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Graphical interface design for children seeking information in a digital library

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Abstract

Background: Children are very curious. They like to play games but lack reading fluency. Conventional interfaces for information-seeking in digital libraries are unsuitable for children because they are rigid, text-based, and task-oriented. Thus, this study developed a customized interface for a digital library. To facilitate children in online searches, the design concepts included user-friendly target icons, icon recognition, and way-finding in a two-dimensional visualized environment.

Methods: In this study, the criteria used to develop visualization tools that children can use for information retrieval were based on theories of human perception related to graphical interfaces for information visualization systems, including iconic representations and information density on visualized displays. Databases widely used by children in the National Library of Public Information were linked to the suggested database frame. The database frame was classified into five major subject categories: Natural Sciences, Fine Arts and Music, Health and Athletics, History and Culture, and Treasure of Knowledge. The web interface was designed according to way-finding concepts and map-structure hierarchies. Information searches in the main frame, sub-frames, and linked database were designed to be simple and intuitive for use by children.

Results: Information search efficiency was measured in 104 children assigned to search the virtual environment for icons (databases) that adequately supported their studies. Statistical analyses showed that, compared to the text-lined interface, the graphical interface improved the success and speed of searches by children.

Conclusions: Incorporating theories of spatial memory and representative icons in designs for visualized retrieval systems helps children to recognize different categories of knowledge content and improves their efficiency in information retrieval. To improve database search efficiency in children, information recommendation issues require further study. However, further research is also needed to identify factors that affect patterns of information-seeking behavior in children.

Keywords: Information seeking behavior; Emotional informational navigation; Child-computer interaction

Background

Information-seeking behaviors substantially differ between children and adults. In a comparison of web search patterns between children and graduate students, Bilal and Kirby (2002) found that the latter had markedly higher search effectiveness and markedly higher web navigation efficiency and quality. Graduate students were also more proficient in recovering from search related "breakdowns." Therefore, current information-searching interfaces, which are usually designed for adults, may be ineffective for children.

Many studies agree that, compared to adults, children have limited information seeking capability and require an improved web interface to help them overcome the information searching barrier. Kulper et al. (1997) found that most children aged 8–11 years cannot perform a search by author name. Other difficulties included spelling or phrasing search statements, applying the search terms used in official subject headings, narrowing the search fields, and using Boolean expressions. Children also tend to stop searching after a few hits. Kulper et al. (1997) then concluded that, in databases designed for

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children, the icons used in the interface should have simple and clear meanings and should be used as a benchmark for orientating children in further searching. Kulper et al. (1997) further used SoftWare Technique for Evolutionary Participatory System development (STEP) to develop "BUCHERSCHATZ" (book treasure) and an OPAC prototype with a graphical user interface (GUI).

Hutchinson et al. (2005) studied the errors and frustrations that limit information-seeking effectiveness in children. For example, some children could not spell, type, read, navigate, compose queries, and/or select small objects. The terms used in book searches differed between children and adults. Since children have difficulty manipulating and understanding conventional interface tools, their searching and browsing strategies often differ from those applied by adults. Based on this finding, Hutchinson et al. (2007) designed a category browser that uses Boolean queries, colorful icons, and a flat-structured, simultaneous-response interface to help children search for information in the International Children Digital Library (ICDL).

The Internet Public Library (IPL) is hosted by the College of Information Science & Technology at Drexel University. Drexel University also hosts the ipl2 FOR KIDS, which provides web-links to useful information for young users to do homework as well as leisure reading. Its nine search categories include Reference, Our World, Computer & Internet, Health & Nutrition, Reading Zone, Math & Science, Art & Music, Sports & Recreation, and Fun Stuff (Drexel University 2012).

Beheshti (2012) designed and tested a virtual information environment for children. The design of the virtual library environment was based on the metaphor of a physical library with rooms, bookshelves and books. Users can scan and open books on virtual shelves and can even use search stations to conduct conventional keyword searches. Book locations are identified by red dots on the floor plan for the virtual library.

Most conventional information-seeking interfaces are ineffective for use by children because they are rigid, text-based, and task-oriented. In his classic study, Solomon (1993) examined four factors that affect the information retrieval behavior of children when the using online public access catalog (OPAC): user characteristics, school setting, interface usability, and information access features. In Table 1, four GUI information-seeking interfaces designed for children are compared in terms of user behavior, interface type/display of information node and icon design, and collection type. While these GUI interfaces were designed specifically for children, they require improvements in intuiting user behavior, categorizing information, and providing a game-like search environment. Therefore, this work presents a customized interface for a digital library with novel design concepts (*i.e.,* the avoidance of conjunction syntax operations and the use of icon recognition, a user-friendly icon layout, a search-target avatar, and wayfinding approach in a two-dimensional visualized environment) to facilitate online searches by children.

