Knowledge Journey: A Web Search Interface for Young Users

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ABSTRACT

This paper describes a new user interface for a web search engine whose main target group are young users. We explain the main challenges for this user interface and discuss design decisions we made. Our interface is audio supported, contains possibilities for both searching through text input and navigating using menu categories, has a guidance figure for emotional support and a result storage functionality to support cognitive recall. It is also colourful which is appreciated by most children. A comparative study with 28 young users was conducted where we compared our user interface with a classic text search user interface provided by most current web search engines. We evaluated what features of both interfaces children like or dislike to further improve the interface.

Author Keywords

Web Search Engine, Children, Search User Interface.

ACM Classification Keywords

H.3.3 Information Storage and Retrieval: Information Search and Retrieval.; H.5.2 Information Interfaces and Presentation: User Interfaces.

General Terms

Design, Human Factors.

INTRODUCTION

In times of digital natives more and more children are going online. According to a recent report [13], children of ages five to nine spend about 28 minutes online daily and this time continuously grows. The German 2010 KIM[1] study [30] reports that about 60% of the German children of ages six to thirteen use the Internet and 42% use search engines. Children are using the Internet for different purposes, especially for entertainment like playing online games or watching videos on *Youtube*, for communication with others and for information search, e.g. related to their school activities [30]. In order to support children in their search, special search engines for children have been launched, e.g. *kidrex.org*, *onekey.com*, *askkids.com*, *kidsclick.org*, *dipty.com*, *blinde-kuh.de*, *fragfinn.de*, *helles-koepfchen.de*, *quinturakids.com* etc. Currently, their main purpose is helping children to find child appropriate content in the WWW. Another important aspect is the usability of those search engines. It is of importance that these search engines match the particular skills of children to increase their usability for this specific user group. Unfortunately, current search engines for children not always match the skills and abilities of children [11]. Furthermore, these search engines are designed for children in general, i.e. the target group consists of users of a very wide age range.

When designing tools for children, there is a need to target very narrow age groups [32]. Cognitive abilities, emotional maturity and knowledge of a fourteen years old and a seven years old child strongly differ. In this paper we concentrate on children of ages seven to eleven. We chose this age range using the knowledge about human cognitive and psychosocial development [22], which explains that human development occurs in stages. Human abilities are different at each stage and new knowledge, abilities and skills are built upon the acquired ones. The age boundaries for each development stage are approximate and may vary from child to child. More specifically, the age range we chose falls into the "industry versus inferiority" period of child's psychosocial development, age 6–12 [10]. In this period it is important that a child succeeds in finding information. In this way, he or she feels competent and develops self-confidence. In contrast, if a child is not able to find good results, he or she may develop a feeling of incompetence [10]. Besides the immaturity in the emotional domain, children's cognitive abilities are also not fully formed [35]. According to Piaget [35] children of age seven to eleven are in the *concrete operational stage* of development with its unique cognitive characteristics. Furthermore, as we are interested in textual information search, our user group should at least be able to read. This is usually the case by children of age nine, they can read simple texts [39]. The special characteristics of children are challenging and should be considered in the development of web search engines, including the design of web search user interfaces (UIs). The aim of this work is to develop a web search UI that meets the needs of children, i.e. fits their cognitive abilities, knowledge and provides the necessary emotional support. Our user interface should support the children in their search in a web document collection. Furthermore, we nar-

[1] KIM is a German acronym for Children and Media ("Kinder + Medien, Computer + Internet"). It is a German user study which is regularly conducted in the form of interviews.

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row down the target group and consider children of primary school age as potential users. The structure of the paper is as follows. In Sect. *Related Work* we describe existing scientific work relevant to our topic. We use the findings of research in information seeking behaviour and web interfaces for children to underline the challenges in design of web search interfaces for young users. We also elaborate on existing search interface concepts for children. For each design challenge we discuss possible design solutions. Based on these analyses we designed a new web search user interface, called *Knowledge Journey*. We describe the user interface and its main components in Sect. *Search User Interface*. This interface was evaluated in a user study whose design and results are described in Sect. *Evaluation*. We conclude with Sect. *Conclusion and Outlook* where we discuss our work and provide possible further research directions.

RELATED WORK

The related work can be subdivided into three parts: research on children's information seeking behaviour, studies about children's preferences in web search interfaces and concepts of search user interface (SUI) for children.

