

Specifics of Information Retrieval for Young Users: A Survey

Tatiana Gossen*, Andreas Nürnberger

Otto-von-Guericke-University, Data and Knowledge Engineering Group, Universitätsplatz 2, 39106, Magdeburg, Germany

Abstract

In this paper, we present the state of the art in the field of information retrieval that is relevant for understanding how to design information retrieval systems for children. We describe basic theories of human development to explain the specifics of young users, i.e., their cognitive skills, fine motor skills, knowledge, memory and emotional states in so far as they differ from those of adults. We derive the implications these differences have on the design of information retrieval systems for children. Furthermore, we summarize the main findings about children's search behaviour from multiple user studies. These findings are important to understand children's information needs, their search strategies and usage of information retrieval systems. We also identify several weaknesses of previous user studies about children's information-seeking behaviour. Guided by the findings of these user studies, we describe challenges for the design of information retrieval systems for young users. We give an overview of algorithms and user interface concepts. We also describe existing information retrieval systems for children, in specific web search engines and digital libraries. We conclude with a discussion of open issues and directions for further research. The survey provided in this paper is important both for designers of information retrieval systems for young users as well as for researchers who start working in this field.

Keywords:

information retrieval, children

1. Introduction

The time of the digital natives has come. Nowadays, computer and Internet access is available in almost every household and the number of children who use modern technologies and Web services from early age grows every year. According to recent report (Gutnick et al., 2011), children ages five to nine spend about 28 minutes daily online and this time continuously grows. The German 2010 KIM¹ study (Medienpädagogischer Forschungsverbund Südwest, 2011) reports that about 60% of the German children of ages six to thirteen use the Internet and 70% of them use search engines. Children exploit the Internet for entertainment, e.g. online games and to communicate or chat with others. Furthermore, they also use the Internet for research related to their school activities or for other information like news, weather and sports (Newburger and Bureau, 2001). More than half of the children search the Internet predominantly alone (Medienpädagogischer Forschungsverbund Südwest, 2011). Unfortunately, not all of them succeed in information inquiry and especially younger children experience difficulties. For example, almost 50% of six and seven years old children claim to have problems in information acquisition (see Figure 1).

In order to better support children at their search tasks, several websites which provide special search services for children have been launched, e.g. *askkids.com*, *blinde-kuh.de* etc.. Currently, their main purpose is helping children to find child appropriate content on the Internet. However, this is only one important aspect of such search engines.

*Corresponding author. tel.: +49 3916758290; fax: +49 3916712020.

Email address: tatiana.gossen@ovgu.de (Tatiana Gossen)

¹KIM 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.

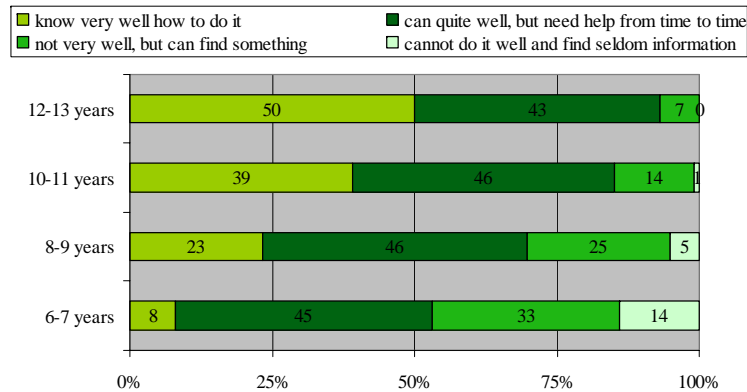


Figure 1: Children’s own assessment of their ability to successfully search for information on the Internet (2010 KIM user study).

Another important aspect is the usability of these search engines. Unfortunately, existing search engines have many drawbacks in design, i.e. do not always match the skills and abilities of children (Gossen et al., 2012). Another issue for children is that there are many good techniques in information retrieval (IR) for adults, but still not much scientific insights on how to design search engines for children in terms of both user interfaces and underlying algorithms. Finding information on the Internet is an important skill that children need to develop and it is important to provide them with the necessary tools to succeed. Thus, research on information retrieval systems for young users is very important.

As we will show in this paper, cognitive, emotional, linguistic, fine motor etc. abilities of children, as well as their perception and knowledge differ from those of adult users. That is why targeted search engines for children should be designed by taken into account children’s specifics in order to make them more usable for their user group. This paper aims to summarize the state of the art that is important to understand the special challenges in design of IR systems for children. This is important for designers of such systems as well as for researchers who start working in this field. When describing children’s search behaviour and information retrieval systems for children in this paper, we mainly concentrate on information search in a web document collection. During the search children intend to find information relevant to their information needs. Though web documents mostly have a textual form and are written in natural language, they can also contain pictures and other media. However, our primary focus is textual information retrieval. In order to search successfully, children require special search engines that should be designed considering the specific requirements and needs of children. Besides of good search engines for children, an underlying (web) document collection for children is an essential component in order for children to succeed in search, but in this paper, we are not further discussing the current usability, quality or amount of websites meant for children.

Information retrieval for young users is a complex topic which is strongly related to cognitive science on human development. Therefore, in Sect. 2, we briefly describe several foundational theories in human development, which in our opinion help understanding the special characteristics of children’s information retrieval. We continue with a discussion of studies about children’s information seeking behaviour and their results. We present algorithms and user interface concepts which were proposed by computer scientists for information retrieval systems for young users in Sect. 4. In Sect. 5 we describe existing information retrieval systems for children. We conclude and give directions for further research in Sect. 6.

2. Aspects of Children Development Important for Information Retrieval Tasks

When designing tools for children, there is a need to target very narrow age groups (Nielsen, 2010). Studies of cognitive science about human development helps to achieve this goal. In this section we briefly describe a human cognitive development model, the main idea of information processing theory and a theory of human psychosocial development, which explain the fact that children’s emotional states, cognitive and motor skills are developing and

differ from that of adults². The summary of these characteristics is given in Figure 2. Further insides into the theories from cognitive science and their impact on digital environment design for children can be found in Cooper (2006). This section concludes with a discussion of the implications that the revealed specifics of young users in different development stages have on the design of information retrieval systems for children.

