Young Children's Search Strategies and Construction of Search Queries

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ABSTRACT
This paper describes a quantitative study focused on two questions: (1) Can children understand and use a hierarchical domain structure to find particular instances of animals? (2) Can children construct search queries to conduct complex searches if sufficiently supported, both visually and conceptually? These two questions have been explored in the context of developing a digital library interface (called "QueryKids") for children ages 5-10 years old that visualizes the querying process and its results. The results of this study showed that children were able to search very efficiently, primarily using a "fewest-steps" strategy, with the QueryKids software prototype. In addition, children were able to construct search queries with a high degree of accuracy. Results are discussed in terms of the scaffolding support that QueryKids provides, and its effectiveness in helping children to search efficiently and construct complex search queries.

Keywords
Children, information retrieval, digital libraries, empirical evaluation, education applications.

INTRODUCTION
Research has shown that the querying process can be difficult for users when the interface is restricting in syntax or abstract in nature [9,12,16,19]. Graphical interfaces for digital libraries have been shown to help adults search efficiently and effectively [1,7,14,17].

The research concerning children and information search strategies, leads us to believe that graphical interfaces can also be supportive of children as technology users [13,26,27]. However, thanks to the importance of the World Wide Web and the proliferation of search engines for it, children typically must negotiate query tools that are language-based and use abstract logical notations for Boolean searches [13]. While the use of text is not an issue for older children and adults, young children (4-7 years of age), have difficulty when it comes to typing skills, spelling, and syntax comprehension [15] [24] [26].

In addition, constructing Boolean-type search queries requires an understanding of the logic of conjunction (intersection, typically represented as *AND* in a standard Boolean search query) and disjunction (union, generally represented as *OR* in traditional Boolean search terms). It has long been understood that even adults have difficulty with these logical concepts, particularly with disjunction [4]. It has also been well documented that children have difficulty with these concepts, and that the differential difficulty of disjunction over conjunction is consistent for children from 5 to 12 years of age [23]. However, under certain circumstances even children as young as three years have been shown to utilize disjunctive concepts to perform significantly better than chance [18]. Although these results were all established quite some time ago, there has been little or no research exploring children's use of computer interfaces to construct search queries based on these logical concepts. Interestingly enough, it has been shown that typical interfaces to the Web promote less strategic thinking concerning searches, and more active browsing [13]. We believe this may be due to the inappropriate searching interfaces available for young children today.

Therefore, we began a study in the fall of 1999, to better understand young children's searching strategies and abilities to construct Boolean-type search queries. At that time, we hypothesized that if we provided enough visual and conceptual support for young children, it might be possible for them to effectively use these complex search concepts. The empirical study reported here examined the following questions: (1) Can children understand and use a hierarchical domain structure to find particular instances of animals? (2) Can children construct search queries if they are provided with visual and conceptual support? Our research questions were addressed by observing and documenting children's searches for animals in a hierarchical information structure, comparing the use of a paper model and an interactive computer prototype we now call QueryKids. In the paper that follows, our research methods, results, and conclusions will be described.

METHODS

Participants

The participants in this study were 106 second and third grade children from Yorktown Elementary School, a public school in Prince George's County, in the Washington DC metropolitan area. Approximately 52% of the children were Caucasian, 36% were African American, and 22% were Asian or Hispanic. The school serves a lower-middle to middle-class population.

The children were divided into two groups. The first group, a total of 56 participants, used a paper prototype (as described in the next sections). This group was made up of 30 second graders (14 females with a mean age of 8 yrs, 1 mo, and 16 males with a mean age of 8 yrs, 0 mos) and 26 third graders (14 females with a mean age of 9 yrs, 1 mo, and 12 males with a mean age of 8 yrs 10 mos). The second group, a total of 50 participants, used the computer prototype. This group was made up of 22 second graders (12 females with a mean age of 8 yrs, 0 mos, and 10 males with a mean age of 8 yrs, 1 mo) and 28 third graders (14 females with a mean age of 8 yrs, 10 mos, and 14 males with a mean age of 9 yrs 0 mos).

