Children's Use of the Yahooligans! Web Search Engine:

I. Cognitive, Physical, and Affective Behaviors on Fact-Based Search Tasks

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This study reports on the first part of a research project that investigated children's cognitive, affective, and physical behaviors as they use the Yahooligans! search engine to find information on a specific search task. Twenty-two seventh-grade science children from a middle school located in Knoxville, Tennessee participated in the project. Their cognitive and physical behaviors were captured using Lotus ScreenCam, a Windows-based software package that captures and replays activities recorded in Web browsers, such as Netscape. Their affective states were captured via a one-on-one exit interview. A new measure called "Web Traversal Measure" was developed to measure children's "weighted" traversal effectiveness and efficiency scores, as well as their quality moves in Yahooligans! Children's prior experience in using the Internet/Web and their knowledge of the Yahooligans! interface were gathered via a questionnaire. The findings provided insights into children's behaviors and success, as their weighted traversal effectiveness and efficiency scores, as well as quality moves. Implications for user training and system design are discussed.

Background and Purpose

Advances in information technology have transformed the way that users seek and use information. The exponential growth of the World Wide Web (Web) and its ubiquitous adoption as a vital information retrieval tool "is exerting power over the evolution and development of information-seeking behavior" (Nahl, 1998b: 157). Children are more persistent and motivated in seeking information over the Web than in using traditional and online sources (Bilal, 1998; Bilal & Watson, 1998).

What implications will this motivation have for teaching and learning? Are children cognitively and affectively prepared to traverse Web space? Children's cognitive abilities (Siegler, 1991), developmental levels (Piaget & Inhelder, 1969), and information needs (Walter, 1994; Goss, 1997) may impact their information-seeking behavior in IR systems. Use of the Web in schools and the increased access to the Web by children at home raise many issues concerning information-seeking and use, the roles of school librarians and teachers in educating and training, and how well designers of Web engines provide user-centered interfaces that facilitate children's information-seeking.

The search engines facilitate seeking information on the Web. Presently, there are over 500 engines, but only three are designed for children: Yahooligans! (http://www.yahooligans.com), Ask Jeeves for Kids (http://www.ajkids.com), and Super Snooper (http://www.supersnooper.com). Yahooligans! began in 1994 as an engine and directory designed for children ages seven to twelve (Yahooligans!, 1998). Ask Jeeves for Kids was developed in 1996 as an engine and meta-engine; the age group is undefined (Ask Jeeves, Inc., 1998). Super Snooper is a newcomer to the Web and gained recognition in early 1998. The engine does not indicate the age group for which it is designed (Cool Sites Network, Inc., 1999).

While the widespread introduction of OPACs and CD-ROM databases spawned several end-user studies, research on end-users of Web search engines has only started to emerge. This study is part of a research project (Bilal, in progress) that examined children's cognitive, physical, and affective behaviors as they used Yahooligans!

The main purposes of this study were:

- To examine children's cognitive, physical, and affective behaviors as they sought information on a fact-based search task in Yahooligans!,
- To measure children's success in finding information on a fact-based search task.
- To compare the cognitive and physical behaviors between children who succeeded in finding the desired information in Yahooligans! and those who failed.
- To develop a new measure for quantifying traversal effec-

tiveness and efficiency scores, as well as quality moves between children who succeeded in finding the desired information in Yahooligans! and those who failed.
- To investigate the relationship between children's characteristics (i.e., reading ability, prior Internet/Web experience, prior knowledge of the Yahooligans! interface, domain knowledge, and topic knowledge) and their success in using Yahooligans!

Results gained from this research project will contribute to both the cognitive and affective theories of children's information-seeking behavior, and to improvement in system design.

Relevant Literature

Research on children's search behavior in using information retrieval systems, such as CD-ROM databases and OPACs provides a context for their information-seeking behavior and the problems likely to be encountered. Does this behavior transfer to the Web environment?

In using online public access catalogs (OPACs), children's success rate ranged from 10% (Edmonds, Moore, & Balcom, 1990) to 88% (Hirsh, 1997). Children's search strategies varied with grade level, search tasks, domain and topic knowledge, and the design and structure of the OPAC used (Hirsh, 1997; Borgman et al., 1995; Solomon, 1993). In using a CD-ROM encyclopedia, children had difficulties in finding search terms and in spelling, and lacked conceptual understanding of how the encyclopedia worked (Marchionini, 1989).

Children and the Web/Internet

To date, only a few studies have examined children's use of the Web and search engines. In a pilot study, Bilal (1998) investigated the searching behavior and success of 22 seventh grade science students in using the Yahooligans! search engine to find information on a research task. Children failed in their quest mainly due to their lack of knowledge of how to use the engine. Children queried Yahooligans! in natural language, a search syntax not supported by the engine; used vocabulary that is either too broad or too specific, scrolled homepages minimally, and rarely read the content of homepages they visited. Yahooligans! misleading titles of the hyperlinks, poor abstracting of hyperlinks, lack of spell-checking techniques, poor indexing of sites and homepages, absence of a natural language interface, and the engine's small database size surfaced as major problems in using Yahooligans!

In a study of a group of elementary children's Internet searching, Schacter, Chung, and Dorr (1998) found that most children sought information by employing browsing strategies and that a few used multiple synonyms to refine their queries. When querying the Internet, 62% of the children used inappropriate syntax (i.e., natural language). Children searched more successfully when the assigned task was vague than when it was specific.

Kafai and Bates (1997) investigated how elementary school children interacted with the Internet by building annotated directories of Web sites for other children. Six elementary classrooms, grades one through six, were involved in the "SNAPdragon" project. Children needed instruction and assistance at different stages of their search process to improve their search results. Typing, spelling, limited vocabulary, search strategy formulation, and Boolean logic skills limited their abilities in finding appropriate resources.

Wallace and Kuperman (1997) examined Web search activities of four pairs of sixth graders on an ecology project. Children made many navigational moves, but rarely examined more than five links from the latest hit list, tended to seek answers rather than aim for understanding, did not evaluate the sources found, used repetitive keywords in their searches, employed natural language in their search statements, and had problems with broadening and narrowing searches.

Using a smaller sample size, Lyons, et al. (1997) examined four science students' Web activities, a pair from sixth grade and another from ninth grade. The students had problems finding appropriate vocabulary to use in their search statements, resorted to books to find suitable search terms, and applied the Boolean operator AND frequently but incorrectly.

The parameters employed in these Web, OPAC, and CD-ROM studies make it difficult to identify typical attributes of children's information-seeking behavior because each of them examined children of a certain grade level and assessed their behavior on certain search tasks as they used various information retrieval systems. However, these studies identified common problems with children's search strategy formulation and refinement, search syntax, concept selection, and spelling.

Studies of Web Search Engines

Evaluation of information retrieval via Web search engines provides an indication of how well end-users interact with these IR systems. The few studies that employed measures to investigate Web search engine performance cannot be easily compared because they neither examined the same engines nor utilized the same metrics for evaluation. To date, only one study has compared the search features and evaluated the retrieval performance of three Web search engines designed for children: Yahooligans!, Ask Jeeves for Kids, and Super Snooper (Bilal, 1999). The engines' retrieval performance was compared on three types of searches (i.e., single keyword, multiple keyword, and natural language) that were formulated by twenty-two seventh grade science students: The retrieval performance criteria included: retrieval output, relevance, overlap, and redundancy. The study shed light on the strengths and weaknesses of each engine and its appropriateness to specific queries. The weaknesses found included retrieval interface design, i.e., categories and sites within categories (Yahooligans!); the display of results with option boxes and pull down menus (Ask Jeeves for Kids); lack of descriptions of returned links (Ask Jeeves for Kids), of a speller (Yahooligans!), of a natural language interface (Yahooligans! and Super Snooper), of an online help (Super Snooper); as well as limited search instructions under online help (Yahooligans! and Ask Jeeves for Kids), and small database size (Yahooligans! and Ask Jeeves for Kids).

Research has shown that popular engines, such as Alta Vista, Infoseek, Lycos, OpenText, Excite, and WebCrawler also had problems, especially with query refinement, application of Boolean logic, and poor indexing and abstracting of returned results. The engines lacked thesauri and concept mapping to assist with the search process, and provided users with little control over managing the results. Precision ratios varied with the type of query and the measurement used. (Su, Chen, & Dong, 1998; Meghabghab & Meghabghab, 1996; Chu & Rosenthal, 1996; Ding & Marchionini, 1996; Leighton, 1995).

One can imagine that children who experience problems in using well-structured information retrieval systems, such as OPACs and CD-ROMs, who have limited cognitive developmental ability, and who lack or have inadequate knowledge and skills for using search engines may therefore search the Web in vain with great frustration (Bilal, 1998). Examination of children's traversal behaviors in Yahooligans! could provide an understanding of the learning requirements and cognitive demands the engine imposes on children. This understanding will have implications for user Web training, and could lead to improvement in Yahooligans! design.

Research Questions

"Information seeking incorporates the experience of interactive thoughts, actions, and feelings in the process of construction" (Kuhlthau, 1993, pp. 8–9). Thoughts relate to the cognitive domain, actions or physical behavior to the sensorimotor domain, and feelings to the affective domain. In this study, children's cognitive behavior is defined as "behavioral acts that relate to cognition, i.e., knowledge, comprehension, problem solving, and critical interpretation"; physical behavior as "behavioral acts that are externally observable, i.e., visual perception, speaking, and navigating"; and affective behavior as "behavioral acts that relate to feelings, i.e., interests, values, motivation, purposes, and goals" (Nahl, 1997, pp. 13–14). In this study, answers were sought to these questions:

(1) What cognitive behavior do children demonstrate to find the answer to the fact-based search task in Yahooligans!?
(2) What physical behavior do children demonstrate to find the answer to the fact-based search task in Yahooligans!?
(3) Is there a difference in cognitive and physical behaviors between children who succeed in finding the correct answer to the fact-based search task and those who do not?
(4) What difference in traversal weighted effectiveness and efficiency scores, as well as quality moves does the "Web Traversal Measure" reveal between children who succeed in finding the correct answer to the fact-based search task and those who do not?
(5) What criteria do children use to judge relevance of the hyperlinks they activate and the homepages they visit?
(6) To what extent do the following characteristics impact children's success in finding desired information in Yahooligans!:

a. Experience in using the Internet/Web
b. Knowledge of the Yahooligans! search and retrieval interfaces
c. Domain knowledge (i.e., science)
d. Topic knowledge (i.e., alligators)
e. Reading ability

(7) What affective states do children experience in using Yahooligans!?