Methods

A graphical interface for children seeking information contained in the National Library of Public Information (NLPI, renamed from National Taichung Library) database

Table 1 Comparisons of four GUI interface designed for children

Children-specific interface	User behavior	Interface type/display of information node and icon design	Collection type
Bücherschatz	Children (age of 8–10) click the mouse on topic (text) cards to access book descriptions or lower level topic cards.	The graphical user interface has three levels. The first level includes three pictures with text; the second and third levels display up to ten topic cards (rectangular shape) in each level.	Online public access catalogs, collections of children's topics in children's libraries, and form KID'S CATALOG (Dynix).
The International Children Digital Library (ICDL)	Children (age, 3–13 years) click icons grouped by reading level, book-cover color, book length, and book content characters for conjunctive searches.	The graphical user interface with a central window is shown on the searched book-cover, and the icon groups are arranged along four sides of the window.	Digital collection for children read online, on 2012, which includes 4,643 books in 61 languages.
Internet Public Library-ipl2 For Kids	Children and teens recognize list texts in line-by-line searches of the target website.	The web interface has a 2-level hierarchy: the first level includes of 9 icons with text; the second level displays a text-listed of websites.	Online digital library for children; merges the collections of resources from the Internet Public Library (IPL) and the Librarians' Internet Index (LII) websites.
The Library virtual environment (Beheshti 2012)	Children and teens (Grade six) use virtual search stations to conduct keyword and term searches.	The graphical user interface uses the metaphor of a physical library with rooms, bookcases and books. The searching results are displayed as red dots on the floor plan of a library.	1500 links to English-language websites on Canadian history.

is developed by applying a user-centered design concept. First, literature review is performed to determine how children use information node layouts and icon representation-related topics, which are essential for effective use of a visualized database and its spatial arrangement. Five design guidelines for the information-seeking interface are then established: (a) providing children with an effective way-finding approach to searching information nodes in a virtual environment, (b) allowing gradual access to the graphic display by spreading out the search targets in an extended virtual reality environment, (c) using icons based on simplified images relevant to the experience of children to allow them to perceive the actual meaning of the database content, (d) integrating both text and relevant images into an icon to represent a database in a digital library to help children recognize its content, and (e) establishing a game-like information search environment that children would enjoy using for information search rather than a work-like and classroom-like machine interface.

The interface prototype is then implemented using the cognitive walkthrough method, which is widely used to develop digital libraries for children, to study educational development in children, and to categorize and visualize information. Based on expert suggestions in each development step, the scope of the database searches are designed to meet the requirements of children completing school homework and leisure reading assignments. Icons are also designed for five different databases categories: Natural Sciences, Fine Arts and Music, Health and Athletics, History and Culture, and Treasure of Knowledge. Finally, Flash software is used to embed all icons in a left-right-extended interface prototype so that users can perform search tasks in experimental tests of interface usability.

Information visualization and density

Although children enjoy searching through icons in play-oriented information visualization interfaces to retrieve information, several topics related to information visualization and iconic representation in GUI design need further study. Shneiderman (1997) reported that the development of window management interfaces should prioritize information visualization and user interfaces. Since the literacy skills of children improve slowly before adolescence, the use of search strategies that combine text with images vary by age. Therefore, information systems require interfaces with improved visual communication properties, including iconic representation and arrangement (metaphor), to help children during the information-seeking process.

Hu et al. (1999) suggested that interface design may substantially affect system–user concept communication, regardless of user familiarity with the search task; for facilitating such communication, they also reported that a GUI is more effective than a list-based design. For supporting concept communications, interfaces that incorporate multiple visual properties may be more effective than those that rely exclusively on visual properties. Although using graphical interfaces and text-based linear lists incur similar cognitive loads, graphical interfaces reportedly provide higher user satisfaction. The importance of user satisfaction with the interface increases in designs with multiple visual properties. Improvements in interface-induced system-user concept communication may increase with the number of system-suggested items but decrease with user task familiarity. Further, differences in size and distance may provide many effective and essential visual cues in system–user concept communication whereas differences in color provides relatively less effective visual cues for such communication support. The findings of Hu et al. (1999) regarding the visual properties that help users communicate with information systems motivated this study of a novel two-dimensional spatial-organized interface for information systems to help children perform search tasks.

Shneiderman (2003) stated that an object can be characterized by using some aspects of the data in the object to indicate its position. Koshman (2006) reviewed the literature on visualization systems used for information retrieval. She analyzed iconic representations and information density in visual displays. Whereas concepts from human perception theory, including proximity, closure, and connectivity, are applicable in graphical displays (*e.g.,* user overviews of large collections in a digital database on limited-scale displays; how collections (presented as symbols), an improved understanding of how information density can be organized into different layouts and level structures to help users identify the structural contents (metaphors) of a database and to obtain accurate search results that can be presented on a screen.

In web-based visualization systems for adults, data are usually spatially organized into a network or polar system in which the information nodes are web sites and databases. The path between two nodes indicates the queried relationship between two databases or the sequential searching actions of web users. For example, the Mapstan.com web tool records collective search results by fixing a map-path width (weight) inferred from the number of web-visited users between two nodes (databases). The relationship between two nodes is clearly defined and implied the content of nearby database groups. Since children are naturally curious and enjoy exploring unknown worlds, they may not use the most efficient search procedure. For example, they may use trial-and-error or fuzzy searches of possible target groups to find their target. Thus, enabling children to apply a free way-finding approach to searching an information node in the virtual environment is the first design guideline.