Information Seeking Behaviour

Catalog Oriented Search: In general there are two interface types for search engines, that are currently used: catalog and query oriented search engines. In query oriented search engines the user needs to input some keywords, whereas in catalog oriented search he browses/navigates[2] through predefined categories. Search engines that integrate both interface types are also common [16] and combine advantages of both. Researchers found that the browsing performance of children is better and that children prefer browsing [4]. Nevertheless, the results of a recent study [21] suggest that children prefer typing keywords rather than "browsing the main categories". This can be explained with the fact that participants have grown more accustomed to keyword-oriented search UIs (had already experience with *Google*). However the search UIs used in the study does not seem to have good navigation capabilities, e.g. categories are hidden within the interface. One reason for children to prefer navigation is that navigation imposes less cognitive load. Less user knowledge is required to recognize and react to offered terms than to recall concepts from the memory. Borgman et al. [4] explain that navigation fits to children's "natural tendency to explore". It also better fits to the fine motor skills of children. Whereas keyword oriented search engines require correct spelling and typing, navigation is possible with simple point-and-click interaction. Nevertheless there are potential problems in category navigation. As children have only little domain knowledge and a smaller vocabulary than adults do, they may have problems finding the right category.

Some research was done considering the structure of categories. Hutchinson et al. [19] confirm that children are able to use both flat and hierarchical organized categories to browse. They found that young children are comfortable navigating a two-level hierarchy. Bar-Ilan and Belous [2] investigated the process of information categorization of elementary school children using a card-sorting method. They found that children can create hierarchical structures (with depth between three and five), but only when the categories correspond to concrete objects.

Keyword Oriented Search: The limited domain knowledge of children is also a problem in keyword oriented search engines. In order to formulate a search query, the user needs sufficient domain knowledge to think about useful keywords [18]. Selecting keywords is difficult for children, because it requires the ability of thinking in abstract categories [19]. Therefore, children tend to input full natural language queries [28]. Children do not use advanced search syntax like boolean operators [3]. Furthermore, children often use too vague or too specific keywords in queries [23, 3]. This makes it more difficult for children to get relevant results. Furthermore, most children have difficulties with typing. They are not able to type commands without looking at the keyboard (touch-typing). Instead they typically hunt-and-peck on the keyboard for correct keys. By looking at the keyboard while typing, children often do not spot spelling mistakes. Utilizing keyword oriented search, which requires correct spelling, is difficult for children [37, 5].

Further Aspects: Compared to adults, children have a different browsing style in Web documents. Children's search behavior can be described by many looping (repeating) and backtracking (clicking the "Back"-button of a browser) actions, with fast reading of the retrieved documents and little focus on the search goal, while adults' browsing style is *linear* or *systematic* [3]. Children click, repeat searches and revisit the same result web page more often than adults [12]. This characteristic agrees with children's lower cognitive recall, i.e. children forget about an already visited page or are lost. Children also have difficulties to evaluate the relevance of retrieved documents to their information need [21]. Children are frustrated by too many results and do not have the ability to quickly determine the most relevant and "best" documents [24]. In task-oriented search, children look for the final "concrete" answer in documents, without trying to read and understand the content [3]. Most children visit only the first result page and click on the first item in the result list [8].

Web Interfaces for Children

Naidu [31] found that children in general prefer websites with many pictures. It is consistent with Large et al. [25] whose user study results suggest using attractive screen designs, based especially on effective use of color, graphics, animation. They also suggest allowing for individual user personalization in areas such as color and graphics. Budiu and Nielsen [5] also came to the conclusion that children like movement, graphics, funny sounds, and colours. But designers should not exaggerate. Too much multimedia can overwhelm children [5]. Budiu and Nielsen [5] also found that metaphors, especially spatial navigation, work very well with children. But if the behaviour of metaphorical UI elements is inappropriate usability problems appear. Furthermore, there is also

[2]Although the term "browsing" is heavily used in the literature about children's information seeking behaviour in the context of "category browsing", it is more accurately to apply the term "navigation" (e.g. see [29]).

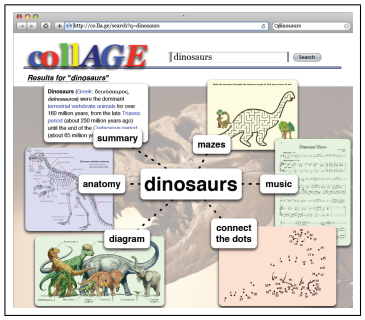

Figure 1: CollAge mockup [14].

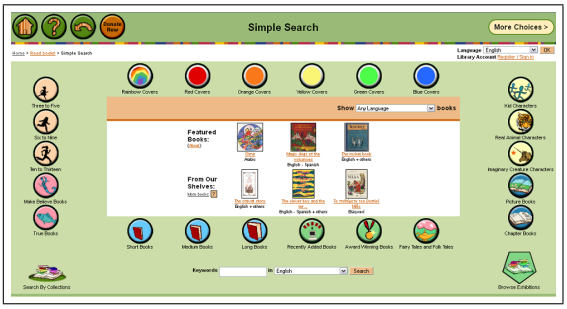

Figure 3: Simple Search mode in International Children's Digital Library, `childrenslibrary.org`.

evidence that children can experience difficulties with too advanced metaphorical navigation interfaces whose meaning they do not understand [21]. With regard to graphical objects, children understand icons better that text because it does not require good reading skills. But icons should also represent real-world concepts children are familiar with.