A fact-based task is one that requires a single, straightforward answer. It is data-based, usually uncomplicated, and may not require research to find the answer. This task was imposed by the children's science teacher for the purpose of practicing use of the Web.

Methodology

This study employed both quantitative and qualitative inquiry methods. The quantitative method provides empirical data about the behavior, success and failure, errors committed, and knowledge of Web and Yahooligans! navigation and use. This method requires that these observations be recorded and viewed at a later time. Lotus ScreenCam (http://www.lotus.com), a Windows-based software package that records and replays captured activities in Web browsers, such as Netscape Navigator, was used to achieve this goal.

The qualitative method generates data from interviews and provides an understanding of the behavior and processes that result from the quantitative method. The researcher developed three instruments: 1. Internet/Web Quiz, 2. Exit interview, and 3. Teacher Assessment of Student Characteristics.

The Setting

This study took place at a middle school, grades 7–9 (designated Middle School for confidentiality purposes) located in Knoxville, Tennessee. The school was selected based on these criteria: (a) the school librarian's willingness to participate in the project, (b) the seventh-grade science teacher's involvement in integrating the Internet into the science curriculum and her willingness to participate in this study, (c) the school administration's willingness to take part in the project, and (d) the availability of an Internet connection.

At the time of the study, the school's enrollment was 1,080. The socioeconomic status was low since sixty percent of the students qualified for a free lunch. The teacher of the three seventh-grade science classes selected for this experiment was a recipient of "twenty-first century classrooms" funding, an initiative established in 1992 by the Tennessee Department of Education to provide hardware and software support for teachers who use technology in their curricula. The library at the Middle School was the site for this experiment. Prior to the beginning of the experiment, the library had two computers with an Internet connection. Three additional computers were networked and connected to the Internet to accommodate use of five computers at a time. Before beginning the experiment, Lotus ScreenCam version 2.0 was installed on each of the five computers and pre-tested for proper software and hardware operation. Captured searches were saved locally and transmitted to the researcher's workstation.

Library Instruction

Library instruction in the Middle School is introduced over the span of a year in the sixth grade and reviewed in the seventh and eighth grades. This instruction covers a routine orientation to the library's rules and procedures, the use of the Accelerated Reader program, the online catalog (OPAC), Dewey classification system, print and online periodical indexes, and the use of the Web. The latter is offered on an as-needed basis as part of the curriculum. Web instruction covers basic search strategies with an overview of search engines and an emphasis on Alta Vista. Searching the Web involves minimal use of the engines, however, and maximum utilization of specific Web sites bookmarked by both teachers and the school librarian.

Participants

Due to the School's Internet Use Policy, which requires parental consent for using the Internet, parental permission was needed prior to selecting the participants. In order to represent all seventh-grade science students in this study, parental permission was sought for all ninety students enrolled in these three classes. Thirty permission slips were received. After the students' consent was sought, the sample was twenty-five. Three students were involved in the pilot-testing, resulting in twenty-two students who remained for the duration of the study.

Search Task

The teacher assigned the following topic to search in Yahooligans!: *How long do alligators live in the wild, and how long in captivity*? The author researched the topic in Yahooligans! prior to the experiment and found the correct answer.

Yahooligans!

Yahooligans! is a search engine and directory designed for children ages 7 to 12. It allows for both keyword searching and browsing by subject categories or headings. Retrieval from Yahooligans! includes the number of categories and the number of sites within each category. It indexes titles of homepages, Uniform Resource Locators (URLs), and descriptions from homepages, although it is unclear how extensive the indexing of these descriptions is. The database is built through automated search robots that crawl new sites at various locations, as well as through user recommendations of specific sites. Yahooligans! does not employ advanced search syntax, such as Boolean logic, proximity, nesting, or natural language (Yahooligans!, 1994–1998).

Instruments

The researcher developed three instruments to collect the empirical data: (1) Internet/Web Quiz, (2) Teacher Assessment of Student Characteristics, and (3) Exit Interview. The Quiz comprised two main sections: Experience with the Internet/Web (six questions), and Fun quiz about Yahooligans! (seven questions). The Quiz took an average of 10 minutes to complete. The Teacher Assessment instrument elicited the teacher's ratings of the children's topic knowledge of the task (i.e., alligators), domain knowledge of the task (i.e., science), and reading ability. The teacher was unable to rate the children's knowledge of computers or the Internet/Web. The Exit Interview instrument comprised questions about relevance judgment and the Yahooligans! retrieval interface features, as well as affective states. It took an average of 20 minutes to complete. These instruments were pilot-tested and refined.

Measurement

The "Web Traversal Measure" was developed here for the purpose of measuring children's weighted traversal effectiveness and efficiency scores, as well as the quality of their moves in using Yahooligans! Each possible search move and hyperlink activation was assigned a score based on its degree of relevance to the search task. A score of 1 was assigned to a relevant search and/or hyperlink activation, a score of 0.5 for a "semi-relevant" search and/or hyperlink activation, and a score of 0 for an irrelevant search and/or hyperlink activation. The higher the score, the more relevant or appropriate traversal actions were. The measure takes into account Transcribed Moves (TM), Selection Actions (SA), and weight for each SA (WSA).

The Transcribed Moves (TM) are *moves* that include *all traversal behaviors*. These are searching (typing a search statement using either single concepts, multiple concepts,

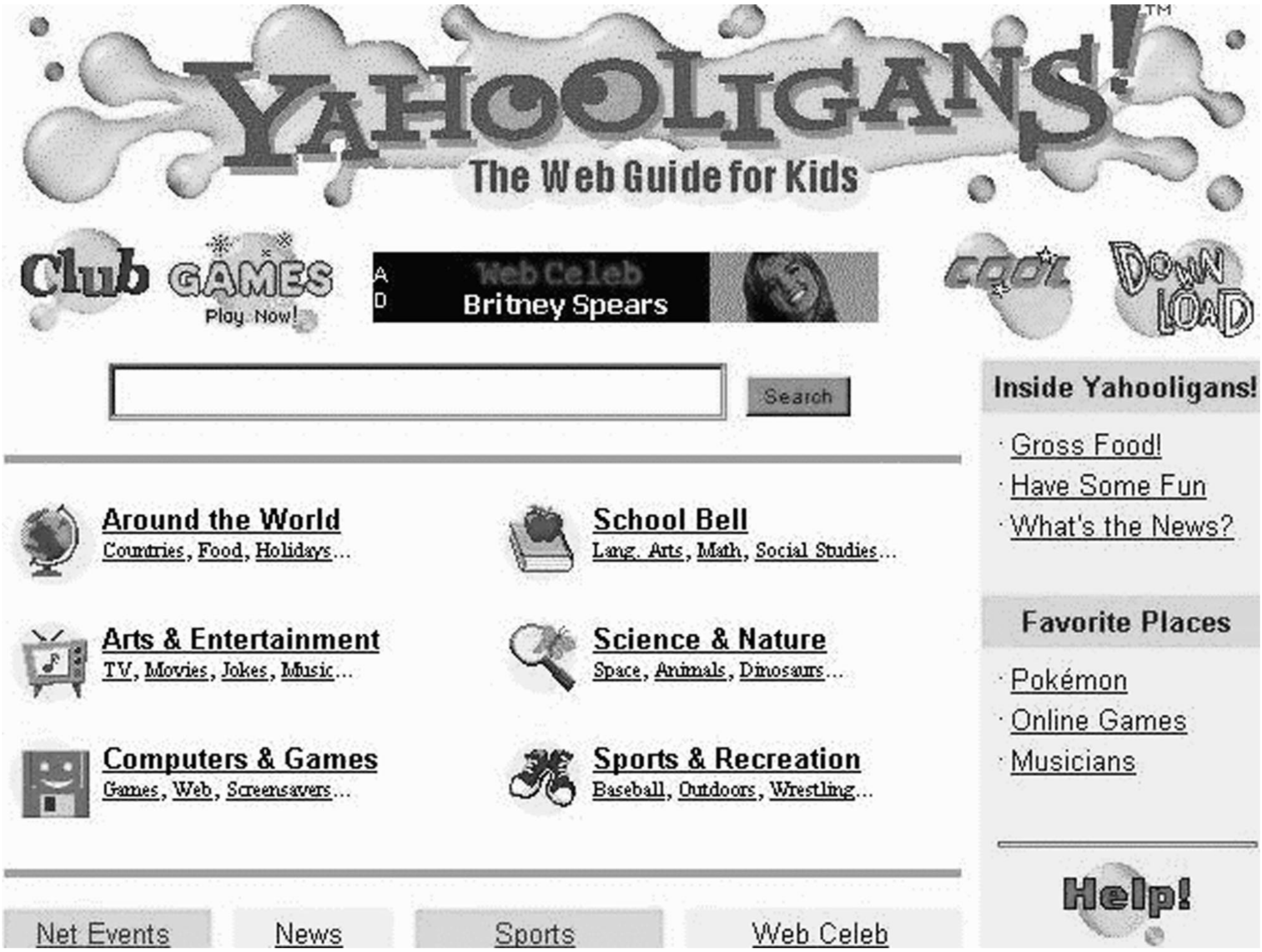


FIG. 1. The Yahooligans! search interface.

and natural language), browsing (visiting subject categories, subcategories, Web sites, and homepages), looping (reactivation of previously visited Web sites and/or of previously executed searches), backtracking (use of Netscape *Back* button), screen scrolling, mouse movements (moving the mouse over text and hyperlinks), and exploratory moves (activating Netscape or Yahooligans! features, such as Help, Search, URL location bar, etc.). Selection Actions (SA) are *moves* that include only *searching* and/or *hyperlink activation and looping*. These moves exclude backtracking, scrolling, mouse movements, and exploratory moves. Each SA was given a weight (WSA), described in Appendix A.