In the first version of the ICDL, Reuter and Druin (2004) reported that elementary school students preferred navigating digital libraries hierarchically (less cognitive load) instead of by using Boolean searches. Hutchinson et al. (2007) redesigned the category browser by using simultaneous menus to allow book searches within minor hyperlink levels (less memory load). Compared to a multi-level hyperlink structure, a board and extended plan structure allows children to search a virtual reality environment more efficiently and without getting lost. Thus, the second design guideline is to distribute the search targets in an extended virtual reality environment so that children can search targets as they gradually move across the graphic display (background). This approach provides visual cues that help prevent children from getting lost in a sectional, breakdown condition. If the user reaches the wrong node, the cues in the virtual environmental help the user find the original path and find the nodes with similar meanings.

Iconic representations

Users must apply information visualization tools to interpret and decode icons and to judge whether the retrieval results are useful. According to Koshman (2006), p.205, a weakness of the web visualized tool is its possible arbitrary assignments of iconic representations to databases with inappropriate content. Even if the map metaphor helps users navigate and identify location parameters, it may not enable them to retrieve desired information represented with meaningful icons. Since the ICDL was developed for English speakers, Bilal and Bachir (2007) stressed the importance of the 'design representations' and 'meaning' of information for non-native English-speaking children who use ICDL. They also reported that older children perform book-searching tasks more efficiently than younger children do. Their objective was to incorporate the meanings and representations of icons in a child-friendly visual interface for information search.

Hu et al. (1999) described the visual properties that improve communication between users and information systems but recommended further study of contextual and emotional issues. Bates (2002) addressed contextual issues related to interface design and reported that an adequate design requires a clear understanding of cascade interactions between the user and system and that each system requires a different interface. Bilal (2001, 2002) suggested that emotions can profoundly impact the overall effectiveness of children in using a Web search engine to perform assigned and fully self-generated search tasks. Several studies have assessed systems that communicate effect by incorporating emotionally expressive computer agents. Leide et al. (2003) mapped the search process used by domain-novice users in a visualized IR system and applied benchmark (lighthouse) concept index user knowledge

boundaries in classification-based visualization schemes. Tzeng (2004) examined the effects of text and emoticons used to express sympathy for failures in computer games and reported that apologetic (sad) emoticons communicate emotions more effectively compared to pure text. Brave et al. (2005) studied how emotionally expressive computer agents affect the perceptions of players during computer games. Participants perceived empathetic agents as likeable, trustworthy, supportive, and beneficial. In addition to reviewing some of the human perceptual theories underlying graphical interfaces for information visualization systems, Schmidt and Stock (2009) applied a similar method of using tags to express basic emotions such as anger, disgust, fear, happiness and sadness in images.

Whereas most related studies have attempted to use standardized abstract-format icons and even text to represent important meanings in a visualized system, children generally ascribe meanings to symbols based on actual objects in their environment. For children, learning a new set of visualized symbols is harder than identifying images they observe in daily life. Thus, the third design guideline is using icons based on simplified images relevant to the experience of children to allow them to perceive the actual meaning of the database content.

Morse et al. (2002) compared visual information retrieval methodologies that used textual, iconic, graphical, and "spring" displays and found that the textual interface provided the highest user performance (p. 35); for the most complex tasks, however, graphical methods (icon, graphs, "spring") were superior. In Heo and Hirtle (2001), a study of how users process large quantities of information presented in a graphical interface revealed that the "expanding outline" is the most effective presentation. Icons, whether they are text or images, may help children of varying age and of varying literacy understand the meaning of an icon. Therefore, the fourth design guideline is to use both text and images as icons to help children understand the content of a digital library.

Blom and Monk (2003) suggested that users have various motivations and emotional reasons for personalizing their computers, including increasing their sense of control and ownership, increasing their enjoyment, and relieving boredom. Zhang (2008) proposed that the three mental models students use for web searches are acquiring information, understanding the working mechanisms of search engines, and devising search tactics. Lopatovska and Arapakis (2011) developed affective systems that can recognize and appropriately respond to human emotions and, ultimately, increase the effectiveness and pleasure of human–computer interaction (HCI). Thus, the fifth guideline is establishing a fun, game-like, and intuitive environment for seeking information instead of a work-like, classroom-like, machine-like interface that children are likely to find boring.

Figure 1 The NLPI text-based interface for children digital library.

Figure 2 The NLPI graphical interface for children digital library.