Straightforward text fonts (14 pt for young children and 12 pt for older children) and simple text layouts make reading easier for children. Both adults and children avoid reading long texts on the Web [5]. Interface elements should be large enough as fine motor skills of children are still developing and are not as good as by adults. The time for selecting a mouse target gets larger, the smaller the target object is. This means, that larger target sizes allow children to make selections more quickly [17]. Therefore, Budiu and Nielsen [5] suggest to make the clickable targets big. During the web search children tend to formulate natural queries instead of using keywords for search [5]. Thus, a large search box should be used in keyword search interfaces. Researchers also suggest that search interfaces should adress both educational and entertainment needs of children [25]. Certain mouse interactions are very difficult for children. For example, they have difficulties with drag-and-drop interactions, because they can not coordinate dragging and holding at the same time [38]. However, better design decisions might help to decrease the errors by drag-and-drop interactions [7]. Children often do not use complex interactions like scrolling a web page [31]. This mostly applies to younger children. Children older than nine are fairly comfortable with scrolling [5].

Search Interface Concepts

TeddIR [20], *CollAge* [14], *JuSe* [36] and *Imagepile* [1] are search user interfaces that are designed for young children, but mostly for preschoolers. In *TeddIR* children search books by putting tangible objects, which represent the search terms, on the screen. This helps children to overcome difficulties in spelling and deriving query terms. The *CollAge* web information retrieval system integrates search results for children's web queries with child-oriented multimedia results. For an user query, the system runs a Google image search and returns images as results in addition to existing search results (see Figure 1). *ImagePile* displays the results as a pile of images where the user navigates horizontally to support children in determining the relevance of results. *Junior Search (JuSe)* is an interface that enables searching through adaptable picture dictionaries. Children can construct queries using these pictures. *JuSe* uses categories derived from children's vocabulary lists and parents can adjust the list, e.g. add new words.

Lingnau et al. [26] presented the *Show and Tell (SAT)* system for children's interactive search. The goal of the system is to train children's ability to identify interesting material and to connect information through telling stories. *SAT* uses a book metaphor. Children have to select an image (e.g. from a Website) using a drag-and-drop operation in order to start a search. This image is placed on the book cover. The book, its left side, is then filled with search results associated with the search image (see Figure 2, left). Children can create their own stories by selecting items from search results and placing them on the right book side (see Figure 2, right).

EmSe [9] is a search service for children in a hospital environment. It was designed for children of ages 8–12. The authors share the idea of a guidance avatar which is also supported by the SUI we propose in this paper. In order to overcome terminology difficulties a novel visual querying inter-

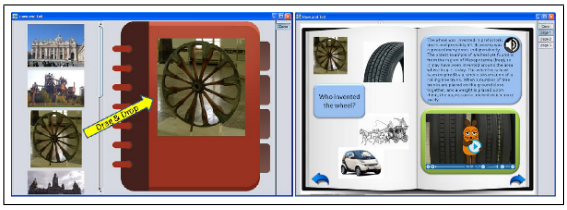

Figure 2: Show and Tell system uses book metaphor [26].

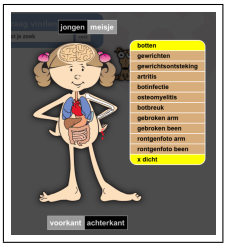

Figure 4: *EmSe* search service: the *Body Browser* with query suggestions [9].

face *Body Browser* (Figure 4) is offered which lets children explore medical information. Furthermore, *EmSe* provides children with relevant documents where medical terms are annotated with explanations.

Besides web search user interfaces, there is research in digital libraries for children. Hutchinson et al. [18] developed a searching and browsing tool suitable for children for the International Childrens Digital Library (see Figure 3). They considered children's differences in motor skills designing the system and provided large icons and simple point-and-click actions to interact with the system. Besides searching, the system supports browsing where child appropriate categories are used. These categories are represented by icons to support children with undeveloped reading abilities. Search results can be filtered by different parameters using the category buttons. Sequential clicking on the categories leads to Boolean conjunctive operations which is also represented in the user interface. The International Childrens Digital Library is publicly available[3].

From our point of view, current research suffers from the lack of evaluation of recently proposed SUI concepts. Children's information-seeking behaviour was studied mostly on classic keyword oriented IR systems. Their searching behaviour and acceptance of "new" user interfaces should be examined in comparative user studies to compare them with existing alternative UI concepts. Children's perception of user interface elements, e.g., different forms of results visualization, should also be compared in the future.

SEARCH USER INTERFACE

In this section we first describe challenges when designing web SUIs for children and propose feasible solutions. After that, we present our search user interface *Knowledge Journey (KJ)* and describe its main components and features.

