chose to support conjunction because a number of studies indicate that children have an easier time with conjunction than disjunction [18], and conjunction narrows down the search results to a more manageable size. We chose to evaluate searching only between facets because certain within-facet searches are not possible in our browser. For example, within the Length category, a book cannot be both Long and Short, but within the Color category, it is possible for a book to be both Red and Blue. Within-facet searches are likely to be easier than between facet searches in a hierarchical design since no backtracking is necessary. It may be useful to evaluate this and other logical combinations in the future.

Third, we would like to see more study on children's browsing skills. In our studies, strict time limits were not enforced during browsing tasks and children were not asked about comprehension while browsing. A more rigorous study might reveal more information about children's comprehension of Boolean queries while browsing. Finally, we would like to see studies done with more children at multiple grade levels to ensure sufficient power to detect differences within each grade. A number of our within-grade measurements suggested more advantages for the simultaneous design, but did not reach significance.

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