Table 2 NLPI databases linked to icons

Category	Icon name	Linked database – Window frame
Natural Sciences	Exploring Ecology	Taiwan Amphibious Reptile Video Database
		Taiwan Ecology Notebook Database
		Taiwan Fish Learning Knowledge Database
		Taiwan Bird Video Database
		Insect Picture Encyclopedia
		Taiwan Marine Ecology Video Databese
		Airiti Nature
		Newton kids Digital Museum
		Compendium of Materia Medica
		Form of Different Animal
	Science Knowledge	Copernicus 21 Sciences Knowledge Database
		The Scientist Magazine Chinese-English Knowledge Database
	Science Experiments	Newton Textbook-Nature Science Learning Treasure(Experiments)
Fine Arts & Music	Performance Arts	Opera in Video, Alexander Street Press Online Products
	Visual Arts	Paper Festival Series - Interactive Multi-Media Net Database
		Tsai Chih-Chung Caricature and Animation Database
		Chinese Poem Database
		Smithsonian Theatre in Video, Alexander Street Press Online
		World Fine Arts Database(ART)
		Collection of Historical Calligraphy
	Music	Cultural Sound-Picture Digital Database(Muzimax)
Health & Athletics	Athletics	The International Athletic and Competition Animation Special Reports
	Human and Food	Compendium of Materia Medica
		Food, Culture and Management Database
		Taiwan Food Culture Database
History & Culture	Native Inhabitants	Taiwan Who's Who in The Present Age
		Taiwan People(1895–1945)
		Biographical Literature
	Historical Buildings	Chinese Historical Building Database
		Taiwan Historical Building Learning Database
		The Palace Museum On-Line Database
		The Palace Museum Hertreasure Database

Category	Icon name	Linked database – Window frame
	Taiwan History	Taiwan Hundreds of Events Database, Dictionary of Taiwan History
		Taiwan Chronicle
		Taiwan Memorabilia Database
		Taiwan History Knowledge Database
		Taiwan Daily Newspaper Database (Chinese, 1905–1911)
		Taiwan Daily Newspaper Database (Chinese, 1898–1944)
		Taiwan Origin-Seeking Database
		Taiwan Documentation Serious of Books(Doc & Index)
		Taiwan Documentation Serious of Books(Image)
		Taiwan Documentation Serious of Books(Digital)
	Social Knowledge	Law Bank
		Info-Cip
		Credit On-Line
		CNS Online Service
		Ttsweb CLISA(1995–2005)
		Taiwan Native Learning Database
Treasure of Knowledge	English Reading Collection	Netlibrary eBook
		Tumble Talking Books
		Tumblebook
		Ebrary
		AMC-GEPT
		MC-NEW TOEIC
		Oxford English Dictionary Online
		Wiley eBook
		Taiwan News Online
		English DNA
		Smithsonian Theatre in Video, Alexander Street Press Online
	Chinese Literary Allusion	Wenhsun Magazine 200 Digital Library
		Jin Yong's Works Database
		Dr.Chinese
		Old Teacher E-Learning Idiom-Caricature Database
		Chinese Poem Database
		Online Chineseall
		L&B Digital Library
		Apabi eBook
		Koobe eBook
		Superstar Digital Library
		UDN Digital Reading Net

Table 2 NLPI databases linked to icons (Continued)

	Chinese Electronic Periodical Services(CEPS)
	China Academic Journals Full-Text Database(CJFD)
Encyclopedia	Gujin Tushu Jicheng, Imperial Encyclopedia
	Holidays eBook
	British Encyclopedia On-Line Chinese Version
	Chinese Encyclopedia Database
	Wiley eBook
	Taiwan eBook Academia
	Siku Quanshu, Emperor's Four Treasuries
	Discovery Digital Curriculum Teaching Video Database
Newspapers	Magv Online Magazine
	Taiwan Panorama Magazine Chinese-English Database(2005)
	Newspapers in Taiwan
	China Daily News Database
	Central Daily News Database
	United Daily News
	Newspaper Title Index Database
	China Times Database(1991–1999)
	China Times CD
	Taiwan Times Database
	Udndata.Com
	Acer Walking Library
	Taiwan News Online
	English DNA Bi-Linguistic -Teaching Post
Children Story Collection	Book Teller
	GURAU BEAR E-Picture Books
	Little Kiss Digital Book
	Charng-Jinn Multi-Media Digital Book
	The Sound-Picture On-Line For K-9 Digital Learning Curriculum
Native Language	Taiwan Word Dictionary Database
Examinations	ITEMS National Examination Database
	Chinese Electronic Theses and Dissertation(CETD)
	National Digital Library of Theses and Dissertations in Taiwan

According to the Gibson Affordance Theory, humans perceive possibilities (affordances) for action in order to operate in the environment. Perception is designed for action. Yu (2012) explained that visual perception affects how children categorize and narrate information. A visual interface design that children can use effectively for searching information must include appropriate affordances to simplify the task. According to a study of information-seeking behavior by Shenton & Dixon (2004), children tend to spend minimum effort to find sufficient information, they apply the same method repeatedly for a special information need, they select the search strategy at the point of need, and they apply untaught, expedient information-seeking methods. Thus, we argue that an effective visualized searching interface must enable repeated use of simple search strategies and must enable intuitive way-finding to the right information node in an extended virtual reality environment. Paivio (2006) introduced the dual-coding theory that visual and verbal information are processed differently and along distinct channels in the human mind. Thus, we argue that the iconic representations and the layouts of visual displays are critical for helping children to interpret and choose correct icons (information nodes) in different visual and textual forms to meet children recognition and living experiences. Most importantly, the visualized interface stimulates attracts the interest of the user.