Design Challenges & Solutions

Emotional Support: Based on Erickson's theory of psychosocial development [10] children require emotional support and a feeling of success. So far, this problem was not covered in HCIR for young users. In the case of an ideal search engine children would always be satisfied with search results and would not get frustrated if their search does not end successfully. Until the ideal search engine is designed we suggest supporting children by their search which can be achieved for example by proper guidance. The idea here is to provide children with enough help to support their search process to avoid frustration. We propose building a guidance figure that captures children's failures, e.g. getting no results or spelling mistakes, and explain how to do better. In contrast to adults, less experienced young users (and thus those who especially require support) are willing to read instructions and thus would pay attention to well-designed help instructions [32]. Furthermore, spoken instructions would be appreciated by children whose reading skills are not well developed.

[3] `http://www.childrenslibrary.org/icdl/SimpleSearchCategory?ilang=English`, accessed on 13.07.2012.

Language Support: Children, especially in the primary school age, read slowly and are still learning to write [39]. In addition, children have a limited domain knowledge [19] and difficulties with typing using a keyboard [37]. This results in problems with query formulation and spelling errors [3, 12]. Thus, spelling correction and query suggestion mechanisms in keyword based search tools are important. Furthermore, a search UI for children should provide different possibilities for children to formulate their information need. Previous research addresses this problem by suggesting alternative ways for query formulation like using a predefined term dictionary in *JuSe* or a set of tangible objects which represent the search terms in *TeddIR* (see Sect. *Search Interface Concepts*). We suggest using a menu with various categories that correspond to children's information needs. This menu should be image based and audio supported to support dual information coding [34] and therefore to allow ergonomic and fast navigation within it. Besides navigating using the menu, we also suggest to provide the opportunity of keyword-oriented search supported by spelling correction mechanisms. Children can choose the way they want to start searching. With an increasing domain knowledge (possibly gained from navigation in categories) children can employ keyword-oriented search more efficiently.

Cognitive Support: According to theories of human cognitive development, human development occurs in a sequential order in which new knowledge, abilities and skills build upon the previously acquired ones [33]. Piaget [35] describes four development stages. Children in the concrete operational stage of development learn to reason logically and have difficulties with thinking abstractly. Their understanding is limited to concrete and physical concepts. It is important to design categories which match the cognitive abilities of children. Therefore, categories used in the menu should not be abstract and the menu should have a flat hierarchical structure. Metaphors used in the user interface should be familiar to children and have a connection to the physical world (this is also advised in [5]).

Memory Support: According to the information processing theory [22], information processing of children differs from the adults' in terms of how they apply information and what memory limits they have, i.e. children can represent and process less information. Information retrieval processes may cause children's memory to overload. This explains children's "looping" behaviour during the information seeking process. Children click, repeat searches and revisit the same result web page more often than adults do [3, 12]. Thus, it is also important to show a clear back-button or just present the search result in the same window (e.g. using frames) to prevent children from getting lost. In our opinion, the aspect of memory support is not covered by the current research and researchers should pay more attention to it. Research would benefit from new approaches in *personal information management* for children. To support children's cognitive recall we suggest providing a result storage functionality.

Interaction Support: The information processing rate influences the fine motor skills of children [6, 17]. Children's per-

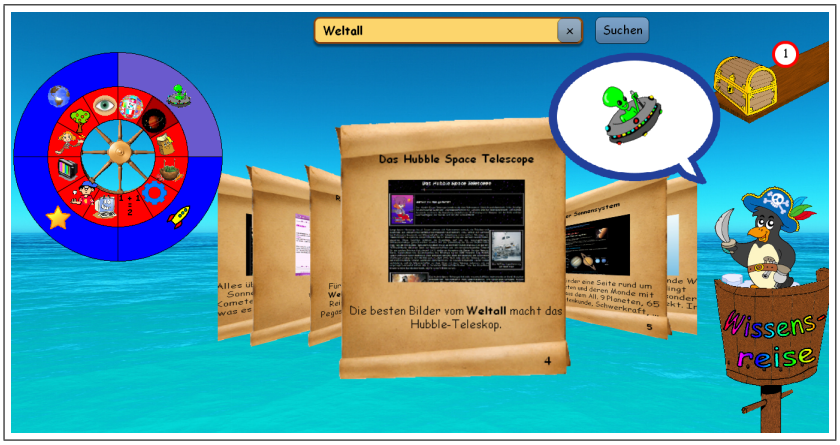

Figure 5: Screenshot of the *Knowledge Journey* user interface: a guidance figure and a treasure chest on the right hand side, query input elements on the top, a navigation menu on the left hand side and a coverflow with search results in the middle.

formance in pointing movements, e.g. using a mouse, are lower than that of adults. Therefore, the search user interface should prefer simple point-and-click interactions and clickable interface elements should be large enough to be easily hit (this is also consistent with [5]).