Materials

Both the paper prototype and the computer prototype were organized to represent four hierarchies (Table 1). At the top level were the names of four parallel "branches": *Animals*, *Where They Live*, *How They Move* and *What They Eat*. All 45 animals in the data set could be found under each of these four branches; i.e., the four branches served as alternative ways of accessing the same information. Under the *Animals* branch heading were the following subcategories: *Amphibians, Birds, Fish, Insects, Invertebrate Sea Creatures, Mammals, Reptiles*.

The Mammals subcategory was then further subdivided into *Cats & Dogs, Rodents, Hooved, Primates,* and *Marsupials*. The second branch, *Where They Live*, was divided into three subcategories: *Land*, *Water*, and *Both Land and Water*. Likewise, the *How They Move* branch was subdivided into *Fly*, *Swim*, and *Walk, Crawl, Hop etc.*, and *What They Eat* had the subcategories *Eats Animals, Eats Plants,* and *Eats Both Plants and Animals.* Under the lowest subcategories in each branch of the hierarchy were entries for individual animals.

Paper Prototype

The paper prototype consisted of a set of hierarchically nested envelopes The four 15"x12" envelopes at the top of the four branches of the hierarchy were labeled *Animals, Where They Live, How They Move and What They Eat*, and decorated with representative pictures (Figure 1). Inside each of these envelopes were smaller envelopes, labeled with the subcategories under each broad category (Figure 2).

Animals	Where They Live	How They Move	What They Eat
Amphibians	Land	Fly	Animals
Birds	Water	Swim	Plants
Fish	Land & Water	Walk, Crawl, Hop, etc.	Animals & Plants
Insects			
Reptiles			
Invertebrate Sea Creatures			
Mammals			
— Marsupials			
— Primates			
— Rodents			
— Hooved			
— Cats & Dogs			

Table 1: Information organization hierarchies for paper and computer prototypes

For the *Mammals* subcategory there was one more subset of yet smaller envelopes, representing the second level of subcategories. Inside the smallest envelope for each branch of the hierarchy were 5x7 white cards, each of which displayed a color picture of one animal with its common name printed below the picture.

In addition, there were two cartoon-style illustrations of children on 4 x 6 cards (Figure 3). These illustrations represented Dana and Kyle, who were introduced to the participants as the "search kids", and were used in searches for groups of animals. Whenever children were constructing a search query to find a group of animals (as described in the *Procedures* section below), they were

Figure 1: The largest envelopes in the paper prototype, representing the four branches of the hierarchy

asked to place the envelopes representing those groups on top of the Dana and Kyle cards.

Figure 2: The envelopes representing the subcategories under Animals in the paper prototype, with animal cards displayed for one envelope

Computer Prototype

The computer prototype, currently called “QueryKids”, was built as a module of KidPad, a collaborative application for children [3] [6]. Like KidPad, it makes use of Jazz [2], a Java package that provides zooming and panning capabilities, and MID [10] a Java package that gives it the ability to obtain input from multiple mice. It runs on Windows 98 and uses a Microsoft Access database to hold metadata about the 45 animals in the data set.

The prototype consisted of three areas: two browsing areas and a search area. Although children were shown the browsing areas, only the search area was used in this study. The search area displayed four icons representing the four main branches in the hierarchy: *Animals*, *Where They Live*, *How They Move and What They Eat* (Figure 4). Each icon was composed of a text label and a representative picture.

To move down through each branch, the user clicks on the

Figure 3: Illustrations of the search kids, Dana and Kyle, that were used with the paper prototype

“shadow” under one of the four main icons. To specify search parameters, the user clicks on the icon or icons representing those parameters. So, for example, to conduct a search for “birds that live on land and water”, one might first click on the shadow beneath the *Animals* icon to reveal the subcategories, then click on the *Birds* icon to make it a search parameter. Next, one would click on the shadow below the *Where They Live* icon, revealing its subcategories, and click on *Land and Water* to add it as a second search parameter (Figure 5).