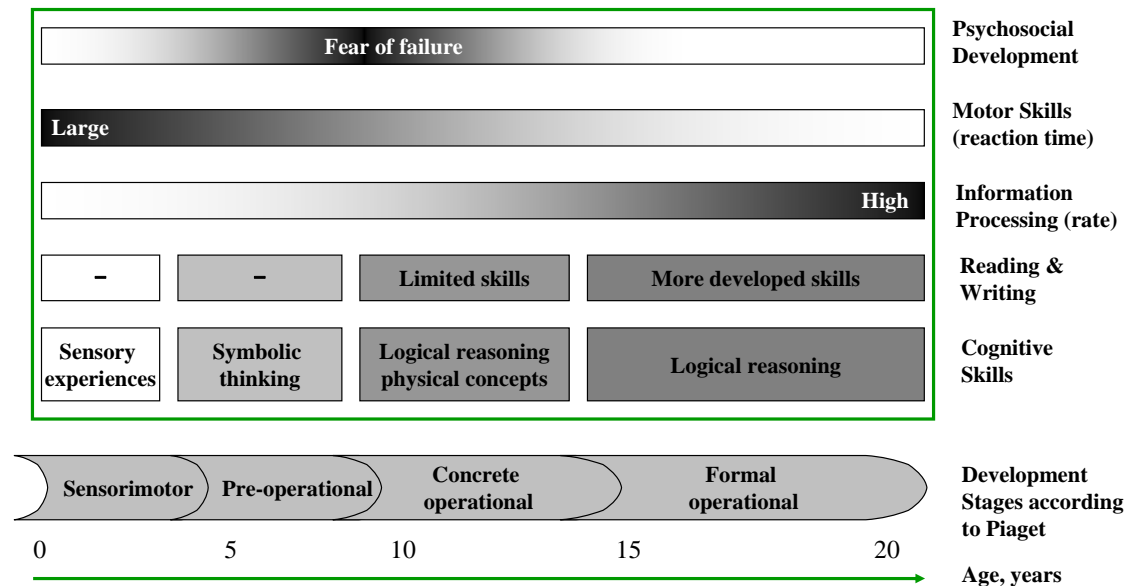


Figure 2: Stages of human development and their characteristics.

2.1. Human Cognitive Development

A child is a human being whose cognitive abilities are not fully formed. A foundational theory of human intellectual development is given by Piaget et al. (1969) and further discussed by e.g. Ormrod and Davis (1999) and Cooper (2006). Piaget's theory explains the differences in the human abilities at different age stages. It says that human development occurs in a sequential order in which later knowledge, abilities and skills build upon the previous ones³. According to Piaget, there are four human developmental stages: sensorimotor (age 0-2), pre-operational (age 2-7), concrete operational (age 7-11) and formal operational (age 11 - ...). These are distinct cognitive development stages with unique patterns of thoughts. These steps can be characterized as follows:

- *Sensorimotor stage*: The child begins to recognise cause-and-effect relationships at this stage, but is not yet able to think about objects other than those directly in front of it (Ormrod and Davis, 1999).
- *Pre-operational stage*: Preschool or primary school children are most likely in the pre-operational stage of development. In this stage they learn to use a language. They have often illogical thinking by adults standards. Most preoperational thinking is self-centred. Children in the pre-operational stage may have difficulties with classification. He or she can classify objects according to one feature (e.g. "select all yellow bricks") (Ormrod and Davis, 1999). Children of age four to five gain pre-reading skills i.e. substitute words in rhyming patterns, write some letters, pronounce simple words, develop vocabulary (Stuart, 2007).
- *Concrete operational stage*: Children are most likely in the second or third grade (see Table 1) at the beginning of this stage. They use the trial and error approach, and begin to reason logically. But, their understanding is limited to concrete and physical concepts (in contrast to abstract ones), they can classify physical objects

²Within this article we use the term "adults" when referring to grown ups without specific disabilities.

³Children's information needs also depend on and relate to their developmental stage (Kuhlthau, 1988).

<i>Educational stage</i>	first grade	second-sixth grades	seventh-twelfth grades
<i>Age</i>	6-7	7-11	11-18
<i>Development stage</i>	pre-operational	concrete operational	formal operational

Table 1: Correspondence between school grades in the United States of America, age and Piaget’s development stages. Educational stages and corresponding age depend on the country.

according to several features and order them along a single dimension such as e.g. size (Ormrod and Davis, 1999). At the ages of six to ten children learn to read. They read simple books by mid-first grade and know about 100 common words. They learn to write with an understanding of words by first grade. They can write stories with a character, action, setting, and a little detail by second grade (Stuart, 2007).

- *Formal operational stage:* Adolescents in the formal operational stage learn to think logically about abstract concepts. This stage begins around age 11 and is typically achieved by age 15 (Ormrod and Davis, 1999). At the age of eleven to thirteen adolescents read to learn about their hobbies and other interests. They read to study for school, understand more fully what they have read, read fiction, and nonfiction, including magazines and newspapers. Their writing skills are more developed with use of correct grammar, punctuation and spelling. They become more fluent writers. They use a computer for writing and research (Stuart, 2007).

The age boundaries of each development level are approximate, i.e. the exact age may vary from child to child. It is worth noticing, that recent research does not entirely support Piaget’s theory: he overestimated the capabilities of adolescents and even adults (they often show signs of concrete operational stage, not formal operational) and underestimated infants and young children in the sensorimotor and pre-operational stages (Ormrod and Davis, 1999). Furthermore, the development speed differs from human to human (caused by cultural and social environment) and even one person could be placed in different stages at the same time considering his or her understanding of different domains’ concepts like social, mathematical, or spatial (Ormrod and Davis, 1999). Maccoby and Jacklin (1976) also discovered gender-based differences in human cognitive abilities: girls are more talented verbally and usually more active in social domains, whereas boys tend to have better mathematical and spatial skills.

2.2. Information Processing Theory

The so called neo-Piagetian theorists explain cognitive growth along Piaget’s development stages from an information processing perspective. Even though, there are many variations of the theory, the fundamental idea of all of them is that children’s information processing differs from the adults’ in terms of how they apply information and what memory limits they have, i.e. limits in the amount of information children can represent and process.

Every act of thinking depends on the sensory memory, the working memory and the long-term memory. External and internal stimuli, e.g. sounds or pictures, are received and held in the sensory memory. This unanalyzed information is stored briefly, for a few seconds, during which unconscious processes determine whether to transfer it to the working memory or discard it. Active thinking, e.g. problem-solving or constructing of new strategies requires the use of information stored in the working memory (also called short-term memory). This is performed using the information in sensory memory in combination with information from the long-term memory by transforming both into “new” information. The working memory has a limited capacity, i.e. it can operate only a limited number of symbols at once. Information which is not processed further (e.g. by moving to the long-term memory) will be lost. The long-term information has no real limits on the information amount or time period to be stored. Information in long-term memory is rarely forgotten, but can be difficult to access (Kail, 2001; Nessel, 2005). Table 2 summarizes characteristics of short-term and long-term memory.

Young children learn new skills and how to perform new tasks using their working memory. Having no or less experience than adolescents or adults, children’s information processing requires a much larger part of the working memory. After children succeed in performing a task, some information of the underlying processes can be transferred to the long-term memory. The working memory gains some free space and the child’s learning of new tasks can proceed. Thus, older children have a larger chance or need less time to succeed in performing complex tasks involving

<i>Memory type</i>	<i>Capacity</i>	<i>Information storage</i>
<i>Short-term</i>	Limited (span 7+/- 2 items)	Rapid loss of information
<i>Long-term</i>	Huge	Reliable

Table 2: Characteristics of short-term and long-term memory (Kail, 2001; Nessel, 2005).

many processes, as they can retrieve some of the processes from long-term memory and perform them automatically. Young children have to think about most of the processes, which leads to a huge load on the working memory's capacity. Children's capacity of working memory for verbal/visual information increases with age (Schneider and Pressley, 1997). Younger children need longer time periods than older ones to perform the same processes (Kail, 2001; Nessel, 2005)⁴.