Relevance Support: Children also have difficulties to judge the relevance of the retrieved documents to their information need [21]. Children are frustrated by too many results and do not have the ability to determine the most relevant and "best" documents [24]. A child-suitable form of results presentation can support children's judgement of results' relevance and provide relevance clues. Each result item should at least have a website image and its description. Akkersdijk et al. [1] also suggest displaying the results using a *Coverflow* technique where the user navigates horizontally. Coverflow allows users to concentrate on one item at a time. It also does not require complex interactions like scrolling as a vertical results list used in common search engines.

Knowledge Journey

We considered the requirements for user interface design and developed a search user interface for children called *Knowledge Journey (KJ)*. We used multimedia elements in the UI design to make the appearance attractive for children. We also took into account that all clickable items are of appropriate size. We used font sizes larger or equal to 14 pt [5]. Our search user interface KJ uses the metaphor of a treasure hunt where a user takes a journey to gather relevant search results. The interface of KJ is shown in Fig. 5. It consists of five groups of elements: a guidance figure (here a penguin pirate), a treasure chest, a coverflow visualization of results, elements for keyword search and a pie-menu for navigation. In the following we describe each element group.

Guidance Figure: In order to start a "Knowledge Journey" a child selects a guidance figure (see Fig. 6a). The guidance figure concept is familiar to children from computer games in form of avatar. It allows individual user personalization, e.g. we assume that girls can select a female pirate or penguin, there are also figures for younger and older users. The guidance figure supports children's search process in order to avoid frustration: in the current version it supports children by providing a spelling correction after a misspelled query is submitted (see Fig. 6b) and enlarges images of menu categories providing animations (Fig. 5). A further possible function of the guidance figure is an explanation how to search and what to do in case of finding no results.

Navigation Menu: In order to support children who have difficulties in query formulation, a menu with many categories is offered. There exist different types of menus. We used a pie menu as it can be operated with simple point-and-click interactions and presents a good overview of available categories. The pie menu is placed on a steering wheel. We use the metaphor that a steering wheel is used to define the search coordinates in order to provide a search direction. Initially the top categories of the menu are shown (see Fig. 7, middle). We chose menu categories like entertainment, sports and hobbies, history, universe, geography, nature, persons etc., as they meet the information needs of children described in [27]. Each category has a number of subcategories. Hutchinson et al. [19] confirm that children are comfortable to use a two-level hierarchical organized menu for browsing. Corresponding subcategories are opened when a child clicks on a top-level category. Mousing over the category triggers an action of a guidance figure, i.e. it shows a large animation to explain the category. Icons and animations are used to indicate categories because images better match the cognitive skills of children than written words [15]. They also make the user interface more attractive as children prefer colourful designs with multimedia content [31, 25, 5]. In addition, we provide audio support. By placing the mouse long enough on a pie menu item, a voice explanation is played telling what category is selected. Users can also hide the menu by clicking in the middle of it. Then, only the wheel is shown (see Fig. 7, left). The menu can be opened again by clicking on the wheel. If a child clicks a category it receives results visualized as a coverflow. The category name is also placed as a text in the search input field.

Results Presentation: The result presentation is shown in

(a)

(b)

Figure 6: Screenshot of the user interface: (a) select which pirate accompanies you during the *Knowledge Journey* and (b) guidance figure makes a suggestion by a misspelled query.

Fig. 5. We use a coverflow where each item is presented on a papyrus roll that contains the webpage's title on top, its thumbnail (preview) in the middle, a textual summary and a result number according to the relevance at the bottom. A child can interact with our coverflow using simple point-and-click operations. It can open a webpage by clicking on the result item that is in focus or switch to the next or previous page by clicking on an item that is not in focus. The whole papyrus roll area is clickable and thus is easy to hit. We decided to open a webpage in the same window using a frame as results opened in a new window or tab inhibit backtracking with the browsers' back button (see Fig. 8). In order to return to the search a child clicks on the "X"-Button. It can also store a webpage using a "+"-Button.

Results Storage: A child can store relevant results in the "treasure chest". This form of storage aims to support children's memory to prevent cognitive overload. The number of stored results is shown near the chest. Furthermore, we use physical concepts like the size of the chest to show the amount of "treasure", i.e. a chest icon becomes larger with each additional stored result (compare Fig. 5 and 9). By clicking on the chest, a journey journal opens (Fig. 9). We use a book metaphor, where each two pages of the book contain information about a stored webpage: its thumbnail, a textual summary and a title. A child can add notes to each website. He or she can also open the website again by clicking on its picture in the book. If a child does not like a website anymore, he or she can delete it by clicking on the "-"-Button. Tiles in the form of small website thumbnails (below the journal) are used to navigate within the book.