Interface prototype development

This study developed a set of guidelines for using an icon-searching interface and a spatial-linked structure for On-line Databases used in the NLPI for Children. The core concept is to present the meaning searching process as a treasure-hunting game by using the virtual reality tool to create a graphical interface prototype, which children can use to search for information databases (icons) in the virtual reality environment. Since NLPI is responsible for information services used by children in Taiwan public libraries, it collects many digital databases used by children. Given the many digital libraries established for children worldwide, the NLPI also plans to establish a user-friendly interface for a digital library for children in Taiwan. Notably, the original text-based interface (Figure 1) for the NLPI digital library for children has already been changed to a graphical interface (Figure 2). The proposed interface has a two-dimensional virtual space that integrates different icons connected to different databases. After receiving approval from the service librarians and NLPI director, this study identified the databases that children typically use for general search (Table 2).

Figure 3 shows how the extended graphical interface uses icons to represent databases linked to the NLPI. Examples of databases include Copernicus 21 Sciences Knowledge database, Taiwan Amphibious Reptile video database, Taiwan Ecology Notebook database, *etc*. Based on guidelines 1 and 2, this study developed an extended visualized environment with icons representing different

Figure 3 Extended graphical design for the interface of NLPI children digital library.

databases to enable children to search for information without getting lost in multiple hyperlink hierarchies.

Concepts of way-finding and map-structure hierarchy were applied in the design of the graphical interface. Since children can typically conceptualize only seven categories, the databases were divided into five subject category groups - Natural Sciences, Fine Arts and Music, Health and Athletics, History and Culture, and Treasure of Knowledge, which are the subjects included in the primary school curriculum. For example, the Natural Sciences category group contained three lower-level icons: Science Knowledge, Exploring Ecology, and Sciences Experiments. Each lower-level icon was then linked to several databases, and each database was presented in a separate window frame (Table 2).

To search for information in the designed mainframe, the user moves the cursor (the spaceman) right or left (Figure 4) in the map to select an icon that represents a category. When the user clicks on the icon for the chosen database, a small window frame presents the detailed content of the database. Figure 5 displays how the up and down arrows can be used to navigate through different window frames to the target database. A video demonstrating how children use the proposed graphical interface for information search is available online (https://www.youtube.com/watch?v=WDLWYfOpg 5Y&feature=youtu.be).

Human perceptual theory, which underlies the development of graphical interfaces of information visualization systems, was applied in the design of the interface by using iconic representations that are easily recognized by children. Since simplified images relevant to the experiences of children enables them to recognize the database content, 19 images were selected (Figure 6). For example, visual arts are represented by paint brushes and color plates; Taiwan history is represented by the national flag.

The icons comprised images associated with the text and phonetic notation in order to help children recognize the database content. Since skills such as literacy, image recognition, and information searching develop at different rates, most children use an integrated method to deduce the content of various databases.

Results and discussion
User-oriented evaluation
Genuis (2004) categorized usability evaluations as expert-oriented or user-oriented. Users do not participate in the process applied by experts to assess usability. Therefore, the expert-oriented assessment process eventually causes a mismatch between assessment results and actual user

Figure 4 The graphical interface for children digital library with a pop-up window frame.

Figure 5 Operations in the pop-up window frame. The up-down arrows are used to move among different databases, after children entering the window frame.

conditions. In the user-oriented evaluation process, researchers collect data when users are performing tasks. However, since the assessment results in this study need to be consistent with the usability requirements, this work also applied the Usability Testing method of user-oriented evaluation to investigate how children use the designed graphical interface and the original text-based interface. While the children performed search tasks on the assigned interfaces, the researchers recorded their behavior in each step. Finally, the researchers analyzed the users in terms of success rates, operating speeds, and satisfaction to improve the interface usability (Rubin 1994).

Figure 7 shows the relationships among the evaluation factors, including children (user) characteristics, searching interfaces, and interface usability. Children characteristic includes grade (age) and computer usage. In a study of interaction design for children, Hourcade (2007) described visual acuity in static and dynamic (moving objects) settings. Static visual acuity rapidly improves from ages 5–7 years and from ages 9–10 years and is usually mature by age 10 years. Dynamic visual acuity similarly improves until ages 11 and 12 years. Thus, the selected age distribution of the sample was age 7 to 11 years. While experts suggest 30–45 minutes of free play for elementary school children with extra time allotted for school work (Matte 2014), this research defined heavy and light computer usage as more than 4 hours per week and less than 4 hours per week, respectively.

The searching interface includes the original text-listed interface and the suggested graphical interface. Interface usability was evaluated in terms of success rate and operating speed. Success rate was defined as the proportion of children who reached the target icon in a test divided by the total number of children assigned to the group. Operating speed is defined as the time children required to complete each task. The graphical interface incorporating visual memory and iconic representation into visualized retrieval systems clearly helped the children recognize different categories of knowledge content. However, further statistical confirmation of improved information searching efficiency is needed.

Experiment and sampling

The experiment was performed at the NLPI. The 104 students were randomly divided into two groups in order to compare the original NLPI text-based interface and the graphical interface prototype in terms of interface usability. Table 3 shows that 23 students were in grades 1–2, 46 were in grades 3–4, and 35 were in grades 5–6. Additionally, computer usage experience was classified as light (less than 4 hours per week) in 83 students and heavy (more than 4 hours per week) in 21 students.