As children grow older, they can process information faster (Kail, 1991). Card et al. (1986) and Hourcade et al. (2004) found that the information processing rate influences the fine motor skills. Pointing movements, required to operate input devices, consist of a distance covering phase and a homing phase. Homing phase movements are not continuous. A homing phase movement is a series of micro-movements with micro-corrections (Meyer et al., 1990). The larger the information processing rate is, the larger is the number of micro-corrections that can be performed in the same amount of time, which translates into smoother motion and better performance. Based on these facts, young children's performance in pointing movements, e.g. using a mouse, are lower than that of adults and increases with age.

2.3. *Psychosocial Development - Emotional Aspects*

Another perspective on human development is given by Erikson (1963). He considers changes from a psychosocial point of view. A child is immature in the emotional domain and, especially in the "industry versus inferiority" stage (age 6 - 12), requires emotional support and a feeling of success and increasing confidence. He found that elementary-age children want to learn and to produce. They want to achieve the skills which seem to be important for their cultural environment and win the recognition of parents, teachers and peers by doing so. Finding information on the Internet is an important skill that a child needs to develop. If a child succeeds in finding the information, it will feel competent and develops self-confidence. In contrast, if it is not able to find good results, a child may develop a feeling of incompetence. This could even lead to a feeling of inferiority.

2.4. *Implications on Design of Information Retrieval Systems*

In the following we discuss what implications different aspects of human development, which were described above, have on the design of information retrieval systems.

Human Cognitive Development: Children in the sensorimotor and pre-operational development stages are very unlikely to use an (textual) information retrieval system because they have very limited reading abilities. They are also more likely to enjoy online games or watch videos than inquire information.

Children in the concrete operational stage are potential users of IR systems with their special characteristics and requirements. These children have more difficulties to translate their information needs into a keyword query than adults do. Finding the right query requires the ability of thinking in abstract categories, large vocabulary and good writing skills, which children of the concrete operational stage lack in. Therefore, keyword oriented search IR systems require spelling correction and query refinement features. As children have difficulties with abstract concepts, IR systems, which support browsing, should have real-world categories which are understandable for children. Children are able to think in images much earlier than to read written texts and, thus, providing pictures and voice menu along with text is a good solution to overcome reading problems. Additionally, the presentation form of query results should

⁴Thus, adults know more than children and tend to apply this knowledge when learning new information. But an interesting fact is, that for some goals existing knowledge may lead to a decrease in task performance. For example, researchers showed that adults use category-based induction (which is likely to be a product of past learning) whereas young children generalize on the basis of similarities among presented entities in the absence of category information (Fisher and Sloutsky, 2005). For some tasks, this similarity-based strategy is more useful.

be understandable with respect to cognitive capabilities of children, e.g. written in a simple language or/and provided with a document screenshot.

Adolescents in the formal operational stage are also potential users of IR systems, but their characteristics become more similar to the ones of adults. They also require support by information retrieval tasks but less than children in the concrete operational stage. These users can better process written texts without any support by images. They can manage keyword oriented search and are less dependant on spelling correction support.

Information Processing Theory: Information retrieval processes may cause children's memory to overload (see Section 2.2). To support children's limited cognitive recall, IR system should have a simple and consistent graphical user interface. Liu (1996) suggested to use large font letters and simple and, thus, more readable font styles⁵. Thus, children can easier address information on the screen. Usage of color and recognizable objects shape can support children's view (Cooper, 2006). Due to memory overload, children can forget actions they have already done, like what queries they already used or which documents contained interesting information. To support children's cognitive recall, IR systems should therefore have a built-in history and result storage functionality. Children's motor skills should be supported by graphical user interfaces, e.g. with large elements/buttons and simple interactions.

Psychosocial Development: As children are immature in emotional domain, IR systems should provide an emotional support in form of extensive help mechanisms. All actions which can lead to failure in retrieval should be covered by the system and hints should be provided if such an action is done by a child. A guidance figure (analogue is the Microsoft Word paper clip) can capture children's failures like getting no results or entering an empty query and explain how to do better.

While cognitive science about human development provides the background, which helps to understand the differences of humans in different age stages, the following section provides another perspective by reviewing user studies with children and their results, which are consistent with and can be explained by the given facts from the cognitive science domain.

3. Children's Information Seeking Behaviour

Sociologist studied information-seeking behaviour of children for decades. In this section, we briefly summarize their main findings. We also discuss problems related to the design of user studies with young users. From the current perspective, "older" user studies with children have different conceptual issues, which we discuss in the following.

Research about children's information-seeking behaviour began in the nineties with the appearance of school class rooms with computer equipment. In the beginning, researchers made observations of children performing different tasks using school computers in groups (e.g. Large et al., 2002b). Later, with the increasing availability of computers, children started to operate computers individually. But the fact remained, that user studies with children were mainly done in the form of lab experiments within the school settings. Thus, findings of these studies may have bias due to the controlled environment.

The majority of research in the area of children's information-seeking behaviour is done with elementary age children, however, usually of mixed age groups, e.g. (Bilal, 2000, 2001; Bilal and Kirby, 2002). This inhomogeneity leads to the problem that the findings cannot be accurately applied to any specific age level or – referring to the previous section – to a specific development stage. By only providing information about the age of studied children, the researchers did not pay much attention to the real level of their cognitive abilities and computer skills. Nowadays, children gain computer experience and skills from an increasingly younger age. In other words, results obtained for a ten-years old a decade ago most probably cannot be transferred to a ten-year old today. Our suggestion is that it would be more accurate to provide information about cognitive and computer skills as the age itself is only a very fuzzy indicator of children's abilities. Another problem are the information retrieval systems used in the studies. In the "old" studies children were observed using information retrieval systems designed for adults while nowadays first attempts in the direction of child-friendly search service environments are made. In addition, the studies were done mostly with keyword based interfaces (OPACs and web search engines).

Because of the reasons we mentioned above the results of recent studies can be different from those done a few decades ago (Budi and Nielsen, 2010; Nielsen, 2010). We advise to take the newer findings into consideration when

⁵Fantasy fonts, for example, are hard to read on computers.

designing IR systems for children. The results of “old” user studies that provide information about children’s cognitive and computer skills are partially applicable by taking into account the new developments in software and hardware.

In the following, we discuss results of previous studies about children’s information-seeking behaviour, considering the issues mentioned above. We describe such aspects of children’s information-seeking behaviour as searching strategies, queries, navigation style, interface preferences and relevance judgement (see Figure 3). We also indicate the age (or school grade if the age information is not provided) of user study participants and their number.