EVALUATION

In this section we describe the design and results of a comparative user study we did to evaluate *KJ*. The results of a recent user study [21] indicate, that children are likely to use *Google* and even perform better using *Google* than on search engines designed for them. That is why, in our evaluation we compared the *SUI* of *KJ* with a classic keyword-oriented *SUI* we called *Google-like*[4] *(GL)*. Thus, we used the *GL* search user interface as a baseline. We fixed the underlying search engine, i.e. used the same backend for *KJ* and for *Google*-like SUI. In this way, the results of comparison are not biased by the backend (e.g. underlying index or ranking algorithms), which can happen if the SUIs of two different search engines are compared. In this first user study our goal was to evaluate one of the usability aspects, namely user satisfaction. The following research questions were issued in the user study:

- What search user interface do young children prefer and why?
- What is children's attitude towards new interface elements like the guidance figure, audio support, pie menu and treasure chest?
- How can both user interfaces be improved?

[4]We did not compare with the *Google* search engine.

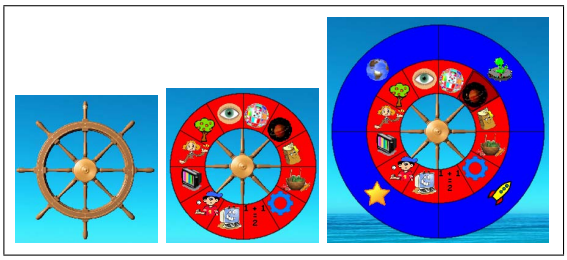

Figure 7: Screenshot of the user interface: navigation menu on a steering wheel in three different levels (closed, opened, opened with 2nd hierarchy level).

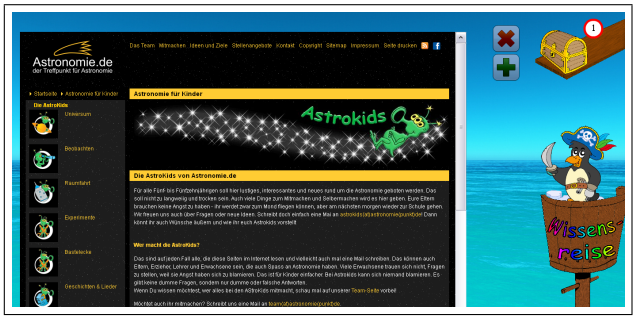

Figure 8: Screenshot of the UI: website opens in a frame.

Figure 9: Screenshot of the user interface: journey journal with favourite web pages.

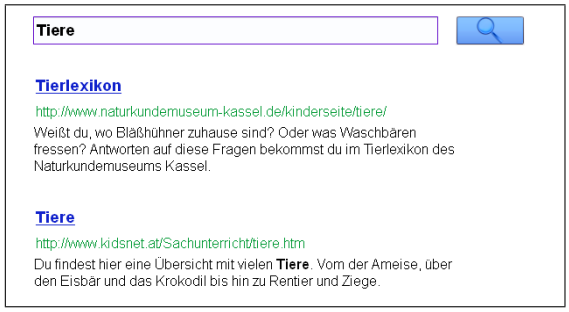

Figure 10: Classic keyword-oriented search user interface.

Study Design

We build a classic keyword-oriented SUI which is shown in Fig. 10. It offers the possibility of a keyword-oriented search and presents search results as a vertical list of snippets. Each snippet has a title, an URL of a website and a textual summary. For the backend we used *Solr*[5] together with *Nutch*[6] to create a search index and provided the possibility to employ a keyword-oriented search. Our index contained 60 web documents[7] crawled from web portals for children. In addition, for each menu category we manually selected corresponding web pages which we added to the Solr results' list. Users received the same results whether they clicked on a menu item or typed the category's name in the input field. We also implemented the spelling correction feature "Did you mean?" using *Solr*[8] in both SUIs.

Our user study was designed as follows: we used a pre-interview to gather users' demographic information and their Internet experience. Then a lab experiment was performed using *KJ* and *GL* SUIs. Finally, we asked the participants what user search interface they preferred. We used a *latin square design* in our lab experiment part, i.e. a half of the participants were asked to use the Google-like interface first and then to use KJ, whereas another half did this in reverse sequence. Latin square design [16] is used to reduce the bias due to the order in which the participants are using the UI. In addition, we took notes about participants UI usage. Thus, the participants from the first half were first introduced to the Google-like interface, were ask to perform a task-oriented search and to show the web pages where they found the answers. After that, they were interviewed about UI features they liked most or disliked and what could be done to improve the UI. Then, these participants were introduced to the KJ interface. We also presented a short tutorial video about KJ and gave children the opportunity to explore KJ themselves. The participants were asked to also perform a task-oriented search using KJ and show the web pages where they found the answers. The same questions as for the Google-like UI were asked about KJ. Another half of the participants started with the KJ UI whereas the procedure remained the same.