Before beginning the experiment, the instructor demonstrated the operation of the interface to each child in the two groups and then introduced two tasks sequentially. The children were required to complete the task in 90 seconds and to inform the instructor after completing each task so that the instructor could record their times. The following two information search tasks were used in the experiment.

You encounter a problem while doing homework and your instructor tells you to search the online Taiwan Historical Dictionary database. You are now trying to find this database.

The second task was as follows:

Search the green sour bear picture books database after school to find books for leisure reading.

Hypotheses for interface comparison

The graphical interface and the original text-based interface were compared in terms of success rates and operating speeds for information searches. As the children were
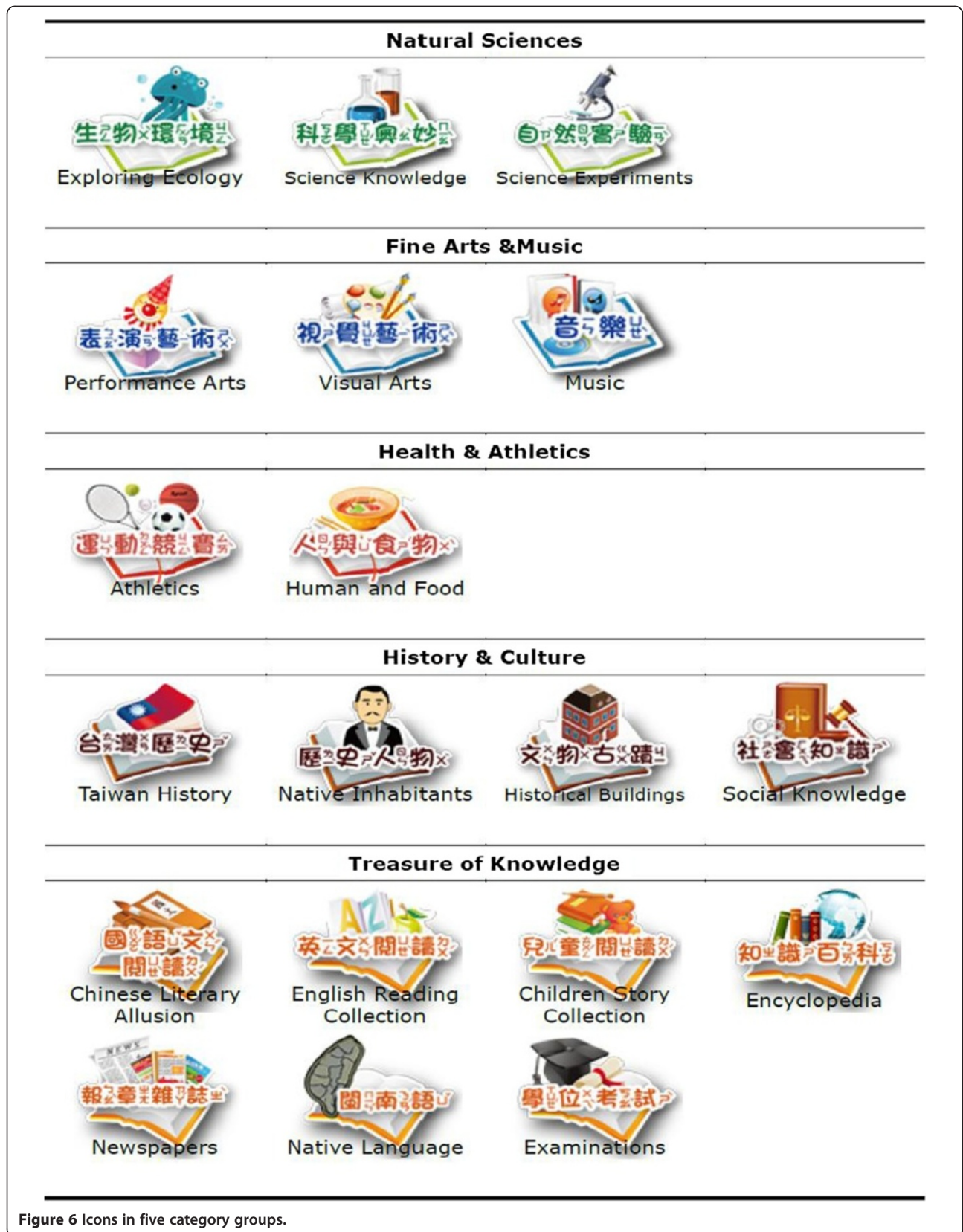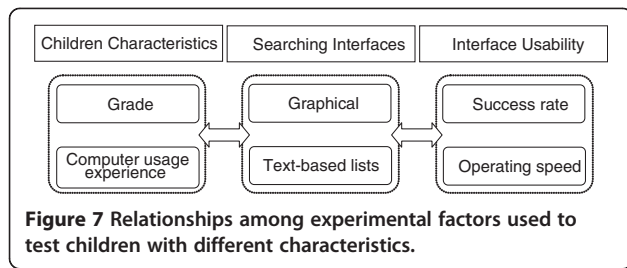
Figure 6 Icons in five category groups.