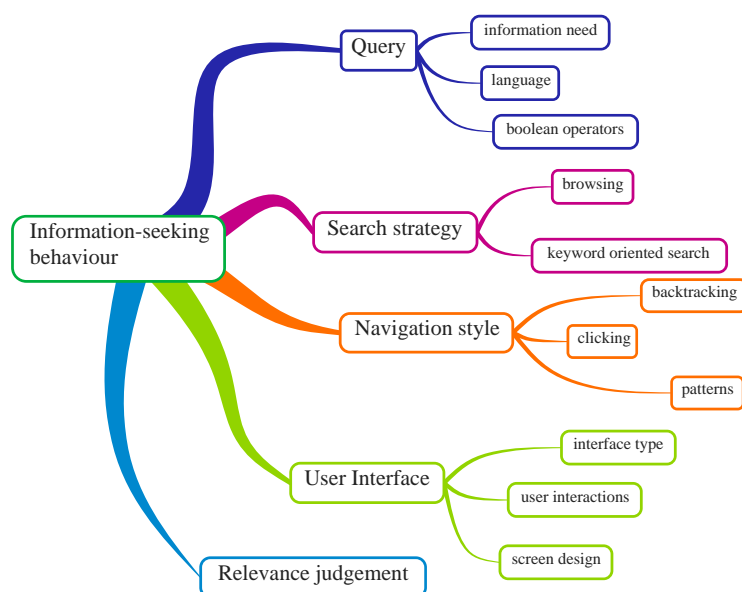


Figure 3: Aspects of information-seeking behaviour.

3.1. Query

IR systems should provide children with information that corresponds to their *information needs*. Common sociological methods such as user studies in the form of questionnaires and interviews can be used in order to identify children’s information needs. However, they are known to give imprecise results and can also be challenging for adults, but especially for children. To overcome these difficulties and get more reliable results researchers also used log files of search sessions to identify the query intent.

Duarte Torres et al. (2010) tried to identify children’s queries in the large-scale AOL⁶ query log⁷. All queries where the user selected a search result whose domain is listed in the DMOZ’s *kids&teens* directory⁸ were regarded as child queries. However, there is a high probability that such pages were accessed by adults intentionally or by accident. Some work was done to analyse the log files of web search engines which are specially designed for children (Gossen et al., 2011). The results indicate that the information need (in terms of the Broder (2002) taxonomy) of children differs from that of adults. Children’s queries have a more informational intention in contrast to the ones of adults, they are misspelled more often and shorter on average (Gossen et al., 2011). Duarte Torres and Weber (2011) extensively analyzed a large query log sample from the commercial web search engine Yahoo! to identify the search behavior of children and young adults between six and 18 years. They used demographic data of users who had an account in order to study the differences between young users of different ages. Their results suggest that younger users tend to formulate shorter queries which also supports the findings of Gossen et al. (2011). A plausible explanation of this

⁶www.aol.com is a web search engine.

⁷The AOL query log contains data of the AOL search engine from the period March to May 2006.

⁸<http://www.dmoz.org/> is an Open Directory Project which has a goal to construct and maintain most comprehensive human-edited directory of the Web.

behavior is that younger users have difficulties to express their information needs using keywords. Younger children surprisingly tend to undo spelling corrections provided by the search engine to insist on their original spelling. They also tend to click on the results presented first regardless of their actual quality (Duarte Torres and Weber, 2011).

Having an information need a child has a challenge to transform it into a form, i.e. a query, that can be processed by a computer. In contrast to adults, children have more problems to formulate their information need due to their limited vocabulary and cognitive abilities. Furthermore, most children have difficulties with typing (Jochmann-Mannak et al. (2010), 32 participants: ages 8-12; Borgman et al. (1995), 33 participants: ages 9-12). 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 (Solomon (1993), 679 participants: school grades one through six).

Younger children tend more to use natural *language* queries, i.e. phrases or sentences, more frequently than older children (Marchionini (1989), 28 participants in third and fourth grade, 24 participants in sixth grade). Children do not use advanced search syntax like *boolean operators* (Bilal and Kirby (2002), 22 participants: seventh grade). Furthermore, children often use too vague or too specific keywords in queries (Bilal and Kirby (2002), 22 participants: seventh grade; Kammerer and Bohnacker (2012), 21 participants: ages 8–10). This makes it more difficult for children to get relevant results.

3.2. Search strategy

In general there are two interface types for search engines, that are currently in use: 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 through pre-defined categories. Search engines that integrate both interface types are also common.

Researchers found that the *browsing* performance of children is better and that children prefer browsing (Borgman et al. (1995), 33 participants: ages 9-12). One reason for this preference is, that browsing imposes less cognitive load (see *Information Processing Theory* in Sect. 2). More knowledge is required to recall concepts from the memory, instead of simply recognizing and reacting to offered terms. Borgman et al. (1995) explain that browsing fits to children’s “natural tendency to explore”. It also better fits to the motor skills of children. Whereas keyword oriented search engines require correct spelling and typing, browsing is possible with simple point-and-click interaction. Nevertheless there are potential problems in browsing. As children have only little domain knowledge and a smaller vocabulary, they may have problems finding the right category. Thus, it is important to design categories which match cognitive abilities of children.

Some research was done considering the structure of categories. Hutchinson et al. (2005b) (72 participants: ages 6-11) 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 (2007) (48 participants: fourth and fifth grades) 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 with concrete objects.

The limited domain knowledge of children is also a problem in *keyword oriented search* engines. To formulate a search query, the user needs sufficient domain knowledge to think about useful keywords (Hutchinson et al. (2005a), 72 participants: ages 6-11). Many children even do not know that they have to select single keywords, so they tend to input full natural language queries (Marchionini (1989), 28 participants in third and fourth grades, 24 participants in sixth grade). Even if they understand that they have to input keywords, it is difficult for children to select the keywords, because it requires the ability of thinking in abstract categories (Hutchinson et al., 2005b). Thus, even if selecting categories better matches the cognitive skills of children, it is useful to offer both keyword and browsing oriented interfaces.

In a recent study (Jochmann-Mannak et al. (2010), 32 participants: ages 8-12) researchers found that children prefer typing keywords rather than browsing the main categories. This can be explained with the fact that these children already had experience with Google, which is a keyword oriented interface. Also the search interfaces used in the study does not seem to have good browsing capabilities, e.g. categories are hidden within the interface. This is a good example of the fact that results of user studies should be careful examined. Some results can not be generalized and are artefacts of the test setup, i.e. may depend on features of a specific interface.

3.3. Navigation style

Compared to adults, children have a different navigational style. Bilal and Kirby (2002) (22 participants: seventh grade) found, that children tend to backtrack very often. When children start a new search, they often navigate back to the home page first. Children have a *loopy* browsing style, whereas adults' browsing style is *linear* or *systematic*. Children *click*, repeat searches and revisit the same result web page more often than adults (Gossen et al., 2011). This characteristic agrees with children's lower cognitive recall, i.e. children probably forget about visiting a page already. Children may also repeat searches/resubmit queries in the expectation that an IR system will provide new search results. Hence, children's search behavior can be described by many looping and *backtracking* actions, with fast reading of the retrieved documents and little focus on the search goal. This *chaotic pattern* of information seeking is also called fast surfing (Sluis and Dijk, 2010)⁹.