[5] `http://lucene.apache.org/solr/`
[6] `http://nutch.apache.org/`
[7] These were also documents relevant to our search tasks.
[8] `http://lucene.apache.org/solr/`

We used searching tasks during the lab experiment as we believe a searching task helps the participants to better explore the system including its UI. Nevertheless, we provided participants with help as the focus of the study was the evaluation of users' attitude towards the UIs and the time per participant was limited to 20 minutes. As we were limited in time, a good balance between time and the right level of complexity was crucial. It was also important that the task was interesting for children and they did not know the answer in advance. Based on those requirements, we used two search tasks of the same degree of complexity, one task per UI:

- *Task 1:* Is it colder in the Arctic Circle on the Earth or on the planet Jupiter?

- *Task 2:* Is it hotter on the planet Venus or in deserts on the Earth?

A user could answer the question by performing two separate searches: to find the temperature on the planet and on Earth and compare both values. It was possible to find an answer using a navigation menu of KJ or employing a keyword-oriented search which was available in both UIs. We also varied the task-UI from participant to participant.

Study Results

Participants

The user study was conducted in June 2012. Our 28 participants were of age seven to twelve (average 9.5 years), 14 female and 14 male. They were mostly third (nine children), fourth (eight children) and fifth (seven children) grade pupils. All the participants had Internet experience. The distribution according to the frequency of the Internet usage is following: everyday (two pupils), two-four times a week (twelve pupils), once a week (nine pupils), once a month (five pupils). We noticed no significant correlation between the frequency of use and age or school grade. 18 participants use the Internet without supervision, seven participants do it with relatives and three participants do both from time to time. All the fifth and sixth grade participants use the Internet without supervision. The children use the Internet mostly to play online games and watch videos on Youtube, but also to search information for school. These activities were mentioned by almost all participants. Some of them also chat. In order to search for information 26 participants use *Google*. Only five participants use also search engines for children.

Information Seeking Behaviour

We noticed that the children had difficulties operating the keyboard and used hunt-and-peck. The participants had no big problems with scrolling operations. Many children's search queries consisted of a group of key-words like "cold planet Jupiter". However, six children (21%) put the whole question as a search query which is known as a type of natural language query. We also noticed the signs of backtracking problems and confusion (see Sect. *Information Seeking Behaviour*) when users used the Google-like UI where the results where opened in a new tab. When scanning a web page for results many children had difficulties to locate the relevant information on the page. Children were impatient and often skipped the page without trying to read it carefully. Note that our search tasks were to compare temperatures and accordingly figures representing it were supposed to be found more easily than textual information.

UI preferences

Comparison of UIs: Overall, 17 participants preferred KJ UI and five liked both UIs. This is statistically significant with $p=0.05$ using the one sample t-test between percents. In the following we discuss the results regarding different UI elements of both interfaces.

Web Design: The participants disliked the large amount of white space in the Google-like UI and wished the UI to be more colourful. One participant also suggested outputting the result list in the middle of the web page instead of the left side in order to avoid *"too much free space"*. They liked that KJ contains many pictures and is colourful, except for one child who did not like the KJ UI because he found the graphics to be *"babyish"*. Furthermore, the young users wished to select a background in some other colour themselves. This is consistent with results of previous research [25] (see Sect. *Web Interfaces for Children*) to allow individual user personalization in areas such as color and graphics. Three participants suggested that the background should adapt to their search query, i.e. when searching information about Venus the planet picture should be shown in the background. Thus, the results of our user study support the UI concept of *CollAge* [14] (see Sect. *Search Interface Concepts*).

Results Presentation: Overall, the preferences of the users varied: some of them preferred the results presentation using a vertical list whereas the other half liked the results presentation with coverflow. The participants liked that the Google-like UI provides multiple search results and that due to the vertical list presentation form they could review several result snippets at once. The Google-like UI is also *"simple"*. Three participants mentioned a drawback of the Google-like results presentation, namely that it is not clear that the list contains multiple results because they are not explicitly separated through UI elements from each other. The KJ UI, on the other hand, presents each result on a separate papyrus roll, thus the connection of each snippet to a website is made clear. This was mentioned by two participants. In addition, three participants found the textual summaries of the result web pages to be too short and wished more information. All the participants liked that KJ UI offers a picture of each website in the results. Even those who had not yet seen KJ UI remarked that they missed a picture. One participant also wished to make the different elements of the result snippets more colourful.

New Interface Elements

Guidance Figure: In order to start a *Knowledge Journey* a child should select a guidance figure. 18 participants chose the penguin pirate to join them on the knowledge journey. The older pirate was selected by five older children (mostly fifth grade). Three female participants chose the female pirate. The participants liked the possibility of selecting a guidance figure. In this way, a guidance figure creates an emotional bond with an SUI which increases children's willingness to accept its help during the search.