As search parameters are selected, their icons move to the two children in the upper left corner of the screen. The metaphor as explained to the children in this study was that these two children (called Kyle and Dana) are “search kids”, and that you are “giving” them icons of things that you want them to find. When items are given to Kyle and Dana, the software runs a query that automatically performs a union among items selected from subcategories within the same branch, and an intersection among items selected from subcategories across different branches. The subcategories within any one branch have been defined such that they do not overlap (i.e. an intersection would yield an empty set). Thus, the user does not need to distinguish between intersection and union in specifying a query, but due to the way the categories and the software searching algorithms have been structured, the “intuitive” result will be delivered most of the time.

Any time an icon is added or removed as a search

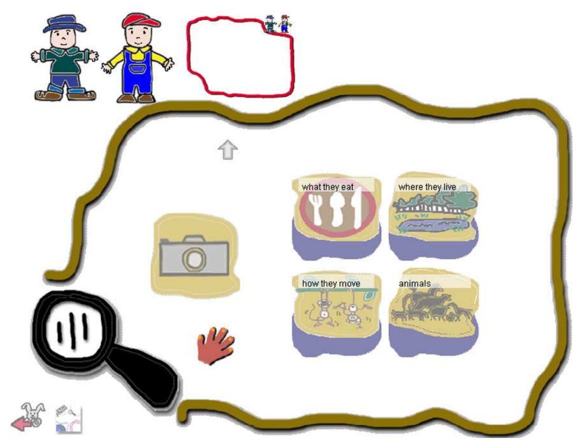

Figure 4: The search area of the QueryKids computer prototype

parameter, the results of the search are immediately displayed in miniature in the outlined area to the right of the search kids. This serves as a “query preview” area for searches as they are in progress, and provides immediate, local feedback regarding the results of the search in progress. The user may then click on the display area to zoom in and examine the search results.