Figure 7 Relationships among experimental factors used to test children with different characteristics.

divided randomly to avoid interference between sequential operations performed by each group, Pearson chi-squared test was used to compare success rates between the two interface groups. Two-way analysis of variance was applied to examine the influence of two categorical independent variables (grade-interface or computer usage-interface) on one dependent variable (operating speed). We hypothesized the following:

H1: Regardless of grade, success rates for search tasks differ between the two interfaces.

H2: Regardless of grade, children who successfully complete the information search tasks use the two interfaces at different operating speeds.

H3: Regardless of computer usage experience, success rates for search tasks differ between the two interfaces.

H4: Regardless of computer usage experience, children who successfully complete the information search tasks use the two interfaces at different operating speeds.

Comparison of grade levels

Table 4 shows the task 1 results. Performance significantly differed between the original text-based interface and the graphical interface in all grade levels (grades 1–2 ($**p = .006 < .01$); grades 3–4 ($***p = .000 < .001$); grades 5–6 ($**p = .003 < .01$)). Regardless of grade, success rates for task 1 were higher for the graphical interface than for the original text-based interface. Success

Table 3 Samples in grade and computer usage experience

Grade	Computer usage experience (hrs/per week)		
	Less than 4 hrs	More than 4 hrs	Total (N = 104)
Grades1-2	22	1	23
(7–8 years old)	(21.15%)	(0.96%)	(22.12%)
Grades 3-4	38	8	46
(9–10 years old)	(36.54%)	(7.69%)	(44.23%)
Grades 5-6	23	12	35
(11–12 years old)	(22.12%)	(11.54%)	(33.65%)
Total	83	21	104
	(79.81%)	(20.19%)	(100.00%)

rates for task 2 also significantly differed between the original text-based interface and the graphical interface in all grade levels (grades 1–2 ($***p = .000 < .001$), grades 3–4 ($***p = .000 < .001$), and grades 5–6 ($***p = .000 < .001$)). In task 2, success rates were higher in all grades of children who used the graphical interface than in those who used the original text-based interface. Hypothesis H1 is thus validated.

Regardless of grade, children who successfully completed the information search tasks used the two interfaces at different operating speeds. Table 5 shows that, regardless of grade, success in completing task 1 significantly differed ($**p = .005 < .01$) between the original text-based interface and the graphical interface. Regardless of grade, successful completion of Task 2 also significantly ($***p = .000 < .001$) differed between the original text-based interface and the graphical interface. In all grades, the average operating speed (time required to complete the task) when using the graphical interface was faster (shorter) than that using the original text-based interface. Hypothesis H2 is thus validated.

Comparison of computer usage experience

Table 6 shows that success in completing task 1 significantly differed between the original text-based interface and the graphical interface in students with light computer usage experience ($***p = .000 < .001$) and in those with heavy computer usage experience ($*p = .011 < .05$). Regardless of computer usage experience, success rates for task 1 were higher in students who used the graphical interface than in those who used the original text-based interface. Success in completing task 2 significantly differed between the original text-based interface and the graphical interface in students with light computer usage experience ($***p = .000 < .001$) and in those with heavy computer usage experience ($**p = .005 < .01$). Regardless of computer usage experience, success rates for task 2 were higher in students who used the graphical interface than in those who used the original text-based interface. Hypothesis H3 is thus validated.

At all computer experience levels, the children who successfully completed the information search tasks used the two interfaces at different operating speeds. Table 7 shows that success in completing task 1 significantly differed ($*p = .021 < .05$) between the original text-based interface and the graphical interface, regardless of computer experience. Similarly, success in completing task 2 significantly ($***p = .000 < .001$) differed between the original text-based interface and the graphical interface, regardless of computer experience. Finally, the average operating speed (time) required to use the graphical interface was faster (shorter) than those required to use the original text-based interface regardless of computer usage experience. Hypothesis H4 is thus validated.

Table 4 Comparisons of success rates between graphical interface and text-based linear lists interface

	Task 1						N = 104
	Graphical interface			Text-based linear lists interface			Significance
	Failure	Success	Success rate	Failure	Success	Success rate	
1-2 grade	6	6	50.00%	11	0	0.00%	0.006 **
3-4 grade	6	19	76.00%	16	5	23.81%	0.000 ***
5-6 grade	2	11	84.62%	15	7	31.82%	0.003 **
	Task 2						N = 104
1-2 grade	2	10	83.33%	11	0	0.00%	0.000 ***
3-4 grade	3	22	88.00%	18	3	14.29%	0.000 ***
5-6 grade	0	13	100.00%	17	5	22.73%	0.000 ***

**p < .01, ***p < .001.

This study elucidates information-seeking behavior of children and compares their navigating experience in each interface. The statistical data obtained in comparisons of success rates and operating speeds contribute to efforts to develop an improved interface for emotional information retrieval. The children also had different comments and complaints about the two interfaces. Typical complaints about the text-based interface included of difficulty finding the right keywords, difficulty typing, difficulty reading the small font, the high complexity of the interface, and the ease of performing the wrong operation. In contrast, the children commented that the images used in the graphical interface were attractive and that its icons were organized consistently with the curriculum structure and were associated with phonetic notation, which enabled easy use of trial-and-error methods without breakdown after a failed search.