Menu: About 90% of participants tried the menu in the warm-up stage of the experiment. They liked that the menu contained so many categories: *"you can find everything there"* and *"the menu is lovely"*. We also did not notice any differences of users operating the menu. But, when receiving a search task, the participants mainly used the search input field. Only one participant used a menu to solve the whole task. Two participants solved a part of the task using the menu. Four children tried using the menu to solve the task but then switched to the input field. These children were not successful with the menu as they only explored the categories of the 1st hierarchy level but the relevant pages could be reached from the second level (that was our design decision). Therefore, the menu is more likely useful for exploration tasks whereas in our user study we had a well-defined (answer-oriented) search task.

Audio Support: The participants had different opinions regarding the audio support. Two children found it *"useful"* whereas three participants commented that it was *"irritating"*. The remaining participants had a neutral opinion, i.e. *"okay"*. One child told us that *"audio support is for children who cannot read"*. Another child suggested for the voice to speak more slowly. One participant wished also to select the gender of voice. Overall, we believe that audio support is useful in order to support navigation in the menu as pictures alone can be misinterpreted by users. However, the possibility of turning the sound off should be given.

Results Storage: The idea of saving interesting results in the treasure chest received a highly positive user feedback, i.e. all the participants mentioned the treasure chest as a most liked feature of the SUI: *"Treasure chest is handy"*; *"One does not have to remember"*. One participant said that he could store the links to the online games there. Less than a half of the participants stored the relevant pages performing the actual task. In our opinion, the treasure chest has no big influence on the success in a task-oriented search as this type of search does not require much memory load. However, SUI benefits from the results storage in case of complex search tasks like research for a child's homework.

UI improvements

Based on the findings of the user study we summarize the possible improvements of UIs as follows.

Both UIs: The background of a result output page should be adaptable and present pictures relevant to the search query. Different kinds of GUI personalization, including even the colour of different elements of the result snippets, should be provided by the UI. A textual summary of a web page should be long enough (probably more than one sentence). SUI should also support children in locating the relevant information on the web page, i.e. by highlighting the query words in the target web page to provide better relevance clues. However, this idea should be evaluated in the future.

Classic Keyword-oriented Search User Interface: Each result element should be clearly separated from the rest and have a thumbnail of the corresponding web page. SUI should show a clear back-button or present the search result in the same window (e.g. using frames) to prevent children from getting lost. New GUI elements like guidance figure, wheeled menu and treasure chest can enhance user experience.

Knowledge Journey: A vertical results list offers a better (and faster) overview of results. Given a proper indicator for items separation we believe that this type of results presentation would lead to a more efficient search over the coverflow. However, this is only true in case of desktop computers which have a relative large screen. Coverflow visualization would be appropriate for SUI designed for single- or multi-touch hardware like smartphones as operating a coverflow using touch is more natural for a user, i.e. it is similar to browsing in a book. Although some participants did not appreciate the voice support, we would retain this feature to support dual information coding in a menu. However, it is useful to offer the possibility of voice gender personalization. In addition, young users should be able to turn the sound off. The SUI for *KJ* was primary designed and evaluated using desktop computers. However, we believe that the offered solutions and interface itself is applicable for single- or multi-touch hardware. One challenge here is mapping the mousing over feature from the desktop based solution to touch based devices. This can be realized by setting time constraints that activate a specific system reaction after the user keeps on touching a certain area for a predefined amount of time.

CONCLUSION AND OUTLOOK

We presented a new user interface called *Knowledge Journey*. It is a web search user interface for young users in the primary school age. When designing the *Knowledge Journey UI* we took into consideration the results of previous research based on which we first outlined the main challenges of that type of user interface. The UI of KJ is colourful and audio supported, and contains possibilities for both searching through text input and browsing in menu categories. It also has a guidance figure for emotional support and a result storage functionality to support children's cognitive recall. With this work we made several contributions to the HCIR for children. We summarized the state of the art in the field of HCIR for young users. We specified the challenges and suggested solution in web search interface design for young users. We developed a prototype of a web search interface for children of primary school age. Furthermore, a significant contribution of this work is a comparative user study we did to evaluate our search interface against a classic keyword-based SUI with a vertical result listing. To our knowledge we are the first who did a comparative user study of search UIs for children with a fixed backend. We used a latin square design and let each of the 28 participants compare between the two UIs. Many participants preferred KJ UI over a Google-like UI. They liked new features of KJ, particularly the treasure chest. In the future we are going to extend the features of the treasure chest in the way users can store the treasure chest on the hard drive. A nice idea is also to support a collaborative search where connected users can share treasure chests. In our user study we evaluated children's attitude toward the different SUIs. In the future further aspects of *KJ's* usability, i.e. effectiveness and efficiency, should be analysed.

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