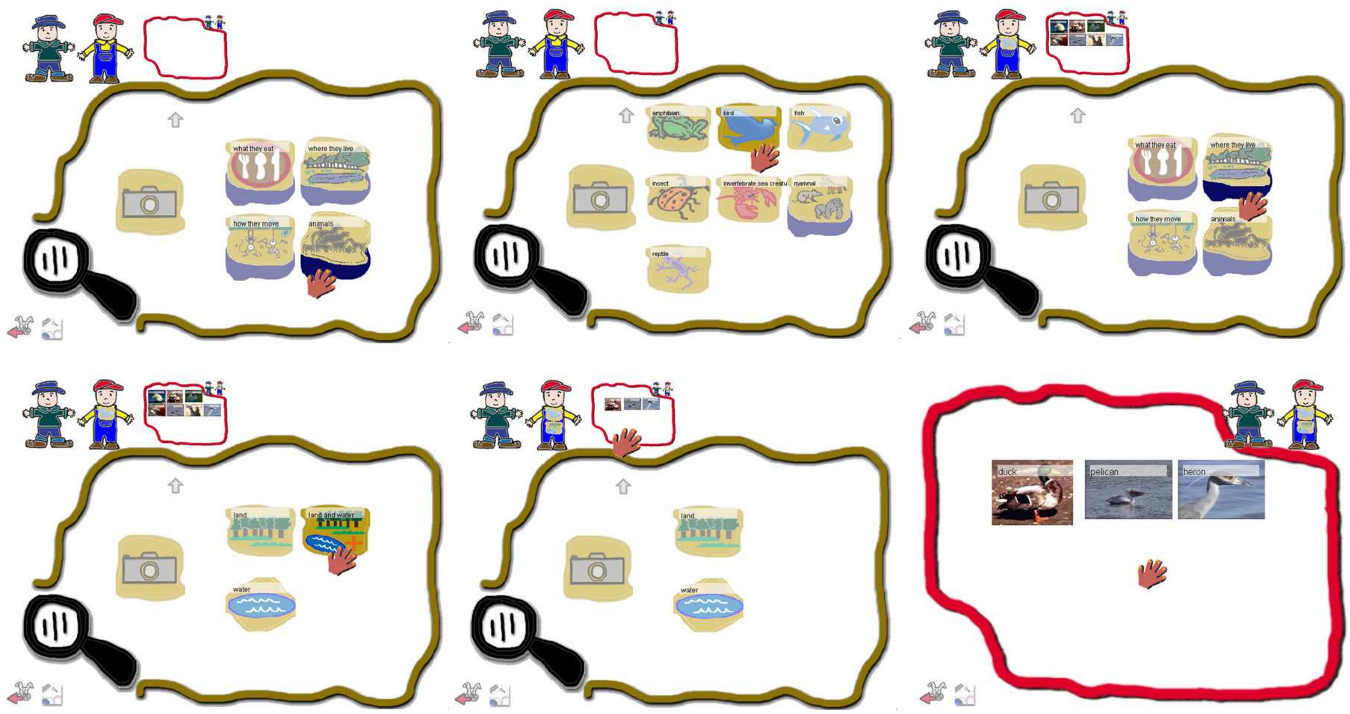

Figure 5: The steps involved in constructing a search query for *birds that live on land and water*

For a more complete description of the QueryKids computer prototype and its design and development, see [5].

Procedures

The children participated in same-sex and same-grade pairs for both paper and computer prototype research.

The participants in the paper prototype group sat on the floor with the four large envelopes arranged on the floor in front of them. The researchers described the task as being like a "treasure hunt", and explained that inside each envelope there were smaller envelopes and inside those were index cards with pictures of animals that the children would be trying to find.

In the computer prototype group, participants sat at a desk, in front of a Sony laptop with the QueryKids application running. All of the prototype functionality was demonstrated, and children were allowed a free-play period of a few minutes to experiment with clicking on icons to see what happened before the experimental procedure began.

For both groups, it was also explained that there were two parts to the research. In the first part, the goal was to find a particular animal, for example, a blue jay. Each child was asked to find four specific animals. The four animals were requested in four different orders, with each animal appearing in each serial position once. The use of these four orders was counterbalanced across prototype condition, grade level and gender groups.

In the second part, the task was to find groups of animals. To help them find groups of animals, children were introduced to the search kids, Kyle and Dana. The participants were told that Kyle and Dana would find groups of animals when given an envelope/icon representing that group. Each participant was asked to construct one single-factor search query (e.g., all insects), one union search query (for example, all reptiles and all amphibians) and one intersection search query (e.g., all birds that live on land). The single-factor search was always first, the union always second and the intersection always third. There were two different sets of specific groups requested for each of the three searches, and each of the children in a pair received a different set.

After the experimental procedure, researchers interviewed the children about their reactions to the task. Children were asked if they thought finding the animals was easy or hard, fun or not, and whether there was anything they would change to make it better or easier.

RESULTS

Two major aspects of children's search behavior were examined in this study: 1) children's **search efficiency** when searching for a specific animal within the hierarchical information structure and 2) their ability to construct a **search query.**

To develop a measure of **search efficiency**, children's responses were recorded when they were asked to find each of the four specific animals in the first section of the study. For the paper prototype group, observers recorded each envelope that the child opened in order. For the computer prototype group, the software logged the sequential history of all mouse clicks. Children's responses were then coded to indicate how many *unnecessary* envelopes were opened or icons were clicked. In other words, search efficiency was the number of search steps taken above the minimum number necessary to find the requested animal, given the branch of the hierarchy chosen by the child. Thus, the higher the search efficiency score, the less efficient the search.

Search efficiency scores were submitted to a 2 (grade) x 2 (gender) x 2 (condition) x 4 (item number) analysis of variance, in which item number served as a repeated measure. Results of this analysis indicated a significant difference between conditions, $F(1,96) = 14.75$, $p < .0001$, a significant condition by gender interaction, $F(1,96) = 4.75$, $p < .05$, and a significant difference between items, $F(3,288) = 2.92$, $p < .05$. Means for the groups involved in these effects are displayed in Table 2.