Differences between children and graduate students

Bilal and Kirby (2002) compared information-seeking behavior between children and graduate students using Yahooligans. They found that graduate students employed advanced search syntax, but the children did not; graduate students applied a "linear or systematic" browsing style to locate information whereas most children had a "loopy" style; graduate students made fewer Web moves, used fewer hyperlinks, and made fewer backtracks than children did; graduate students did not deviate from any designated targets whereas most children did; graduate students could quickly recover "breakdowns" in keyword searches whereas children could not.

Since the graphical interface improved the effectiveness of information searches by children, this study further evaluated the interface in graduate students. In two tests performed in six graduate students, the average time needed to complete task 1 was 29.67 seconds (range, 13 to 83 seconds), and the average time needed to complete task 2 was 33.83 seconds (range, 22 to 48 seconds). The graduate students tended to view each icon quickly and sequentially to find the first target (online Taiwan Historical Dictionary of databases), and they tended to remember the icons they reviewed. In task 2 (finding green sour bear picture books database), all students were confused about the meaning of recently viewed

Table 5 Comparisons of operating speeds between graphical interface and text-based linear lists interface

	Task 1						N = 48
	Graphical interface			Text-based linear lists interface			Significance
	Mean	Std. Dev.	Number	Mean	Std. Dev.	Number	
1-2 grade	59.33	15.397	6	-	-	-	
3-4 grade	40.11	20.981	19	61.00	11.640	5	
5-6 grade	38.64	18.559	11	64.71	13.425	7	
Average	42.86	20.370	36	63.17	12.298	12	.005**
	Task 2						N = 53
1-2 grade	44.50	20.239	10	-	-	-	
3-4 grade	37.36	19.817	22	79.67	9.609	3	
5-6 grade	35.08	17.090	13	67.20	13.255	5	
Average	38.29	19.056	45	71.88	12.977	8	.000***

**p < .01, ***p < .001.

Table 6 Comparisons of success rates between graphical interface and text-based linear lists interface for children with different computer usage experiences

| | Task 1 | | | | | | N = 104 |
| | Graphical interface | | | Text-based linear lists interface | | | Significance |
	Failure	Success	Success rate	Failure	Success	Success rate	
Light-experience	14	28	66.67%	35	6	14.63%	0.000***
Heavy-experience	0	8	100.00%	7	6	46.15%	0.011*
	Task 2						N = 104
Light-experience	5	37	88.10%	38	3	7.32%	0.000***
Heavy-experience	0	8	100.00%	8	5	38.46%	0.005**

*$p < .05$, **$p < .01$, ***$p < .001$.

Visual Arts icons, and none performed backtrack searches correctly. When they could not find the target, they searched the other side of the extended interface and found the target located on Children Story Collection icon. Since the organization of the icons was consistent with the school curriculum structure, children seldom confused the meanings of the icons. However, topics related to Information Categorization and Information Recommendation both require further study. Although the average operational speeds for graduate students were faster than those for children in both primary examinations, larger samples are needed to confirm the usability differences between children and graduate students (and even adults).

Conclusion

The information-seeking behaviors of children when using interfaces associated with different media differ from those of adults. For example, children perform web searches in different affective states of navigation. This study developed a customized interface to help children overcome obstacles to using the NLPI digital library for information seeking. Comparisons of usage behavior between the existing text-based interface and the new graphical interface show that the latter is preferred by the children who participated in this study.

Since the children indicated that they enjoyed using the NLPI graphical interface, the statistical results provide a valuable reference for considering the effects of visualized information in the design of information retrieval systems. While children are a special user group with unique characteristics, further studies of Information Recommender in children are needed to enhance the usability of interfaces that present information graphically. Many information recommender systems collaboratively evaluate and filter web content and are useful for individual searches of relevant information (Ardoin et al. 2013; Chen et al. 2013; Jafarkarimi et al. 2012; Tejeda-Lorente et al. 2014). To develop appropriate recommendations of information items (textual and graphical), a visual interface must consider how graphical information-seeking behavior differs between children and adults.

In addition to adequate information-seeking skills and intelligent affective strategies, children require customized, enjoyable interfaces to help them surf digital libraries online (Druin 2005; Nesset & Large 2004). To develop an effective graphical interface for a digital library for children, further confirmatory statistical analysis is needed to determine how the information-seeking behavior of children is affected by latent variables such as information type, media type, and affective state during information search.

Table 7 Comparisons of operating speeds between graphical interface and text-based linear lists interface for children with different computer usage experiences

| | Task 1 | | | | | | N = 48 |
| | Graphical interface | | | Text-based linear lists interface | | | Significance |
	Mean	Std. Dev.	Number	Mean	Std. Dev.	Number	
Light-experience	43.57	21.923	28	66.50	13.939	6	
Heavy-experience	40.38	14.550	8	59.83	10.572	6	
Average	42.86	20.370	36	63.17	12.298	12	.021*
	Task 2						N = 53
Light-experience	40.19	19.379	37	58.33	7.095	3	
Heavy-experience	29.50	15.611	8	80.00	7.036	5	
Average	38.29	19.056	45	71.88	12.977	8	.000***

*$p < .05$, ***$p < .001$.

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