Scoring Method

All possible search moves (e.g., alligator, wild, captivity, etc.), as well as all possible hyperlink activation moves (e.g., Science & Oddities) a child might make in Yahooligans! were assigned a score of either 1 (relevant), 0.5 (semi-relevant), or 0 (irrelevant). The Yahooligans! subject category *Around the World* and its subcategories *Countries*, *Politics*, *History*, for example, were assigned a score of 0. The subject category *Science & Oddities* (currently Science and Nature) and its subcategory *Animals* were assigned a score of 1, whereas the two other subcategories *Space* and *Robots* under *Science & Oddities* were assigned a score of 0. Relevance was determined as follows:

1 = Relevant, was assigned to a search or hyperlink which, based on its formulation/title and/or description, *is appropriate or appears to lead* to the desired information and *it does.*
Search Example: **alligator**
Hyperlink Example: **Science and Oddities: Living Things: Animals**

0.5 = Semi-relevant, was assigned to a search or hyperlink which, based on its formulation/title and/or description, *is appropriate or appears to lead* to the desired information but *does not.*
Search Example: **alligator in captivity**
Hyperlink Example: **Wildlife**

0 = irrelevant, was assigned to a search or hyperlink which, based on its formulation/title and/or description, *gives no indication* of and *does not contain* information relating to the search task.
Search Example: ***Life lines***
Hyperlink Example: **Biology Database**

Examples of this "scoring method" under Yahooligans! category Science & Oddities.

Category	**Weight**
Science and Oddities	1
Animals	1

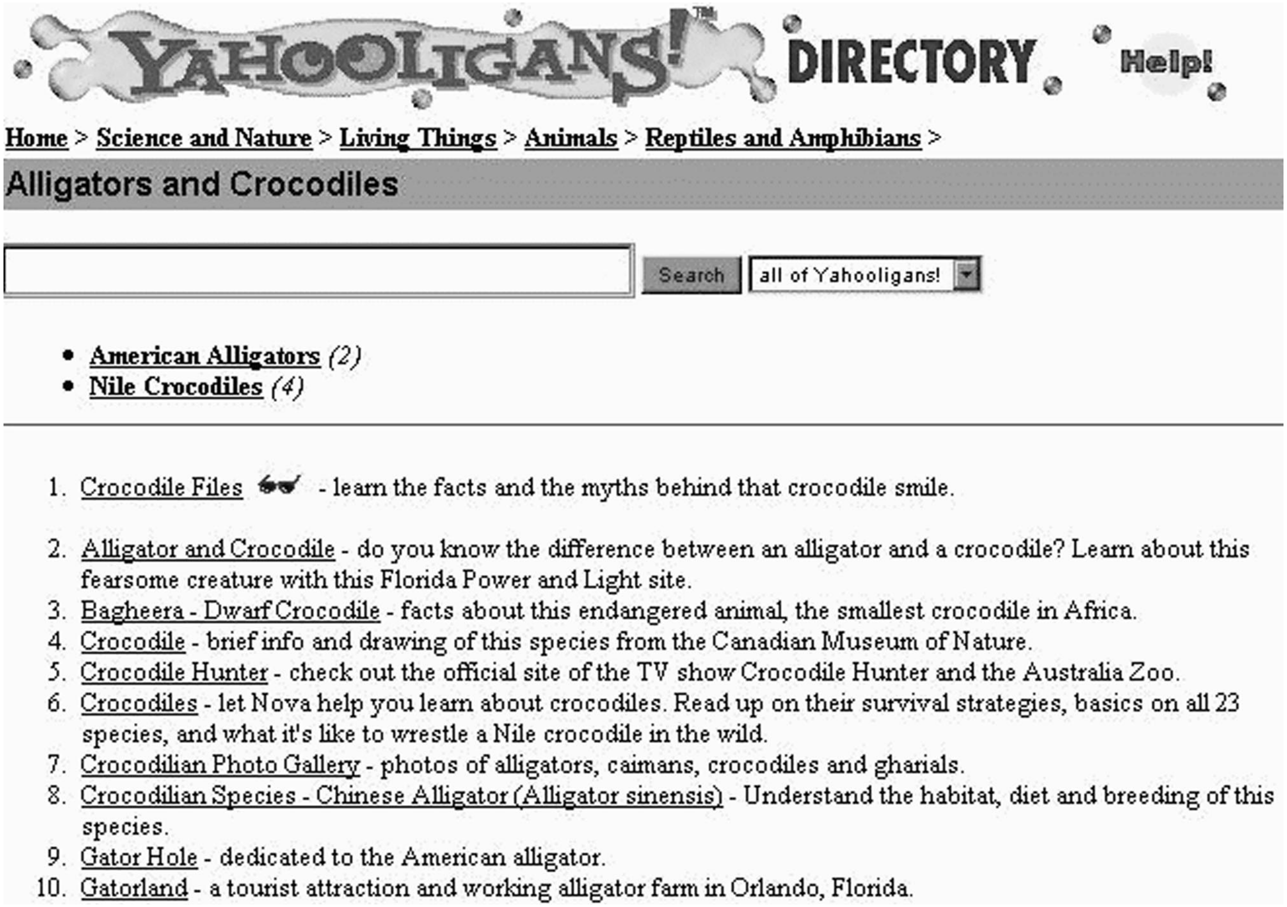


FIG. 2. The Yahooligans! retrieval interface.

Mammals	0
Marine Life	0
Organizations	0
Pet Care	0
Reptiles and Amphibians	1
Wildlife	0.5
Worms	0
Zoos	0.5

To quantify children's weighted traversal effectiveness and efficiency scores, as well as the quality of their moves, these three parameters were derived from the Transcribed Moves (TMs), Selection Actions (SAs), and Weighted Selection Actions (WSAs):

Weighted effectiveness score: $\sum_{i=1}^{i=n}(WSA_i \times SA_i)/\sum_{j=1}^{j=m}(TM_j)$ (Equation 1), where n is the total number of SAs and m is the total number of transcribed moves to the target hyperlink. Equation 1 is the sum of the weight for each Selection Action multiplied by the Selection Action and divided by the sum of Transcribed Moves to the target hyperlink (i.e., *Gator Hole*). Each Selection Action (SA) is assigned a weight (WSA) based on its relevance. This weight can be either 0 (irrelevant), or 0.5 (semi-relevant), or 1 (relevant). As seen in Appendix A, each TM is a single move, and only a "meaningful" TM is an SA move. Screen scrolling which is a TM, for example, is not an SA move, whereas typing the concept *alligators* is both a TM and an SA move. If a TM is an SA move, then it is given the number 1 to indicate it is a single move. If a TM is not an SA, then it is given a 0. Thus, not every TM move is a "meaningful" SA move. The number 1 next to each TM indicates a move and *not a value or weight*. Similarly, the number 1 in the SA column indicates a "meaningful" TM and *not a weight given to a TM*. The number 0 in the SA column means that the respective TM is not an SA. Further, a weight (WSA) is only assigned to the "meaningful" SAs based on relevance as indicated earlier. In Appendix A, for example, seven SAs are relevant and have a weight of a 1 each, and one SA is semi-relevant and has a weight of 0.5.

Weighted efficiency score: $\sum_{i=1}^{i=n}WSA_i/\sum_{j=1}^{j=k}TM_j$ (Equation 2), where n is the total number of SAs and k is the total number of all TMs. Equation 2 is the sum of the weight of each SA divided by the sum of all TMs.

Quality moves: $\sum_{i=1}^{i=n}SA_i/\sum_{j=1}^{j=k}TM_j$ (Equation 3), where n is the total number of SAs and k is the total number of all TMs. Equation (3) is the sum of SAs divided by the sum of

TMs. This parameter quantifies the percentage of "meaningful" moves a child makes during traversal.

Application of Equations 1, 2, and 3 to the data in Appendix A.

A child made 20 total Transcribed Moves (TMs) of which only 8 TMs were "meaningful" (equals 8 SAs). Seven of these SAs are relevant and given a weight of a 1 each; one SA is semi-relevant and is given a weight of 0.5. The total weight for these SAs is 7.5 ($\sum_i WSA_i$) The child reached the target hyperlink *Gator Hole* at move number 18.

Based on Equation 1, the child's Weighted Effectiveness Score becomes:

$$\sum_{i=1}^{8} (WSA_i \times SA_i) / \sum_{j=1}^{18} (TM_j) = 7.5/18 = 42\%$$

Based on Equation 2, the child's Weighted Efficiency Score becomes:

$$\sum_{i=1}^{8} WSA_i / \sum_{i=1}^{20} TM_i = 7.5/20 = 37.5\%.$$

Based on Equation 3, the child's Quality Moves becomes:

$$\sum_{i=1}^{8} SA_i / \sum_{i=1}^{20} TM_i = 8/20 = 40\%.$$

Procedure

The experiment began in April 1998. The teacher informed the children about the purpose and nature of the project. The researcher reiterated this information before the children signed the consent form to participate in the study. Each child was assigned a number and given a folder labeled "My Web Searches." Children were drawn five at a time from their science class, and were taken to the school library. Children took the Internet/Web Quiz and were placed at different computers to start their search sessions. Instructions for using Yahooligans! were not provided, but assistance was given as needed.

The experiment for this part of the research project occupied one day. Prior to searching, children were instructed to (a) perform the assigned task in Yahooligans! only, (b) limit search time to thirty minutes, (c) highlight the best answer using the mouse, (d) print the answer and place it the Web folder, (e) highlight the answer on the printout with the marker located in the folder, and (f) announce the completion of the search session to the researcher and/or the school librarian. Additionally, children were instructed to report problems immediately. When technical problems occurred, children were given additional time to complete the task.

Limitations of the Study

This study was limited to seventh graders and in specific science classes. It took place at one middle school, and used only Yahooligans! The children who participated in this study may not represent the traversal and affective behaviors of all middle school students in Tennessee, nor may they represent the whole population of seventh-grade science students.

A second limitation includes the reliability of the children's affective states gathered from the exit interview. Unlike the quantitative method that provided one hundred percent accuracy of children's behaviors in using Yahooligans!, the qualitative method using an exit interview relied on children's perceptions of and feelings about their experience with the search engine. This experience was not checked against sources, such as videotapes of traversal activities or verbalization during traversal. Therefore, the reliability of the interview data may be affected.