Researchers also explored the influence of children's gender in patterns of searching the Web. Roy and Chi (2003) (14 participants: ages 13-14) investigated how boys and girls use the Web to find the answer to a specific question. They found that girls and boys have different pattern of search. Boys use *horizontal search*. They iteratively submit searches and scan the document snippets returned as search results. Girls employ *vertical search*. They tend to open and browse the result web pages (returned by the search engine) without going through the list and filtering the non relevant results in the first place. The boys' strategy lead them to better search performance in the end. Large et al. (2002b) (53 participants: sixth grade) studied collaborative search behaviour in same-sex groups of boys and girls. They found that boys make significantly more clicks (in the number of searches executed, the extent of clicking on hits, the next page of search results, etc.) during browsing than girls. Groups of girls tend to use natural language queries more often than boys, whereas boys use fewer words (even only one) to formulate the query.

3.4. User Interface

There is evidence that children can experience difficulties with too advanced metaphorical navigation interfaces¹⁰ whose meaning they do not understand (Jochmann-Mannak et al. (2010), 32 participants: ages 8-12). Additionally, researchers suggest that the *interface* should support both educational and entertainment needs of children as it was asked for by some participants (Large et al. (2002a), 23 participants: ages 10-13).

There was some research on *children's interactions* with interfaces using such input devices as mouse. The results are important to consider when designing interfaces for children's IR systems. Certain mouse interactions are very difficult for children. Children have difficulties with drag-and-drop interactions, because they can not coordinate dragging and holding at the same time (Strommen (1994), 94 participants: first and second grade). However, better design decisions might help to decrease the errors by drag-and-drop interactions (Donker and Reitsma (2007), 103 participants: Kindergarten 2 and Grade 1, six years old on average). Furthermore, children often do not use complex interactions like scrolling a page (Naidu (2005), 30 participants: ages 7-11). Interface elements should be large enough as fine motor skills of children are still developing and not as good as by adults. The time for moving a mouse gets higher, the smaller the target object is. This means, that larger target sizes allow children to make selections more quickly (Hourcade et al. (2004), 39 participants: ages 4-5, ages 19-22).

Naidu (2005) (30 participants: ages 7-11) found that children in general prefer websites with many pictures. It is consistent with (Large et al. (2002a), 23 participants: ages 10-13) whose user study result suggest to use attractive *screen designs* based especially on effective use of color, graphics, and animation and allow individual user personalization in areas such as color and graphics.

Budiu and Nielsen (2010) (35 children, ages 3-12) studied usability issues in designing websites for children. They claim that metaphors, especially spatial navigation, work very well with children. Only if virtual attributes differ from the ones in the physical world there comes to problems. Children like movement, graphics, funny sounds, and colours. But it should be in rational portions in order not to overwhelm them. Children understand icons better when they represent real-world concepts they are familiar with. Straightforward text fonts (14 point young children and 12 point for older children) and simple text layouts make reading easier. Both adults and children avoid reading long

⁹Existing patterns of information seeking are fast surfing, broad scanning, and deep diving.

¹⁰A metaphorical interface employs a visual metaphor. It makes the computer screen appear as if users are navigating not through a screen but rather through some familiar environment (Ohl and Cates, 1997). The purpose of it is to provide users with knowledge about how to interact with the user interface. An example is shop metaphor, i.e. shopping basket in an e-commerce shop (Lanquetin, 2007).

<i>Aspect</i>	<i>Properties</i>
Query	informational intention, natural language queries, spelling mistakes
Search strategy	prefer browsing in pre-defined categories
Navigation style	loopy browsing style
User Interface	attractive design, simple interactions, large objects, spatial navigation metaphor
Relevance judgement	difficult to determine the most relevant result

Table 3: Main finding of user studies on children’s information seeking behaviour.

texts on the Web. Budiu and Nielsen (2010) (35 children, ages 3-12) also confirm that children use a hunt-and-peck approach to typing and therefore make relatively more typing mistakes than adults. Thus, spelling correction and query suggestion mechanisms are important. Children in the study also had problems with mouse and many didn’t know how to drag. Budiu and Nielsen (2010) suggest to make the clickable targets big and static to overcome these problems. The study also shows that most modern children older than nine are fairly comfortable with scrolling but younger children are not. During the web search children tend to formulate natural queries instead of using keywords for search. Thus, Budiu and Nielsen (2010) recommend to design large search box.

3.5. Relevance judgement

Children also have difficulties to judge the relevance of the retrieved documents to their information need (Jochmann-Mannak et al. (2010), 32 participants: ages 8-12). Children are frustrated by too many results and do not have the ability to determine the most relevant and “best” documents (Large and Beheshti (2000), 50 participants: sixth grade). In task-oriented search, children look for the final “concrete” answer in documents, without trying to read and understand the content (Bilal (2000, 2001) (22 participants in seventh grade). Most children visit only the first result page and click on the first item in the result list (Druin et al. (2009), 12 children: ages 7,9,11).

3.6. Design Challenges of Information Retrieval Systems for Young Users

In the following, we describe challenges for design of information retrieval systems for young users, which are guided by the findings of the user studies about children’s information seeking behaviour described above. We also propose directions for their solution.

As already discussed, children (in contrast to adults) have a limited domain knowledge, which causes difficulties to formulate a query in case of an keyword oriented search. Furthermore, using a keyboard while typing, children often do not spot spelling mistakes. Therefore, alternative input methods for specifying a query which can replace the common, but challenging, keyword query input using a keyboard should be developed. Compared to adults, children have a different navigational style, called a *loopy* browsing. Children click, repeat searches and revisit the same result web page more often than adults. This behaviour can be a sign of children’s cognitive overload during the search. In order to prevent this, different history mechanisms should be incorporated in IR systems for children’s. Designing user interface for an IR system is also challenging. Many requirements should be considered: simple interaction with interface elements of an appropriate size, large text fonts, attractive screen designs etc.

Also challenging is supporting children by judging the relevance of the retrieved documents to their information need and finding information in documents. For example, this can be done by marking and highlighting the search terms directly in the opened document. Furthermore, there is a need to define child-specific ranking mechanisms. For example, an intuitive assumption is that less complex documents, i.e. those containing a good structured cohesive text with an appropriate readability level, and supported by images and tables, should be ranked higher as they would better fit the children’s cognitive abilities.

As mentioned above, children’s queries have a more informational intention in contrast to the ones of adults. Hence, children would prefer web sites which have explanatory information rather than a website where the facts are

explained shortly, assuming that the reader already have the basic knowledge to understand it. Therefore, a child-specific ranking algorithm could assign a higher rank to less complex and more informative documents.

A summary of the main findings of the studies on children’s information seeking behaviour is shown in Table 3. In the next section, we describe existing algorithms and user interface concepts which were proposed to be used in IR systems for children.

4. Existing Algorithms and User Interface Concepts

Sociologist started studying information-seeking behaviour of children several decades ago and marked the beginning of children’s information retrieval. Some years ago computer scientists joined them to apply algorithms and techniques from information retrieval, natural language processing, machine learning and human computer interaction¹¹. This research is at the beginning and, for now, suffers from the lack of evaluation with children’ involvement.

In this section we describe related work in the area of children IR, i.e. what methods were proposed by the computer scientists to contribute to children’s IR and adapt IR systems to children’s needs. We start with an architecture of an information system (see Figure 4) and analyse how each of the components can be adapted to be appropriate for children. There are various challenges to design IR systems for young users: support children’s information needs and make it possible for children to submit the right query; rank/retrieve documents that are relevant for children; provide a “good” content; visualize the results properly; and carry out an evaluation of a newly designed system. An overview of these aspects and related work about proposed algorithms and user interfaces is given below.