Condition			
Paper	**Computer**		
0.69	0.28		
Item Order			
First	**Second**	**Third**	**Fourth**
0.67	0.60	0.42	0.29
Gender by Condition			
	Paper	**Computer**	
Female	0.89	0.21	
Male	0.54	0.35	

Table 2: Search efficiency means for significant effects. The lower the score, the more efficient the search

Examination of these means shows that computer searches were significantly more efficient than paper searches. Tukey post hoc tests on the condition by gender interaction indicated that the females' searches were significantly more efficient in the computer condition than in the paper condition, while there was no significant difference for the males. In addition, comparison of the means in the item effect indicates that children's searches became more efficient with each subsequent item, indicating a practice effect. An additional analysis indicated that there were no significant differences in search efficiency for one particular animal vs. another.

To quantify children's **search query** abilities, their responses in the second portion of the study were examined. Their attempts to formulate search queries to find groups of animals were scored as shown in Table 3. Search query scores range from 0 to 1, with 1 being the highest possible score.

Search query scores were analyzed using a 2 (grade) x 2 (gender) x 2 (condition) x 3 (query type) analysis of variance, in which query type (single-factor vs. union vs. intersection) served as a repeated measure. Results of this analysis indicated a significant difference between conditions, $F(1,94) = 14.96$, $p < .0001$, a significant difference between query types, $F(2,188) = 3.12$, $p < .05$, a significant interaction between condition and query type, $F(2,188) = 7.15$, $p < .05$, and a significant interaction between gender and query type, $F(2,188) = 7.15$, $p < .001$.

Means for the groups involved in these effects are displayed in Table 4.

Examination of these means shows that overall, search queries were more accurate in the computer condition than in the paper condition. Tukey post hoc tests on the query type effect indicated that union queries were significantly more successful than intersection queries, while neither differed significantly from the success rate for single-factor-searches. However, this main effect is qualified by two interactions. Post hoc tests on the condition by query type interaction showed that both single-factor queries and intersection queries were significantly more accurate in the computer condition than in the paper condition, but for union queries there was no difference between conditions. In addition, post hoc comparisons on the gender by query type interaction demonstrated that for females union queries were significantly more successful than intersection searches, whereas for males there were no significant differences between the three query types.

Score	Definition
1.00	Completely correct
0.75	Two-factor query, one correct and a taxonomic superordinate for the other
0.50	Two-factor query, one correct or A taxonomic superordinate for a one-factor query or All correct icons/envelopes, with extra incorrects
0.25	Two-factor query, one incorrect and one taxonomic superordinate
0.00	Completely incorrect

Table 3: Scoring system for search query responses

Discussion

In general, children were quite efficient in their searches for specific animals. The overall search efficiency mean for the entire sample was 0.48. This means that, on average, children looked in less than one extra envelope, or clicked on less than one extra icon per search beyond the bare minimum needed to find the animal that they were looking for. So, for the most part, children successfully employed a strategy of trying to find each target animal in as few steps as possible, in an extremely focused and goal-directed manner. Children's ability to use this "fewest-steps" strategy effectively improved over time within the course of the four trials in this section of the research. In addition, children who used the computer prototype searched significantly more efficiently than those using the paper prototype.

The one apparent exception to the use of the fewest-steps strategy occurred in the searches of the females using the paper prototype. Their searches were significantly less efficient (i.e., used significantly more extra steps) than the searches of the girls using the computer prototype or the searches of the boys in either prototype condition. It should be noted, however, that the absolute differences in number of extra steps are small: even for the females using the paper prototype the average search efficiency was only 0.89, still less than one extra envelope opened or icon clicked per search.

Qualitative observations of the children as they engaged in the search tasks led researchers to suspect that a number of the females who used the paper prototype were intentionally *browsing*, rather than engaging in goal-directed, fewest-steps-type searches. They seemed to enjoy looking through all the pictures of animals as a goal in itself, sometimes continuing to look at animal pictures even after the target animal had been found. It's not clear why there was so much less of this intentional browsing behavior with the computer prototype, but perhaps it was due to fact that children were working exclusively within the search area of the QueryKids prototype. This area is clearly structured to support purposeful, goal-directed searches, whereas other sections of the prototype support browsing.