A third limitation concerns the small sample size (22 children), which may impact the external validity or generalization of the results of this study to the whole population of seventh grade children.

Results

The results are presented within the context of the seven research questions posed. Due to Lotus ScreenCam failure to replay eight recorded sessions from the beginning to the end, the data reported here is based on fourteen instead of twenty-two Web sessions.

1. What cognitive behavior do children demonstrate to find the answer to the fact-driven search task?

Children's cognitive behavior was examined in regard to their Selection Actions (SA) which included keyword searching, browsing by subject categories and subcategories, keyword searching within subject categories, and looping (i.e., reactivation of a search or hyperlink).

Search strategy

Search strategy is a process of expressing one's information need in an information retrieval system. In their approach (i.e., initial move), most children (64%) represented their need using single concepts and multiple concepts. Thirty-six percent (36%) browsed under subject categories. In subsequent moves children searched by keyword and natural language.

Children used the concrete concept *alligator* and its plural form *alligators* from the search query: *How long do alligators live in the wild and how long in captivity*? The singular form was employed 15 times and the plural one 36

TABLE 1. Children's Keyword Search Formulations in Yahooligans!

Single concept	Frequency/no. of hits	Multiple concepts	Frequency/no. of hits	Natural language	Frequency/no. of hits
alligator	15/1-C, 15-S*	wild alligators	1/1	alligators in the wild	2/0
alligators	36/1-C, 15-S	alligator captivity	1/0	alligators in captivity	1/0
animals	7/4-C, 157-S	life lines	1/0	alligators life in the wild	1/0
lifespans	1/0-C, 0-S	animal captivity	1/0	alligators in wild	1/0
age	1/1-C, 65-S	alligator life	1/0	lifespans of animals	1/0
captivity	1/0-C, 0-S			alligator in the wild	2/0
				alligator in captivity	2/0
alligatorlive	2/0-C, 0-S				
wild	1/6-C, 118-S				

C = Category; S = Site.

times (Table 1). All nine children who began their initial moves using keywords typed either *alligator* or *alligators*, except for one who entered the term *life spans*. Children's subsequent moves varied in number (6–28); their traversal process showed a pattern of moving back and forth between searching and browsing — from using natural language, to visiting sites, to browsing under subject categories, and to searching by keyword within subject categories. One child, for example, followed these traversal moves: (1) typed the term *alligator*, (2) clicked on the site *Crocodilian Species*, (3) typed the phrase *alligators life in the wild*, (4) search looped step 3, (5) clicked on the site *St. Augustine Alligator Farm*, (6) typed the term *alligators*, (7) clicked on the category *Science and Oddities: Animals: Reptiles: alligators and Crocodiles*, (8) clicked on the target hyperlink *Gator Hole*, (9) hyperlink looped to step 7, (9) searched under *alligators in wild*, *lifespans of animals*, *wild alligators*, and *alligators* within the category in step 7, and (10) clicked on the site *Gatorland*. These moves excluded backtracking, scrolling, mouse movements, and the like actions. This child activated the target hyperlink *Gator Hole* in step 8, but did not examine its home page; instead, the child continued searching and browsing and ended his/her Web session unsuccessfully.

In following moves, a few children searched under other concrete terms, such as *captivity* and *wild*, and manipulated search term relations by employing abstract concepts that are either semantically related (e.g., *age*, *lifespans*) or hierarchically related (e.g., *animals*). This approach indicates that these children understood the relationship among these concepts. A few children also formulated statements with multiple concepts and natural language phrases based on the concepts they used in their keyword searches. One child, for example, evolved a strategy — from typing the term *alligator*, to *wild alligators*, to *alligators in the wild.*

Children employed both searching and browsing methods to complete a goal-oriented task that required finding a specific answer to a query. In fact, searching and browsing are inclusive activities; and shifting back and forth between them may be part of a user strategy that is constantly evolving (Bates, 1989). Being a dynamic hypermedia system, the Web encourages this type of task switching, especially in search engines, such as Yahooligans!, that support both searching and browsing by subject categories. The fact that children were not given instructions to either search by keywords or browse under subject categories as they interface with Yahooligans!, and the fact that they only asked for assistance when technical problems occurred during traversal, indicate that they were comfortable with their problem-solving process. Children were "initiators" trying to learn about the appropriate form of search formulation in the engine to find the target information and when this goal failed, they sought alternative strategies, such as browsing under subject categories and searching by keyword within subject categories. Children were "divergent thinkers," creative," and managed to "negotiate" different strategies. Their frequent looping of identical hyperlinks and searches, however, suggest disorientation during traversal, novice Web navigational skills, limited "sequential" thinking strategies, and lack of focus on the task.

Information retrieval problems

The search strategies children employed impacted their information retrieval. While utilization of single concepts, such as *alligator* and *alligators*, for example, resulted in a few hits (1 category and 15 sites) and retrieved the target hyperlink *Gator Hole*, use of concepts, such as *captivity*, *alligator captivity*, *life lines*, *animal captivity*, and *alligator life* retrieved zero hits (Table 1). This failure was mainly due to Yahooligans!' selective indexing of the sites and homepages in its database. An example of this indexing problem is represented in this paragraph that was extracted from the target home page that contained the correct answer to the query: "*Alligators in the wild are believed to live 35–50 years. In captivity, their lifespan may be significantly longer, perhaps 60–80 years*." Children utilized the keywords *alligators*, *wild*, *captivity*, and *lifespan* appearing in this paragraph in their search statements, but only the term alligator(s) returned hits.

Another retrieval problem resulted from searching by natural language. In fact, this search formulation was employed in subsequent traversal activities rather than initial moves. The five children (35%) who adopted natural language searching were most likely unaware that Yahooligans! did not support this type of search syntax. This was evident in their reformulation of natural language phrases when failure occurred. One child, for example, typed *alligators life in the wild*, revised it to *alligators in wild*, then entered *lifespans of animals.* Lack of search instructions, search examples, and error recovery methods from both Yahooligans!' search and retrieval interfaces increased search repetition under inappropriate syntax. In addition, the limited instructions and guidance provided under Yahooligans!' online *Help* compounded children's retrieval problems.

Children's natural language searching in Yahooligans! is not a new phenomenon. Earlier studies of children's search behavior in information retrieval systems, such as OPACs and CD-ROM databases, found that children employed this type of searching frequently (Borgman et al., 1995; Solomon, 1993; Marchionini, 1989). A recent study of children's Internet searching on two types of search tasks confirmed these findings (Schacter, Chung, & Dorr, 1998). A search engine designed for children, such as Yahooligans!, should build on both children's cognitive ability and behavior. Implementation of a natural language interface, for example, would better support children's information-seeking in Yahooligans!

A few children were confronted with information overload that resulted from searching under the broad term *animals.* Use of this term returned 4 categories and 157 sites; and necessitated selection of the appropriate category (*Science and Oddities: Living Things: Animals*) and the subsequent subcategories *Reptiles and Amphibians; Alligators and Crocodiles* to arrive at the target site with the target hyperlink. It was apparent that children who were confronted with a high number of hits were uncertain about their navigational decisions. One child, for example, typed *animals* within the category *Science and Oddities*, scrolled down the screen, moved the mouse over the hyperlinks, paused, scrolled up, then typed *alligators,* clicked on the site *Jackson Zoological Park*, made several moves before he/she activated the subcategory *Animals*, looped this subcategory twice, made additional search and browse moves, and finished his/her Web session unsuccessfully.

There were two instances of misspelling. One child typed *aligator* but immediately recovered the error by correcting the spelling and another one typed *alligatorlive* twice, but instead of correcting the spelling, the child initiated a new search. Although children in this study committed a very few spelling errors, Yahooligans!, like other engines designed for children (i.e., Ask Jeeves for Kids and Super Snooper), should support a spell-checking technique to enhance children's spelling skills and reduce retrieval failure.

TABLE 2. Children's Subject Browsing in Yahooligans!

Subject Category	Frequency
Science and Oddities: Animals: Reptiles: Alligators and Crocodiles	23
Science and Oddities	7
Science and Oddities: Animals: Zoos	2
Animals	5
Reptiles	2
Alligators and Crocodiles	2
Animals: Myths and Legends	1
Around the World: U.S. States and Florida	1

TABLE 3. Frequency of Children's Keyword Searching Within Subject Categories in Yahooligans!

Science and Oddities
Alligator (2)
Alligators (5)
Animals (3)
Reptiles (1)
Science and Oddities: Animals
Alligators (1)
Science and Oddities: Animals: Reptiles: Alligators and Crocodiles
Wild (1)
Alligators in wild (1)
Live (1)
Alligators (1)

Browsing strategy

"Browsing is an interactive process of skimming over information and selecting choices. Browsing relies on recognition knowledge and requires less well-defined search objectives than does directed keyword searching" (Borgman, et al., 1995, p. 666). Thirty-six percent (36%) of the children began traversal by browsing under the appropriate subject category *Science and Oddities* (currently *Science and Nature*). This selection denotes children's understanding of the search task and their ability to categorize the topic under the appropriate subject hierarchy. This ability was most likely influenced by their adequate domain and topic knowledge, as revealed by their science teacher.

In subsequent moves, two children activated the subcategory *Animals*, and three searched by keyword within the subject category *Science and Oddities*. Although these children began traversal by browsing under an identical subject category, their traversal process varied. Like the children who started their initial moves using keywords, these children shifted back and forth between browsing categories, visiting sites, searching by keywords within subject categories, and looping searches and hyperlinks. Their traversal actions ranged from 8 to 37.

Regardless of their initial moves, however, all children selected appropriate subject categories to browse. As shown in Table 2, the most frequent ones were *Science and Oddities: Animals: Reptiles: Alligators and Crocodiles* (23 times), *Science and Oddities* (7 times), *Science and Oddities: Animals: Zoos* (2 times). They also browsed under appropriate subcategories, such as *Animals* (5 times), *Reptiles* (2 times), and *Alligators and Crocodiles* (2 times). As shown in Table 3, children's keyword searching within subject categories included: *alligators* (within *Science and*

Oddities: Animals); and *wild*, *alligators in wild*, *live*, and *alligators* (within *Science and Oddities: Animals: Reptiles: Alligators and Crocodiles*).