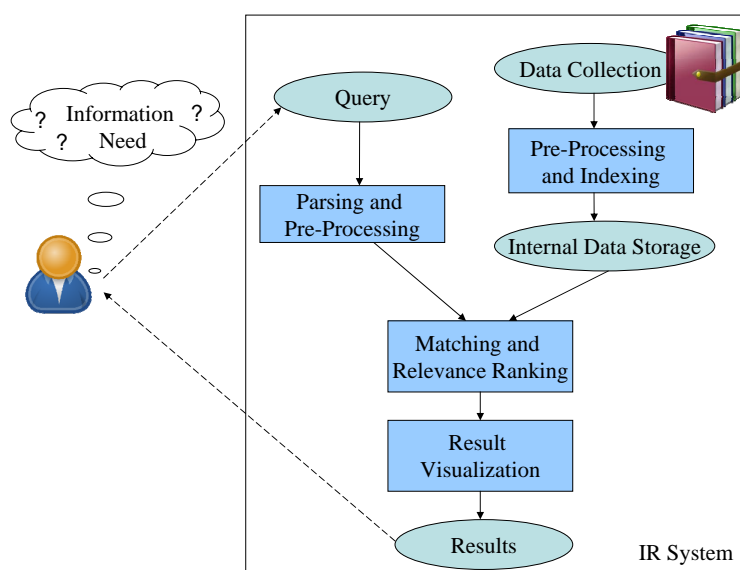


Figure 4: Information flow in the high-level software architecture of an IR system (Baeza-Yates and Ribeiro-Neto, 2011).

4.1. Query

Researchers study the types of errors in children’s queries to provide methods of automatic reformulation of search queries to get better search results. Kalsbeek et al. (2010) explored different types of query errors made by children, e.g. typing errors, slang or no vowels, and explored potential solutions for each of the error types. Synonym expansion (using WordNet) and phonetic expansion showed promising improvements.

¹¹ A good example of the work in this direction is PuppyIR project (<http://www.puppyir.eu/>).

Alternative input methods for specifying a query that can replace the common, but challenging, keyword query input using a keyboard were studied. For instance, Jansen et al. (2010) proposed a tangible interface called *TeddIR*. The system helps children to retrieve books they are looking for. Instead of typing in keywords, children search by putting tangible figurines or books in the boxes to indicate that they like or dislike them. Thus, difficulties in spelling and finding query terms are overcome. A small user study with seventeen children (third or fourth grade pupils) showed that children playing with *TeddIR* were successful in retrieving the books using several figurines for connecting the search concepts (AND operator). But this solution works with a small number of concepts and new ideas are required to design a similar system with large number of search concepts.

Junior Search (JuSe) (Polajnar et al., 2011) is an interface that enables searching through adaptable picture dictionaries. Children can construct queries using the pictures (see Figure 5). *JuSe* uses categories derived from children's vocabulary lists and parents can adjust the list, e.g. add new words. *TeddIR* and *JuSe* can help preschoolers who have problems to formulate a text query due to weak writing skills or small vocabulary.

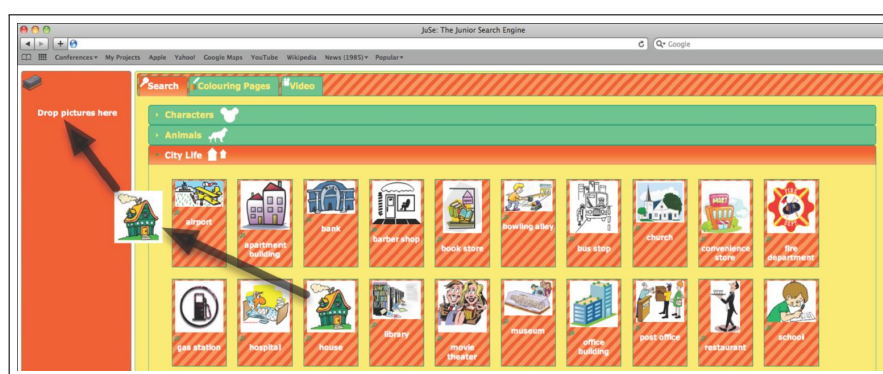


Figure 5: The screenshot of the JuSe interface (Polajnar et al., 2011).

4.2. Content

Search system for young users should provide a child with results which are on the one hand *child-appropriate*¹² and on the other hand *not too complex for a child*. Thus, the construction of a document collection (index) is an issue. There are several possibilities to create a child-safe collection:

- *Manually*: Educators filter suitable documents/content before it is added to the index of the IR system¹³. In this way overhead is really large and the number of checked documents is limited, but it guarantees reliable results.
- *Automatically*: One can use machine learning techniques, e.g. classification, to identify appropriate content. Machine approaches allows checking a great number of documents, but missclassifications are not rare.

The two methods should be ideally combined to maximize both precision and recall: first automatically identify potential documents and then manually verify them.

Eickhoff et al. (2010) and Eickhoff and de Vries (2010) worked in the area of document classification on child suitability. They proposed features for automatic web page classification with two classes, suitable for children or not: child-friendliness (textual complexity, presentation and navigation) and focus towards child audiences (language models, reference analysis and URL features). They also used classification to identify suitable YouTube videos for children. The features for classification they proposed are a video's tag and its description, author information, meta information and community-created information.

Text or web documents can be written using varying language complexity. Therefore, providing a safe content only is not enough: children should also be able to understand its meaning. There are several ways to overcome

¹²A child-appropriate content should not contain any material that is harmful to child's development, such as pornography or violence.

¹³An example is the German search engine Blinde-Kuh.de

this problem. First, texts written in a complex language can be simplified. De Belder et al. (2010) and De Belder and Moens (2010) proposed lexical and syntactic methods of text simplification. In the lexical case they simplify the text by replacing each word one by one with a synonym, e.g. using language models from a large, unlabeled training corpus or WordNet, which should be easier to understand. In the syntactic case they split complex sentences into several simple sentences. The researchers did not succeed in reducing the reading difficulty enough for children, at least not without removing information from the text. The syntactic simplification failed. Lexical simplification showed promising results.

Another way to provide an understandable content is to influence the results ranking so that the documents written in a simple language are ranked higher and are shown first to children. Approaches that follow this idea are discussed in the following.

4.3. Ranking

The search results ordering, i.e. ranking, is of importance. The standard method for document ranking in common IR systems is to calculate the similarity between the query and the documents and rank the documents according to the achieved similarity score (see Manning et al., 2008, Chapter 6). For web documents we can also calculate the popularity of the document given the link structure of the web, i.e. hyperlinks are also used for ranking web search results (see Manning et al., 2008, Chapter 21). *PageRank* is a famous algorithm which uses the link structure. To put it simple, *PageRank* employs a heuristic that a good document is linked to by many other good documents. Thus, the ranking of web documents is calculated by combining the similarity score and the popularity of the page.