Condition			
Paper	**Computer**		
0.64	0.85		
Query Type			
Single	**Union**	**Intersec**	
0.73	0.81	0.69	
Query Type by Gender			
	Single	**Union**	**Intersec**
Female	0.72	0.85	0.61
Male	0.72	0.75	0.76
Query Type by Condition			
	Single	**Union**	**Intersec**
Paper	0.58	0.79	0.53
Computer	0.87	0.82	0.86

Table 4: Search query accuracy means for significant effects. Scores range from 0 to 1, with 1 most accurate

The second portion of the study focused on children's abilities to construct search queries. Once again, overall, children were strikingly adept at this task. Across the entire sample and all of the search query types, the average accuracy of constructing a search query was 0.72 of a total 1.00. Moreover, the children who used the QueryKids computer prototype achieved an 85% accuracy rate with their search queries, which was significantly higher than the accuracy of those using the paper prototype.

What accounts for this surprisingly high level of performance, especially in light of the research previously cited which has established that children have difficulty with the underlying logical concepts involved in constructing union and intersection searches?

We believe that these positive results are the result of several different kinds of support that were built into the software as "scaffolding" devices. Scaffolding is a well-established educational technique that often enables children to complete tasks that otherwise would be beyond their capabilities [25,28], and has been shown to be an effective learning tool when used by teachers [21]. Recently, scaffolding has begun to be incorporated as a learning support in educational software [8,11,20], and there is evidence to suggest that educational software with extensive scaffolding is more educationally effective than software without such support [22].

There were several kinds of scaffolding support built into the QueryKids prototype. First, the search interface was visually concrete and involved direct physical manipulation of the search elements, both of which were designed to support children in constructing search queries that they would have been unable to accomplish with a typical text-based search tool.

Second, the display of "in-progress" search results on the same screen, while the search query is being formulated, makes it extremely easy for children to see whether their queries have been formulated correctly or not, and to adjust and modify their queries when needed. This immediate, dynamic feedback is one of the major points of difference between the paper prototype and the computer prototype, and probably plays a large role in the significantly better performance of those children using the computer version.

Finally, and perhaps most importantly, because of the way the information was organized and the search software was written, children did not need to distinguish between an intersection search query and a request for a union search. This lightens the cognitive complexity of the task immensely, allowing children to first focus solely on identifying the proper parameters to conduct the search they have in mind.

We believe that the kind of scaffolding described here could serve as a first step toward helping children learn to understand and use Boolean search concepts. Scaffolding is typically designed to be "eased out" as the child becomes more and more capable of completing the task with fewer supports. In future work, we plan to research systematic ways of reducing this support to gradually guide children into constructing queries with the full power of Boolean logic under their control. In addition, we intend to work with younger children (ages 6-7) to see whether or not the current prototype will support their search abilities, and to see how their searching strategies may differ from those of the somewhat older children in this study.

In summary, this study has shown that even young children are capable of efficient and accurate searching. With the support of a visual query interface that includes scaffolding for Boolean concepts, children can use a hierarchical structure to perform searches and construct search queries that surpass their previously demonstrated abilities using traditional search techniques.

ACKNOWLEDGMENTS

This work was supported by the National Science Foundation's DLI-2, Discovery Channel, Patuxent Wild Life Refuge, and the Baltimore Learning Community project. We thank Prince George's County Public Schools for their cooperation and support. The children and teachers from Yorktown Elementary School were critical to this research. They included 106 children in the 2nd and 3rd grades along with their teachers. Also, thanks to Delfin Barral for allowing us to use his illustrations to represent Dana and Kyle in the paper prototype. On-going inspiration and intellectual discussion has come by way of Ben Shneiderman, Catherine Plaisant, Anne Rose, Joseph JaJa, and the KidStory research project supported by the i3, ESE.

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