Children's preference for keyword searching (64%) to browsing (36%) as they interfaced with Yahooligans! may have been influenced by the query itself, the interface design of Yahooligans!, as well as children's problem-solving style. The fact-driven query was precise and included concrete keywords that reflected the subject matter of the search task. The fact that Yahooligans! places its *Search* box above its subject categories gives keyword searching a priority to browsing. Though children's learning style preference was not examined in this study, it is speculated that children who adopted the keyword approach may be "immediate," "nonconforming," whereas those who used the browsing approach may be "systematic" and "sequential" in their problem-solving approach.

Overall, children's cognitive behavior reflected an understanding of the search task, term relationship, concept selection, search formulation, and subject hierarchies. The quality of their traversal process, however, impacted their effectiveness and efficiency in finding the target information. One child, for example, arrived at the target site *Gator Hole* in traversal move number 28, backtracked immediately before exploring the target homepage, and activated the category *Science and Oddities*. From there, the child made four search moves, clicked on the site *Gatorland*, did not explore the site's homepage, looped the site twice, and ended his/her search session in vain. Most children (85%) looped searches and hyperlinks during traversal. Looping ranged from 1 to 16 per search session. There was an instance when one child looped the hyperlink under the letter *A* for *alligator* five times in a row and every time this action was made, the child did not examine the information retrieved. In fact, looping may occur when a user does not recall the hyperlinks he/she had visited or the searches he/she had executed, and/or when a user decides to revisit previously retrieved results. Recall requires a cognitive load for all types of tasks in information retrieval systems (Borgman, et al., 1995). Children's limited recall knowledge (Siegler, 1991), novice navigational skills, limited knowledge of how to use Yahooligans! command features (e.g., *Next Search* box), and lack of focus on task during traversal surfaced as main problems.

2. What physical behavior do children perform to find the answer to the fact-driven search task in Yahooligans!?

Children's physical behavior included backtracking (i.e., use of Netscape *Back* button), scrolling, and navigation of hyperlinks from hit lists. Like looping, backtracking occupied a large segment of the children's behavior. Backtracks ranged from 1 to 14 per search session. The use of the *Back* button seems to be common among Web users, regardless of their age or Web experiences. Fidel (1999), for example, found that high school students made a frequent use of the *Back* button and considered it as a safeguard when they were lost. In a study of graduate student use of the Web, Wang (1998) found that most students used the *Back* button frequently during traversal. The research of Catledge and Pitkow (1995) revealed that use of the *Back* button by a group of staff, faculty, and students at the College of Computing, Georgia Institute of Technology, accounted for 41% of their traversal activities, and was the second preferred method of traversal after visiting hyperlinks. Indeed, the *Back* button provides a linear path of previously retrieved pages and makes it easier on a user to trace his/her hyperlink activation. Bieber and Wan (1994) introduced the concept of "task-based backtracking," in which a user backtracks to compare information from different sources for the same task. When the *Back* button is used heavily, however, it makes one's traversal inefficient. In cases when a user needs to revisit previously retrieved sites, the Netscape *Go* button is more appropriate since it keeps site history and provides direct activation of each site. The fact that children did not use the *Go* command confirms that they did not have adequate knowledge of Netscape features.

Another aspect of the physical behavior is screen and homepage scrolling. Each child's scrolling percentage was obtained by dividing the frequency of his/her total scrolling by the total number of hyperlinks he/she retrieved. Screen and homepage scrolling was not included in cases when hits were displayed in short screens that can be viewed without full scrolling. Four children scrolled less than fifty percent, five scrolled between fifty and seventy-five percent, four scrolled seventy-five to eighty-eight percent, and only one child scrolled ninety-one percent. Although most children scrolled the returned hits and homepages above fifty percent, they still missed viewing at least twenty-five percent. The level of screen and homepage scrolling may be associated with screen design. In general, children did not scroll long screens as fully as they did short ones. This finding confirms the results of research by Wang et al. (1998) which showed that the majority of graduate students who searched the Web to find information on a specific task did not fully scroll a homepage when the page was longer than one screen. In general, children in this study activated the hyperlinks appearing on the top of screens more frequently than those displayed in the middle or the bottom of the screen. Full screen or homepage scrolling may not be necessary, however, in cases when relevance ranking of returned hits is provided; a feature not supported in Yahooligans!

Children's navigation was calculated by dividing the total number of the hyperlinks they activated by the total number of hyperlinks retrieved. Their homepage examination was calculated by dividing the number of pages visited by the number of hyperlinks activated. Children navigated a low number of the hyperlinks they retrieved. Although successful children made fewer traversal moves and spend less time in using the engine, they navigated 26.14% compared to 14.42% by unsuccessful ones (Table 4). Children's homepage examination, however, was higher than navigation (71.14% and 59.14%, respectively). Since Yahooli-

TABLE 4. Summary of Children's Performance and Traversal Behavior

Performance	Successful $n = 7$ Percentage	Unsuccessful $n = 7$ Percentage
Weighted effectiveness	31.14	12.42
Weighted efficiency	26.28	22.14
Quality moves	32.14	28.85
Behavior		
Scrolling	77	61
Navigation	26	14.4
Page examination	71	59
	Mean score	Mean score
Looping	2.2	8.0
Backtracking	5.8	6.4

gans! does not support relevance ranking, factors that impacted children's navigational decisions were titles of hyperlinks and their descriptions. The level of abstraction associated with the Web requires that system designers provide precise titles of hyperlinks and represent the content of homepages as accurately as possible. Many titles of hyperlinks in Yahooligans! are poorly represented and the content of their homepages are poorly indexed and abstracted. This problem increases the level of abstraction of hyperlinks and, therefore, makes it more difficult for children to choose their navigational moves.

3. Is there a difference in cognitive and physical behaviors between children who succeed in finding the correct answer to the fact-driven search task and those who do not?

Seven children (50%) found the correct answer to the search task and seven did not. The approach successful and unsuccessful children made as they interfaced with Yahooligans! was similar. Four successful and five unsuccessful children searched by keyword under either *alligator* or *alligators*. Only one successful child used the term *lifespans*. Three successful and two unsuccessful children browsed by subject categories under *Science and Oddities*. While children's approach was similar, their traversal process varied.

Process

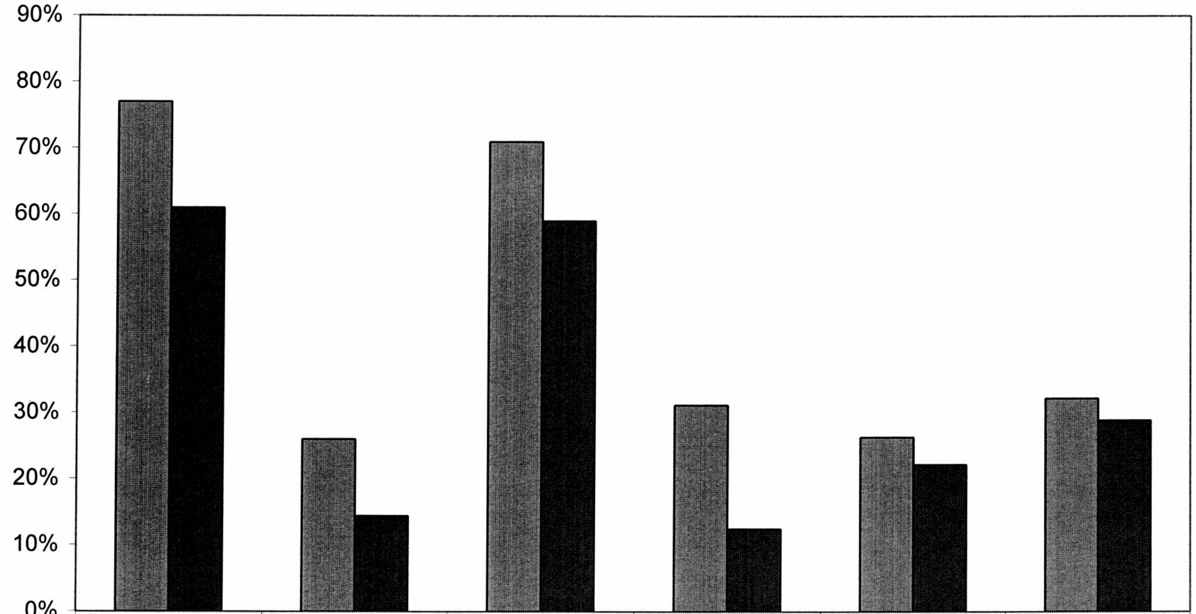
Process is the subsequent moves children made in traversing Yahooligans! These moves included searching, looping, backtracking, scrolling, navigating, target location and deviation, and exploratory moves. While successful and unsuccessful children took a similar approach in using the engine, their traversal process varied greatly, especially in regard to these moves.

Searching Successful children formulated their searches using either single or multiple concepts, whereas unsuccessful ones employed these kinds of concepts in addition to natural language phrases. Use of natural language resulted in zero hits and subsequently increased unsuccessful children's retrieval failure. It is noteworthy that Yahooligans! does not support natural language searching.

Looping and backtracking Looping searches and hyperlinks was more prevalent among unsuccessful children. The average looping for successful children was 2.2 compared to 8.0 for unsuccessful ones. A slight variation in backtracking was found between the two groups. The backtracking mean for successful children was 5.8 compared to 6.4 for unsuccessful ones (Table 4).

Scrolling and navigation Although successful children made fewer moves than unsuccessful ones, they scrolled a little more, navigated more hyperlinks and examined more homepages (77%, 26.14%, and 71.14%, respectively) than unsuccessful ones (61%, 14.42%, and 59.14%, respectively, as shown in Figure 3). The fact that navigation was lower than homepage examination may be attributed to how well the hyperlinks and their descriptions are represented in Yahooligans! Good representation of the content of hyperlinks will lower the level of abstraction and may, consequently, increase the level of navigation. This is an issue that designers of Yahooligans! should address.