Gyllstrom and Moens (2010b) adapted *PageRank* to a link-based ranking algorithm for children. A new ranking algorithm *AgeRank* ranks web pages according their age appropriateness. *AgeRank* is a modification of *PageRank*, which considers that pages for kids are more likely to link to and be linked from other kids pages. Each page has four scores (p_{out} , p_{in} , n_{out} , n_{in}) which state the probability to link to a children page, the probability to be linked by a children page, the probability to link to a non children page and the probability to be linked by a non children page. The *AgeRank* value of a page, called *Tot* is set of these four components and is calculated as the ratio of the positive scores (p_{out} , p_{in}) to the negative scores (n_{out} , n_{in}). The authors evaluated the algorithm using Mechanical Turk¹⁴ participants. Hence, evaluation with children would be beneficial.

An important factor for children is the complexity of the language in a document. Researchers suggest to use the complexity to additionally influence the ranking. Where two topical articles are available, the simpler one should be preferred (Sluis and van den Broek, 2010). Sluis et al. (2010) and Sluis and Dijk (2010) discuss three components that should be considered by children IR: *complexity*, *interestingness*, and *affective value*. The complexity can be measured, for example, through text readability and coherence. The interestingness of information can increase motivation. The interestingness can be measured, for example, through novelty. The website interactivity can influence the affective state. Text, interactivity of a website and multimedia can influence the emotions like enjoyment and are indicators of the affective state.

4.4. Search Results

In addition to ranking, the visualization and presentation of results is important as it affects the searcher judgement about the documents' relevance (Hearst, 2009, Chapter 5).

CollAge, a system which incorporates search results for children's web queries with child-oriented multimedia results, such as coloring pages and music sheets, was proposed by Gyllstrom and Moens (2010a). Given a query researchers create new queries for each media type like mazes, maps, puzzles, flags, music sheets, diagrams, paintings, coloring pages, crosswords, tracings, etc. They verify if the new queries make sense using the Google Suggest database. For each media query, they run a Google image search and return images as results in addition to existing search results (see Figure 6).

Elliot et al. (2010); Glassey et al. (2010) proposed a mockup of the results presentation interface where they used the amount of space allocated to document title to indicate the relevance of a document (see Figure 7). To support children in determining the relevance of results Akkersdijk et al. (2011) proposed a touch interface, called *ImagePile*, which displays the results as a pile of images where the user navigates horizontally (see Figure 8) instead of the

¹⁴<https://www.mturk.com/mturk/welcome>

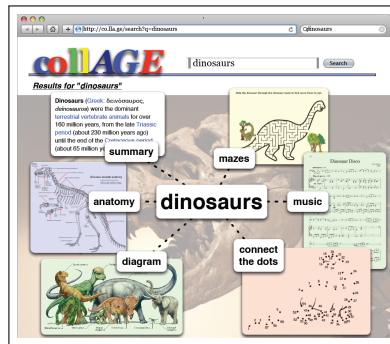


Figure 6: CollAge mockup (Gyllstrom and Moens, 2010a).

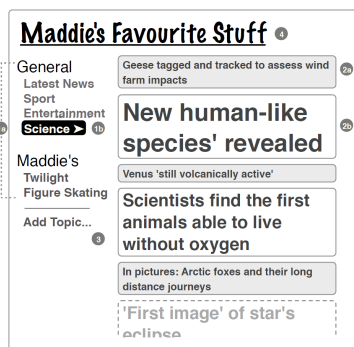


Figure 7: Interface supports relevance clues (Glassey et al., 2010).

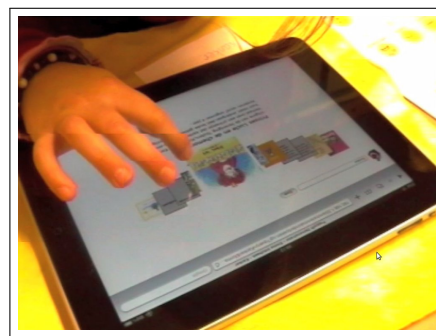


Figure 8: The ImagePile system (Akkersdijk et al., 2011).

commonly used vertical scrolling. They did a small (eight children) evaluation of ImagePile system and came to the conclusion that the horizontal results list does not improve the searching process, mostly because of the gesture problems.

4.5. Evaluation with Children

A minimum requirement in human computer interaction (HCI) is to conduct user studies at least after the development of a new system. Unfortunately, standard evaluation tools are not directly applicable to children's studies: questionnaires require high degrees of literacy, interviews require high degrees of reflection and techniques such as think-aloud require high degrees of cognitive aptitude (Read and MacFarlane, 2006).

Mohd et al. (2010) suggest that *fun* should be measured when evaluating online systems designed for children. They discussed the differences of evaluation where children participate and conducted a user study to test their evaluation methodology. The study with young children aged three to four years old in a nursery and five to six years old in a school was carried out to see if the children have fun playing a game which they could chose from the web site *CBeebies*. The researchers suggestions after the study are that, as children are emotionally driven, evaluation techniques should pay attention to their emotional state: shyness, boredom, joy etc. As a reflection of the emotional state researchers asked the children to draw a figure which they associated with the web site. They used the children's pictures as a fun indicator. The researchers also showed that children have difficulties to answer open-ended questions.

5. Existing Information Retrieval Systems for Children

While we have discussed research prototypes above, there exist several IR systems for children that are publicly available. Those are mainly web search engines which target group are children with exception of one digital library. In the following we describe their main characteristics.



Figure 9: Simple Search mode in International Childrens Digital Library (Hutchinson et al., 2006).



Figure 10: Waiting mode in International Childrens Digital Library (Hutchinson et al., 2006).

Hutchinson et al. (2006) developed a searching and browsing tool for the International Childrens Digital Library suitable for children (see Figures 9,10). 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 weak 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 indicated in the user interface.

An overview of existing web search engines for children and a methodology for the usability assessment of web search engines for young users can be found in (Gossen et al., 2012). Existing web search engines for children provide first of all a child-safe content. Here we list several English and German search engines¹⁵: *quinturakids.com*, *kidrex.org*, *onekey.com*, *askkids.com*, *kidsclick.org*, *blinde-kuh.de*, *helles-koepfchen.de*, *fragfinn.de*, *dipty.com* etc. For example, Google-based search engine *Kidrex* supports a safe search and has a funny start page. In other ways it is the same as Google, including additional information such as advertisement.

Most of these web search engines (e.g. *blinde-kuh.de*, *askkids.com*, *kidsclick.org*) also care about text complexity and provide those web pages as search results, that are easy to read for children. *kidsclick.org* also provides information about the reading level of the retrieved web pages. The majority of the engines have a colourful design of a start page which should attract children attention (e.g. *quinturakids.com*, see Figure 11).

In every other aspect, existing web search engines for children have the same design as common search engines do. They have a keyword-based interface. Thus, a child should input a text query to an input field in the first place

¹⁵The list is not exhaustive.