Target location and deviation Three targets were examined: target site, target hyperlink, and target homepage. Children's location of and deviation from each target was examined to determine their subsequent paths and navigational style. Here also, the behaviors between successful and unsuccessful children varied. The number of moves successful children made to locate the target site ranged from 9 to 61, whereas those for unsuccessful ones ranged from 28 to 94. Successful children located the target site and took a direct path that lead to the correct answer. They clicked on the target hyperlink *Gator Hole*, browsed the target homepage, activated the heading *Myths and Facts*, and highlighted the correct answer. Only one child, however, activated an inappropriate heading from the target homepage (i.e., *Habitat*) and looped it twice before clicking on *Myths and Facts* and finding the correct answer. Unsuccessful children took different paths. Three of them deviated from the target hyperlink after activating it and four never activated it. One child, for example, clicked on the target hyperlink in traversal move 28, backtracked before browsing the target homepage, made five consecutive keyword searches, activated the site *Gatorland*, looped it once, backtracked again, and ended his/her session in vain. Another child who activated the target hyperlink in traversal move 60 (the last move he/she made) did not examine the target homepage and ended his/her session in vain. Similarly, the child who activated the target hyperlink in traversal move 94 did not explore the target homepage, backtracked, browsed under *Crocodilian Species*, clicked on the site *American Alligator*, highlighted the text with the word



	Scrolling	Navigation	P-examination	Effectiveness	Efficiency	Quality
Success	77%	26%	71%	31.14%	26.28%	32.14%
No success	61%	14.40%	59%	12.42%	22.14%	28.85%

FIG. 3. Summary of children's performance and traversal behavior (excluding looping and backtracking).

captivity as the answer, and exited Yahooligans! This child provided the wrong answer to the query either because he/she did not comprehend the text or that he/she based the answer on the presence of the keyword "captivity" in the text. This child's failure may be due to his/her poor reading ability, or to domain and topic knowledge, which were rated 3 and below on a ten-point scale (1 = low, 10 = high) by the science teacher. The child's low level of experience in using the Web (less than one month) may also have contributed to failure.

Exploratory moves Exploratory moves are actions the children made during traversal to learn about Netscape or Yahooligans! features and/or to solve problems. Successful children made fewer moves than unsuccessful ones. Only two successful children explored Netscape; one child clicked on *NetSearch* but immediately clicked on the *Stop* button, and another clicked on Netscape *Options* twice and Yahooligans! online *Help* once. All unsuccessful children made exploratory moves. One child clicked on Netscape *Options*, two children accessed Yahooligans! online *Help*, one child clicked on *Netscap*e button, and another one made four moves (clicked on *NetSearch*, then on the *Location* bar, deleted the existent URL, and typed Yahooligans! address). Two children clicked on Netscape *Home* once, on *Handbook* four times, and on Yahooligans! *What's Cool* once. The child who clicked on *Handbook* the first time, he/she did not wait for the results to come up; instead, he/she backtracked and clicked on *Handbook* a second time. After backtracking, the child typed *alligator* in the Yahooligans! *Search* box, went back to *Handbook* before exploring the results, backtracked, and searched under the concept *alligator*. The difference in the number of exploratory moves between successful and unsuccessful children suggest that prior experience in using the Web has a great influence on exploration of Netscape and Yahooligans! features during traversal.

The findings of children's cognitive and physical behaviors suggest that both the quality of their traversal process and the design of Yahooligans! influenced their outcome in finding the target information. These two factors are key issues to be addressed by mediators and system designers.

4. Is there a difference in traversal effectiveness, efficiency, and quality moves between children who succeed in finding the correct answer to the imposed fact-based search task and those who do not?

Children's weighted traversal effectiveness and efficiency scores, as well as the quality of their moves were measured using the "Web Traversal Measure" described in the methodology. The measure assigns a score of 1 for a relevant search and/or hyperlink activation, a score of 0.5 for a semi-relevant search and/or hyperlink activation, and a score of 0 for an irrelevant search and/or hyperlink activation (see Appendix A for an example). Table 4 and Figure 3 show that successful children had a mean percentage of weighted effectiveness score approximately three times higher than unsuccessful ones (31.14% and 12.42%, respectively). The mean percentage of weighted efficiency score and quality moves, however, was slightly higher for suc-

TABLE 5. Children's Experience in Using the Web and Search Engines

Experience level	Successful $n = 7$	Unsuccessful $n = 7$
Length of experience with Internet	1 (< one month), 3 (1–6 months, and 3 (over 12 months)	3 (< one month), 1 (1–6 months), 1 (6–12 months), and 1 (never used)
Use of Web search engines	1 (never used); 5 used one or more (Yahoo, Excite, Alta Vista, WebCrawler, Infoseek); one used Yahooligans!	3 (never used); 4 used one or more (Yahoo, Alta Vista, WebCrawler)
Knowledge of Yahooligans! features	7 (Search box), 7 (search button), 6 (Help button), and 5 (underlined words)*	3 (Search box), 3 (search button), 3 (Help button), and 3 (underlined words)*

*The number of children who identified Yahooligans! features correctly.

cessful children (26.28%, 22.14%, respectively) than unsuccessful ones (32.14%, 28.85%, respectively).

These findings indicate that successful children were more effective than efficient (31.14% and 26.28%, respectively) in their traversal, whereas unsuccessful ones were more efficient than effective (22.14% and 12.42%, respectively). Although successful children had a higher mean score on effectiveness, efficiency, and quality moves (31.14%, 26.28%, 32.14%, respectively) than unsuccessful ones (12.42%, 22.14%, 28.85%, respectively), all scores were below 33%. This fact is not surprising, especially since these children had limited cognitive developmental ability (Siegler, 1991), were novice users with novice Web navigational skills, and used a search engine that was not designed to build on their cognitive ability to search, browse, explore, and recover from errors or breakdowns.

5. What criteria do children use to judge relevance of the hyperlinks they activate and the home pages they visit?

Relevance judgment of term selection and information retrieval is a new area of children's information-seeking behavior. Children were asked during the exit interview to articulate the criteria they employed for activating hyperlinks and visiting homepages. The main relevance criteria that were identified from children's comments were "topicality" and "concrete answer." "Topicality" implies "aboutness," whereas "concrete answer" denotes an "exact" answer to the query. Forty-six percent (46%) of the children who indicated the first criteria seemed to be searching for relevant information about the task, whereas thirty-seven percent (37%) who mentioned the second criteria appeared to be searching for an answer to the search task. Ten-percent (10%) of the children did not know the criteria they used. "Topicality" as a dominant relevance criteria was also found by Hirsh (1998) in her study of elementary children's relevance judgement of electronic resources.

Although all children admitted an understanding of the search task prior to using Yahooligans!, the criteria mentioned here indicate that most of them were still unclear as to the type of information sought. This suggests that mediators and teachers ensure that children recognize the kind of information needed for different types of search tasks (e.g., factual, research). Factual queries, for example, may be fact- or data-based and require single, straightforward answers, whereas research-based queries demand gathering relevant information rather than finding a specific answer.

6. To what extent do the following characteristics impact children's success in finding desired information in Yahooligans!?

a. Experience in using the Internet/Web
b. Knowledge of Yahooligans! search and retrieval interfaces
c. Domain knowledge (i.e., science)
d. Topic knowledge (i.e., alligators)
e. Reading ability

a. Experience in using the Internet/Web

Data about children's Internet/Web experience were gathered prior to the experiment. Here, experience was examined vis-a-vis children's success in finding the correct answer to the search task. Successful children had more experience than unsuccessful ones in using the Internet and Web search engines. They also had more knowledge of the Yahooligans! interface features. Table 5 shows that only one successful child had less than one month of experience compared to three unsuccessful children; three successful children had one to six months experience and three others had over twelve months. Only one unsuccessful child had one to six months of experience, another had six to twelve months, and one never used the Internet/Web.

The level of prior experience in using Web search engines varied slightly between successful and unsuccessful children. Only one successful child never used the engines compared to three unsuccessful children. Five successful children used one or more search engines (Yahoo, Excite, Alta Vista, WebCrawler, and Infoseek) and only one used Yahooligans! Four unsuccessful children used one or more engines (Yahoo, Alta Vista, and WebCrawler). The very low correlation ($r = .22$, $p = .05$) that was found between children's prior experience and success provides a base for further investigation. Research should consider use of a larger sample size to determine whether prior Web and search engine experience significantly impact success.

b. Knowledge of Yahooligans! search and retrieval interfaces

Children were given snapshots from the Yahooligans! search and retrieval interfaces, and were asked to identify certain interface features during the exit interview. The data generated were examined vis-a-vis children's success. From the search interface (Figure 1), seven successful children identified both the purpose of the *Search* box and *Search* button correctly compared to three unsuccessful ones; six successful children recognized the purpose of the *Help* button compared to three unsuccessful ones, and five successful children described the function of underlined words (i.e., hyperlinks) correctly compared to three unsuccessful ones.

From the retrieval interface (Figure 2), most children (64%) described the function of the *Next* button incorrectly, forty-six percent (46%) identified *Categories* incorrectly, and forty-one percent (41%) recognized the function of the *Site* button. The fact that most children did not recognize the purpose of certain interface features in Yahooligans! is not surprising since all children had not used the engine prior to this experiment, except for one child.

c, d, e. Domain knowledge, topic knowledge, and reading ability

The science teacher rated children's domain knowledge, topic knowledge, and reading ability on a scale ranging from 1 to 10 (1 = low, 10 = high). Only one unsuccessful child had a rating of 3 and below on these factors; all other children had a rating of 7 or higher. While research by Hirsh (1996) showed that children's science domain knowledge significantly impacted their success in identifying resources on imposed science tasks in an OPAC, this study revealed that children's domain knowledge, topic knowledge, and reading ability did not significantly influence their success. This finding, however, was based on one search task and a small sample size. To gain knowledge of various factors that contribute to children's success, further research in the area of children's Web traversal behavior are needed. Such research should use a larger sample size and examine whether a significant relationship exists between success and different types of search tasks (i.e., factual, research; imposed, self-directed).

7. What affective states do children have in using Yahooligans!?

A holistic view of the information-seeking process encompasses user affective experience as well as cognitive constructs (Kuhlthau, 1993). The children's affective states were examined during the exit interview to capture their feelings before, during, and after searching, and to examine whether these feelings influenced their behavior.

Positive feelings

Most children (87%) enjoyed using the Web for the following reasons: (a) ease of use over other types of sources, especially print; (b) ability to employ keyword searching; (c) visiting different Web sites to find the information; (d) availability of graphics, and (e) fun. Negative feelings were few and related to "lack of matches" and "difficulty in finding the answer."

Motivation

Motivation in using Yahooligans! was expressed by most children (85%). The reasons implied increase in self-confidence, discovery, challenge, and convenience. Some children noted: [Yahooligans!] "showed me I could do it because I didn't know I could do it (self-confidence); [I learned] "something I did not know before on topics I'm interested in," (discovery); [it is] "still new to me and gives me something different," (challenge and discovery); and [I can] "use the Internet from home," (convenience).

Persistence and patience

Persistence and patience in using Yahooligans! was prevalent among children. The reasons were efficiency, exploration, enjoyment, comfort, as well as self-confidence, discovery, challenge, and convenience. Some children commented: [I] "know the answer is there … and know I'll probably get the information eventually … It's got to be there, so I keep trying" (confidence and resilience); [I] "know I can do it … [it is] a challenge to find pictures" (confidence and challenge); [it has] "more information and doesn't take as long … it is all in one place" (convenience and efficiency); "it's fun to go different places to find the answer" (exploration and enjoyment); and "it is easy to use and read" (comfort).

Confusion and frustration

Forty-three percent of the children, including a few of those who were motivated to use Yahooligans!, were confused and/or frustrated during traversal. Their reasons include that Yahooligans! (a) "doesn't give you information," (b) [is] "slow," and (c) [has a] "confusing and a bad screen display." Frustration also occurred when Netscape failed during searching and required rebooting, which was done by the researcher. Children wondered whether this failure was caused by something they had done wrong. Although software and hardware were tested for proper operation before each child used Yahooligans!, software failure occurred due to limited computer memory.

Children's motivation, self-confidence and challenge in using Yahooligans! surfaced as main affective factors that positively influenced their persistence and patience in traversing its space. Despite the frustration and confusion a few children expressed, all children pursued their traversal until the end of the time allotted (30 minutes). The positive affective states the children had confirm Watson's (1998) findings of middle school students' positive perceptions of using technology, especially the Internet. This affective behavior should be nurtured, however, with effective end-user training, as well as improvement in Yahooligans! design.

Discussion

This study presented the results of the first part of a research project that is investigating children's cognitive, physical, and affective behaviors in using the Yahooligans! search engine. It was conducted with a group of seventh grade science children at a middle school located in Knoxville, Tennessee. It examined children's traversal behaviors in seeking information on an imposed fact-driven search task. The use of a new measurement called "Web Traversal Measure" provided insights into children's traversal effectiveness, efficiency, and quality. The logging technique that captured children's traversal activities shed light on their traversal approach (i.e., initial moves), process (i.e., subsequent moves), and outcome (i.e., success). The qualitative method that captured children's affective states uncovered positive and negative feelings about using Yahooligans! The results of this study revealed important characteristics about children's search engine traversal behaviors. These results are discussed within the context of children's approach, process, and outcome in using the Yahooligans! search engine.

Approach

Most children (64%) adopted the keyword searching approach as they interfaced with Yahooligans!, and used the most concrete concept from the search query (i.e., *alligators*). Children who adopted the browsing approach (36%) selected the appropriate subject category (*Science and Oddities*) and subcategories (*Animals—Reptiles and Amphibians—Alligators and Crocodiles*). Both successful and unsuccessful children employed either approach as they interfaced with Yahooligans! Since children were not given exact instructions for using Yahooligans! (i.e., search, browse, or both), it is believed that the approach they took was most likely influenced by their learning style preference, the type of search task, as well as the design of the Yahooligans! search interface. The approach children took indicates that children who used the keyword approach were most likely "immediate," "nonconforming," and certain about the keywords to use, whereas those who embraced the browsing approach were "systematic" and "orderly," but possibly uncertain about the keywords to use. The task the children were given was fact-driven and formulated clearly with concrete keywords which may have influenced keyword search preference to browsing by subject categories. The fact that Yahooligans! places the *Search* box above the subject categories automatically encourages keyword searching and gives it priority over browsing.

Process

Children's search processes showed an interaction between the concrete cognitive operational stage and the formal cognitive operational stage described by Piaget and Inhelder (1969), as evidenced by their use of concrete concepts (e.g., *wild*, *captivity*, *live*) and abstract concepts (e.g., *age*, *animals*, *lifespan*) in all types of searching (i.e., single concept, multiple concepts, and natural language). While children's formulation of alternative search and browse strategies during traversal implies "rational" thoughts and "creativity" in problem solving, their traversal process was "chaotic" and afflicted with low effectiveness, efficiency, and quality. This process was characterized by the following:

Task switching and navigation

Children frequently shifted back and forth between keyword searching, visiting sites, browsing under subject categories, and searching by keyword within subject categories. Although this switching may have been part of the children's evolving strategy to learn about Yahooligans!, their minimal navigation of the hyperlinks returned (below 27%) contributed to frequent task switching. Despite the fact that unsuccessful children examined 59.15% of the homepages they visited, their percentage is low considering that near 40% of the pages were not explored. Other factors that may have impacted these behaviors are "disorientation" during traversal, limited Web navigational skills, as well as the high level of abstraction in the titles and descriptions of Yahooligans! hyperlinks. While the former two problems can be remedied through effective Web user training, the latter requires improvement in the engine's indexing and abstracting which should be considered by system designers.

Frequent looping

Search and hyperlink looping was prevalent in children's traversal actions. Children's looping may have been influenced by their limited recall knowledge (Siegler, 1991) of search and hyperlink activation, limited knowledge of how to use Yahooligans!, as well as the "cognitive overhead" and "disorientation" associated with the Web. The recall problem was confirmed in this study by the interview data gathered at the end of the experiment that showed twenty-eight percent of the children (28%) did not remember the concepts they used in their search statements. When asked to identify certain features from Yahooligans!' retrieval interface, most children (64%) described the function of the *Next Search* button incorrectly and 46% identified *Categories* incorrectly. This function appears at the bottom of the screen with a search box for entering a new search. It is noteworthy that the engine keeps a previously executed search in the box until erased or modified by the user. When a child is disoriented and lacks adequate knowledge of the purpose of this feature, a child may reactivate the button frequently. While children's frequent search looping may have been influenced by system design and limited recall of the searches already executed, their frequent hyperlink looping may be been impacted by lack of focus, cognitive overhead, as well as limited recall of the hyperlinks previously visited and/or retrieved.

Frequent backtracking

Children backtracked several times within the sites and home pages they visited. Although backtracking is common among Web users (Fidel, 1999; Wang, 1998; Catledge & Pitkow, 1995; Bieber & Wan, 1994), it makes Web traversal less efficient and more time consuming. This problem can be remedied by using the Netscape *Go* button that keeps a session history and allows direct activation of the hyperlinks previously visited. Use of the *Go* button requires training, however, since a child needs to recall the name of the sites he/she had previously visited. In cases when backtracking occupies multiple screens, initiation of a new search may be more efficient.

Target location and deviation

Overall, all children looped searches and hyperlinks during traversal. However, their navigational behavior when they arrived at the target site that contained the target hyperlink (i.e., *Gator Hole*) revealed three types of navigational styles: "linear," "nonlinear," and "looped." Children who followed a "linear" style, arrived at the target site, clicked on the target hyperlink, scrolled the target homepage, clicked on the heading *Myths and Facts*, or located it through scrolling the page; and highlighted the correct answer using the mouse. This style was direct and without backtracking or looping. Children who used a "nonlinear" style, arrived at the target site, clicked on the target hyperlink, did not examine the target page, backtracked, searched or browsed under new terms or categories, either returned to the target site and hyperlink and succeeded in finding the answer, or never did so and failed. Children who embraced a "looped" style arrived at the target site, did not activate the target hyperlink, made several searching and browsing moves, backtracked, looped searches and hyperlinks, and ended their Web session unsuccessfully. This finding implies that the navigational style children adopted from their point of arrival at the target site had a great impact on their effectiveness, efficiency, and outcome. Therefore, further research into the nature of children's navigational style is highly recommended. Of special importance is the impact of navigational style on success, traversal quality, and time to complete a task.

Outcome

Outcome is the success and traversal quality in finding the correct answer to the search task. Seven children succeeded and seven did not. While the approach successful and unsuccessful children adopted was similar, the traversal process they used varied. Table 5 shows that successful children looped searches and hyperlinks less frequently than unsuccessful ones, navigated and examined a higher percentage of hyperlinks and homepages, and scrolled a slightly higher percentage of the screens and pages returned. What did contribute to children's outcome? Based on the findings of this study, it is believed that the outcome was influenced by these factors:

- *Children's level of understanding of the type of information sought.* As revealed in the interview data, most children (64%) were seeking information about the topic rather than a specific answer to the search task.
- *Children's prior level of experience in using the Web and search engines.* Successful children had a higher level of prior experience than unsuccessful ones.
- *Children's navigational style, especially at point of arrival at the target site.* Five successful children had a "linear" navigational style and two had a "nonlinear" one. Three unsuccessful children had a "non-linear" style and four had a "looped" style. Unlike children who had "linear" and "nonlinear" styles, those that had a "looped" style never activated the target hyperlink when they arrived at the target site. This behavior resulted in a zero weighted traversal effectiveness.
- *Search strategy.* Both successful and unsuccessful children used single and multiple concepts in their search statements. However, only unsuccessful ones employed natural language searching, which resulted in retrieval failure since Yahooligans! does not embrace this search syntax.
- *Relevance judgment criteria.* As revealed in the interview data, children judged relevance of hyperlinks and home pages retrieved on two main criteria: "topicality" and "concrete" answer. Those who were seeking information "about" the search task from the titles of hyperlinks and/or their descriptions were likely more successful than those who aimed at finding the "concrete" answer. On the contrary, when relevance judgment concerned home page examination, those who sought a "concrete" answer were likely more successful than those who fetched information about the answer.
- *Cognitive overhead and disorientation.* Unlike traditional media, the complex organization of Web information in nonlinear, associative form, as well as the enormous amount of existing information imposes disorientation and cognitive overhead on users. Links lead to other links and webs of information generate additional webs. Users find themselves "lost" in space while trying to make navigational decisions to find certain information.
- *Hyperlink abstraction.* Web-based information is highly abstract because detail about its description is concealed until activated (Dede & Palumbo, 1991). This abstraction will most likely increase children's disorientation and consequently affect their navigational decisions.