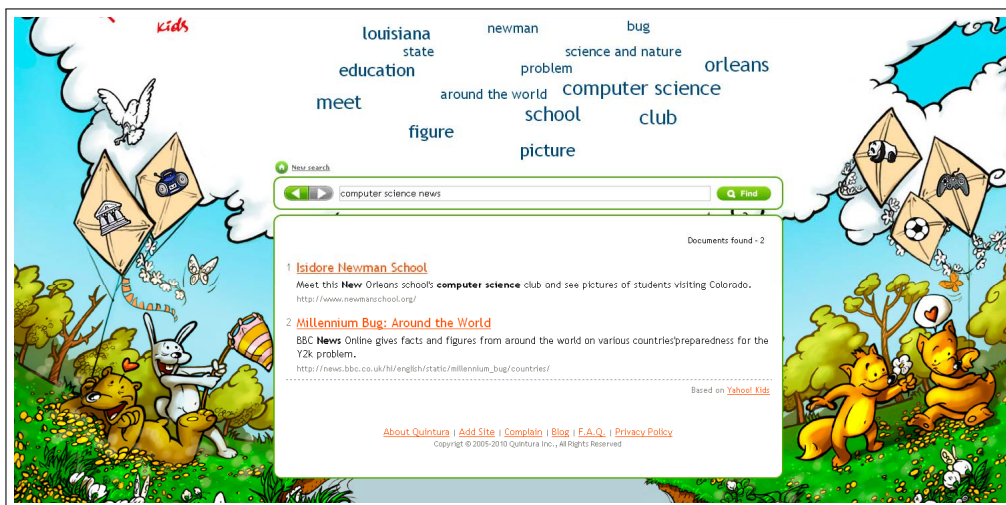


Figure 11: Colourful design of Quinturakids.com web search engine.

This screenshot was taken from Quinturakids.com on 2012-03-09.

to initiate the search. A few web search engines also have flat categories. For example, *quinturakids.com* has five categories (music, history, animal, computer games, sport and recreation) which are shown as moving kites (see Figure 11).

The visualisation of search results is also very similar to standard search engines (like Google), i.e. a vertical results list of text snippets. The positive fact is, that some search engine also provide pictures along with text summaries to support the relevance filtering process of children (e.g. *helles-koepfchen.de*, see Figures 12).

Usually, there are ten results per page (as by Google). But, for example, search engine *kidsclick.org* places all the results on one page. Thus, it can be forty-fifty results on the page. The query input field moves to the bottom of the page, after results (see Figure 13). This makes scrolling unavoidable which may be difficult for children.

One drawback of many search engines for children is the absence of spellchecking and query suggestion mechanisms which are especially important for children. For example, *askkids.com* does not process misspelled queries (see Figure 14). Another drawback is small text fonts which make it hard to read for children. Thus, current web search engines for children not always match the skills and abilities of children. Because of that, using them might frustrate children. In order to avoid these problems, it is important not only to take child-friendly content into account. The search interface has to be child-friendly (usable for children), so that children are able to use it without problems.

6. Conclusion and Outlook

The research on information retrieval for young users is still in its infancy. Currently, there are no solid and approved solutions for a child-specific IR system. With this paper we attempted to provide an overview of existing achievements in this field. However, information retrieval for young users is a complex topic. It is strongly related to the cognitive science on human development and sociological studies on information-seeking behaviour of children. Much knowledge is already gained in those two fields that can be transferred to information retrieval for young users.

Cognitive science explains the specifics of children in different age groups and helps to derive requirements for the design of IR systems. In this paper, we provided a short overview of the basic theories about human development and derived implications for children's information retrieval systems. When designing information retrieval systems for young users, we should always keep in mind, that children's cognitive and motor skills are developing and differ from that of adults. Children also require emotional support and a feeling of success otherwise they easily acquire feelings of helplessness and inferiority. Results of user studies about information-seeking behaviour are just as important as the knowledge from cognitive science because they provide empirical proof for the latter, complement and enrich the knowledge needed to derive implications for the design of IR systems for children. In this paper, we summarized



Figure 12: Helles-koepfchen.de web search engine. Each search result is accomplished with a picture.

This screenshot was taken from Helles-koepfchen.de on 2012-03-09.



Figure 13: Kidsclick.org web search engine provides information about results' page reading level.

This screenshot was taken from Kidsclick.org on 2012-03-09.

the main findings about children's queries, search strategy, navigation style, preferred user interfaces and relevance judgement. We also discussed several conceptual issues of these studies. Based on the studies results, we outlined the challenges for the design of information retrieval systems for young users. When describing children's information retrieval systems and information-seeking behaviour in this paper, we mainly concentrated on information search in a web document collection.

Furthermore, we gave an overview of existing algorithms and user interface concepts in the field of information retrieval for young users. We also described existing information retrieval systems, web search engines and a digital

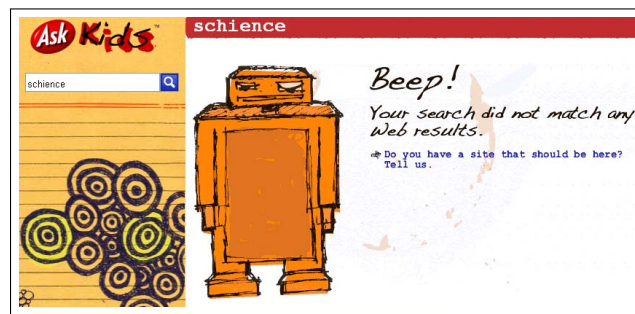


Figure 14: Askkids.com web search engine returns no results for a misspelled query “schience”.

This screenshot was taken from Askkids.com on 2012-03-09.

library for children, that are publicly available. Nevertheless, many research questions are still open. In our opinion, the current problem in research of information retrieval for young users is that researchers view children as a consistent user group. They often do not consider that children of different age require different solutions that influence the design of information retrieval systems. Theories of human development confirm, that children in different development stages do differ in cognitive abilities (and motor skills). That is why, when designing UI concept and algorithms for children, there is a need to target very narrow age groups.

Current research also suffers from the lack of evaluation of recently proposed algorithms and user interface concepts. Children’s information-seeking behaviour was studied mostly on keyword oriented IR systems. “New” user interface concepts, e.g., *JuSe* (Polajnar et al., 2011), still need to be examined in comparative user studies to evaluate them against existing alternative interface concepts. Children’s perception of user interface elements, e.g., different forms of results visualisation, should be compared in the future. Furthermore, some usability questions still require an answer (Budiu and Nielsen, 2010), e.g. what children consider to be clickable. It would be beneficial to apply relatively new technologies like *eye tracking* (Duchowski, 2007) to study children’s usage of IR systems. Furthermore, it is still unclear how to deal with children’s *loopy* browsing style. In fact, no solution was proposed to solve this problem. This type of browsing behaviour can be a sign of children’s cognitive overload. In the future, mechanism to prevent this overload should be developed. There is also no study of mechanisms for emotional support of children during the search, which is also a potential future direction.

There is also much potential in the development of new ranking algorithms for children. Until now, only one algorithm, AgeRank (Gyllstrom and Moens, 2010b), was proposed and evaluated, but unfortunately not with children. There are some conceptual suggestions what elements should effect the ranking for children, e.g. complexity, interestingness, and affective value. Ranking algorithms based on these suggestions should be implemented in the future. An open research question here would be how much influence each of the mentioned components has on the target ranking value.

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