In sum, children's outcome and quality of the outcome was influenced by four main factors: (1) Novice Web navigational skills, (2) limited knowledge of using Yahooligans!, (3) Yahooligans! system design, and (4) the structure of hypermedia. Based on the results of this study, it is believed that the quality of children's traversal process had a greater impact on their outcome than either the approach or factors such as reading ability, topic knowledge, or domain knowledge.

Implications

The findings of this study has major implications for user Web training and system design improvement.

User Web Training

Many of the problems children encountered during traversal can be remedied through effective user training. Mediators should make the use of the Web and search engines as an integral component of information skills programs. "Without such training, the introduction of the Internet into schools will not help improve learning and may even help some students to develop unproductive learning habits" (Fidel et al., 1999, p. 34). Mediators should ensure that children not only understand the search task, but also adopt a process that yields quality outcome. Navigating the Web can be complex due to the levels of abstraction embedded in the detail. Information is concealed under hyperlinks and revealed by activating a link (Dede & Palumbo, 1991). In addition, the Web imposes cognitive overhead and disorientation on the user during traversal. As Nahl notes: [Use of the Web and search engines are] "typically embedded in a multimedia screen environment that splits the searcher's focus" (1998a: 61). This conveys the importance of developing information skills programs that incorporates new strategies for user education and training.

Web training adds a new dimension to information skills. Children need to adapt to the use of the Web and search engines and learn new techniques that support effective navigation and traversal. Children in this study performed a search task that did not require collection of a large amount of information; instead, it necessitated finding the correct answer to a fact-driven task. With this task, half of the children failed. While the other half succeeded, the researcher observed children's inefficiency during traversal. These children were not exposed to formal Web or search engine training. Thus, it is not surprising to find that they employed various strategies to learn the searching and browsing mechanisms of Yahooligans!

Web training should include the features of the browser used (e.g., Netscape) and the nature of Web information structure and organization. What is the nature of hyperlinks, for example? Are there a midpoint and an endpoint in visiting hyperlinks? How to begin navigation and end it? Criteria for visiting hyperlinks and evaluating information are of special importance. Should children activate hyperlinks based on keywords in their titles and descriptions, for example, or use trial and error? These are key issues in user Web training.

Mediators should teach effective navigational skills and traversal. In order to decrease disorientation during traversal, for example, mediators may encourage children to keep a "conceptual map" of their traversal activities. As novices, children should learn to document their search history, possibly in writing, to decrease backtracking and search looping and hence, increase their traversal effectiveness and efficiency.

This study revealed that most children made futile task switches (i.e., shifting back and forth between searching, activating links, visiting sites), looped searches, and hyperlinks frequently, backtracked several times during traversal, and navigated the sites they visited minimally. This behavior not only decreased their efficiency and effectiveness, but also increased their frustration. Children need to develop conceptual understanding of the structure of Web-based information. The Web should not be viewed as another textbook with a table of contents where a child goes to a certain page and finds the target information. The Web is an associative, nonlinear hypermedia system that imposes challenge; it requires cognitive load, focus on task, and effective search and navigational techniques.

Effective integration of the use of the Web and search engine into a school's curriculum calls for collaboration between teachers and school librarians. These two mediators should diagnose children's common skills and problems during traversal and design information skills programs that respond to children's needs. Of importance is assessment of children's cognitive, physical, and affective behaviors in interacting with the Web and search engines.

System Design

The findings of this study revealed that the design of Yahooligans! influenced children's cognitive and physical behaviors during traversal. The Yahooligans! search and retrieval interfaces lack instructions for and examples of searching and browsing. Its online help is not context-sensitive and has little guidance for searching and browsing. The retrieval interface, which displays the results in categories and sites within categories, were confusing to most children, as was revealed in the interview data. In fact, making navigational decisions in Yahooligans! can be complex due to the high level of abstraction in its hyperlinks and descriptions. The engine has many misleading titles of hyperlinks, suffers from poor indexing and abstracting of sites and home pages, and does not provide comprehensive representation of the content of the sites or home pages it indexes. The target hyperlink, *Gator Hole*, for example, had the description: *dedicated to the American Alligator*, which did not represent well the content of its respective home page. The latter included the headings *Alligators and their kin*, *Habitat*, *Feeding habits*, *Myths & facts*, to name a few. Adequate representation of these headings in the description of the target hyperlink would have assisted children in making better navigational decisions.

A search engine designed for children should support children's learning. System designers should develop search engines with powerful searching and browsing mechanisms that built on children's cognitive and physical behaviors to search, browse, navigate, and explore information with certainty and positive affective behavior. This can be achieved by providing search instructions, search examples, browsing instructions, browsing examples, a natural language interface, retrieval relevance ranking, simple screen displays, a context-sensitive help Wizard, a spell-checking technique, an effective feedback method, and an online tutorial. Designers of Yahooligans! may want to also consider applying neural networks and analogical reasoning to provide interactive query negotiation for identifying children's information needs. Neural networks may also be used to model children's traversal profiles to assist them with their problem solving (Meghabghab & Meghabghab, 1994).

As children learn how to effectively traverse Web space and use Yahooligans!, and as they develop effective navigational skills and knowledge of the search engine they use, they will be able to acquire new strategies, solve new problems, and transfer their skills and knowledge from one search engine to another. To support learning, school librarians and other mediators should develop training programs that incorporate children's thoughts, actions, and feelings as they seek and retrieve information.

Conclusions

This study reported the results of part one of a research project that is investigating children's cognitive, physical, and affective behaviors on different types of search tasks. The goal of this study was to understand children's behaviors in using Yahooligans! to find the correct answer to an imposed fact-driven search task, and to examine how the engine facilitated children's traversal behavior and supported their search for information.

Yahooligans! is a search engine and directory; it allows for keyword searching and browsing by subject categories. While children's cognitive behavior in using the search engine reflected an understanding of the search task, term relationship, concept selection, search formulation, and subject hierarchies; their traversal process showed low weighted effective and efficiency, as well as low quality. This process was also clouded with frequent looping and backtracking, as well as low navigation. These findings convey the need for effective user Web training. Mediators and teachers play a major role in ensuring that Web traversal outcome is not only judged on success but also on quality.

Future research should examine the nature of children's Web traversal process, including their navigational style. The question to be addressed is: Do children's traversal process and approach change with the type of search tasks? This study examined children's behaviors as they sought the answer to an imposed, fact-driven search task. To gain a better understanding of children's behaviors on different types of search tasks, the researcher is analyzing data gathered from these children's Web sessions on two additional search tasks, self-directed and research-based (Bilal, in progress).

The "Web Traversal Measure" developed by the researcher proved suitable for measuring children's weighted traversal effectiveness and efficiency, as well as quality moves. Use of this measurement is recommended, especially for fact-driven tasks that have a target hyperlink and answer. The researcher is testing this measurement on both research-based and self-directed search tasks to determine its suitability.

The online monitoring technique using Lotus ScreenCam used to capture children's cognitive and physical behaviors in using Yahooligans! was accurate, unobtrusive, and easy to replay and transcribe. However, it resulted in data loss due to inadequate hardware. To avoid this problem, a minimum use of a 486 PC with 64 megabytes of RAM is highly recommended.

APPENDIX A. Example of Application of the Web Traversal Measure

TMs	Description	SAs	WSA*
1 TM	Click on *Science and Oddities*	1 SA	1
1 TM	Type *alligators*	1 SA	1
1 TM	Scroll screen	0	—
1 TM	Click on *Science and Oddities: Animals: Reptiles: Alligators and Crocodiles*	1 SA	1
1 TM	Move mouse over links	0	—
1 TM	Scroll screen	0	—
1 TM	Click on *Crocodilian Species: Chinese Alligator*	1 SA	0.5
1 TM	Scroll screen	0	—
1 TM	Move mouse over links	0	—
1 TM	Click on Netscape *Net Search*	0	—
1 TM	Click on Netscape *Stop*	0	—
1 TM	Click on *Back* button	0	—
1 TM	Type *alligators*	1 SA	1
1 TM	Click on *Science and Oddities: Animals: Reptiles: Alligators and Crocodiles*	1 SA	1
1 TM	Type *alligators*	1 SA	1
1 TM	Scroll screen	0	—
1 TM	Move mouse over links	0	—
1 TM	Click on *Gator Hole* (target hyperlink)	1 SA	1
1 TM	Scroll screen	0	—
1 TM	Highlight text for answer	0	—
Total = 20 TMs		Total = 8 SAs	Total weight for SAs = 7.5

TM = Transcribed Move; SA = Selection Action; WSA = Weight for each SA.

*(1 = relevant); (0.5 = semi-relevant). Note that each TM is a move; each SA is a "meaningful" TM. The number 0 in the SA column indicates that the respective TM is not an SA.

Weighted Effectiveness Score:

$$\sum_{i=1}^{8} (WSA_i \times SA_i) / \sum_{j=1}^{18} (TM_j) = (7 \times 1 + 1 \times 0.5)/18 = 7.5/18 = 42\%$$

Weighted Efficiency Score:

$$\sum_{i=1}^{8} WSA_i / \sum_{i=1}^{20} TM_i = 7.5/20 = 37.5\%.$$

Quality Moves:

$$\sum_{i=1}^{8} SA_i / \sum_{i=1}^{20} = 8/20 = 40\%.$$

The findings of this study suggest that additional work on children's search engine traversal behaviors is a fruitful area of research. Such work will enhance our understanding of how children traverse Web space, and will assist us in developing a framework for the learning requirements and cognitive demands Web search engines designed for children impose on users.

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