What Is Known About the Impact of Impairments on Information Seeking and Searching?

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Information seeking and access are essential for users in all walks of life, from addressing personal needs such as finding flights to locating information needed to complete work tasks. Over the past decade or so, the general needs of people with impairments have increasingly been recognized as something to be addressed, an issue embedded both in international treaties and in state legislation. The same tendency can be found in research, where a growing number of user studies including people with impairments have been conducted. The purpose of these studies is typically to uncover potential barriers for access to information, especially in the context of inaccessible search user interfaces. This literature review provides an overview of research on the information seeking and searching of users with impairments. The aim is to provide an overview to both researchers and practitioners who work with any of the user groups identified. Some diagnoses are relatively well represented in the literature (for instance, visual impairment), but there is very little work in other areas (for instance, autism) and in some cases no work at all (for instance, aphasia). Gaps are identified in the research, and suggestions are made regarding areas where further research is needed.

Introduction

Approximately 15% of the world's population is living with an impairment (WHO, 2011). Although this is a large user group, up until the last decade users with impairments were almost absent from the research on information seeking and searching (Hepworth, 2007). However, it is reported that people with impairments are often excluded from access to knowledge (Garbutt & Kyobe, 2013). Furthermore, motor, sensory, or cognitive levels are not included as variables in any of the user models generally applied in information retrieval research (Beverley, Bath, & Barber, 2007).

There has been a change in the user perspective of the research literature, and some impairments are now relatively well investigated, for instance, the effect of reduced sight on information searching (Hill, 2013). In contrast, other user groups are either underrepresented or almost absent from the literature. According to Zhang and Salvendy (2001), the perspective has been especially limited regarding how cognitive abilities affect information searching. However, a growing number of studies have been published over the last decade, for instance, on visual impairments and dyslexia. In contrast, users with, for instance, aphasia, autism, and Down syndrome seem still to be underrepresented in the research literature.

The underrepresentation or absence of work in significant areas related to impairments is problematic. Access to information is essential, and there are both legal and social pressures to deal with this issue. Equal rights to accessible information and technology (ICT) are embedded in international human rights treaties such as the Convention on the Rights of Persons with Disabilities (UN, 2006). However, user knowledge is key to better understand how to ensure everyone equal access to information.

Disability rights are included in various national legislations, such as Australia (Australian Human Rights Commission, 2014), Canada (Treasury Board of Canada, 2013), Norway (Lovdata, 2013), and the UK (UK Government, 2010) through, among others, demands for universally

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designed ICT systems, learning environments, and libraries. These issues are also included in the EU's eAccessibility Programme (EU, 2002) and European Accessibility Act (EU, 2015).

According to Hill (2013), most library and information science literature related to impairments discusses accessibility in the context of the web, databases, and software. Moreover, a majority of the studies have addressed accessibility testing and electronic accessibility, with a system focus. However, researchers have also investigated actual behavior and much effort has been put in to increase the knowledge of how different types of impairments actually affect human behavior when seeking and searching for information. This research is surveyed here.

Extensive user knowledge is a premise for accessible search systems. A better understanding of how impairments affect information seeking and searching in different ways and degrees is therefore required to make a more inclusive society and to comply with the UN Convention and national legislations. The rationale for this article is thus to survey what research has been carried out on impairments in the context of information seeking and searching. Moreover, gaps are identified and researchers and practitioners are provided with an overview of areas that need to be investigated in future work.

The review is structured as follows: The first part addresses disability as a concept and its relation to impairment, followed by accessibility versus universal design and the classification of impairments applied in this survey. The subsequent sections discuss the search strategies and inclusion criteria. Then follows some definitions used in this article and a review of relevant studies investigating the cause, effect, and impact of impairments on information seeking and information searching (both directed and undirected search). The review is organized according to cognitive, sensory, and motor impairments. The final section contains an overall discussion on future work, and a strategy is suggested for the community to address the issues identified.

Background

Disability as a concept has changed significantly in the recent past, both in the perception of what a disability actually is, and how disabilities and people with impairments are referred to (see Figure 1). It also affects the terminology applied in this survey.

In the 1980s, there was a paradigm shift in the disability discourse from a medical to a social model (Shakespeare, 2013). The medical model defined disability as a discrepancy between normative and individual models and regarded disability as an individual problem where personal treatment was the key. The social model challenged this view, by discussing disability as a concept created by society. Within this framework, demands were made for social action to develop more accessible environments (Oliver, 1996).

A third perspective on disabilities is the Nordic relational model, also referred to as The Gap model (see Figure 2) or the Scandinavian model (Shakespeare, 2004). In this perspective, a disability occurs when there is a mismatch between a person's abilities and the demands from society. According to this view, disabilities may be reduced or removed by either changing the environment, strengthening the individual, or both. This review is written within the Gap model perspective, assuming that there is much that can be done to reduce the gap that creates disabilities. The main purpose of this review is to emphasize the variations in user behavior and show how empirical data from user studies can support the development of universally designed search systems and other information sources.

The concept of universal design was introduced as a consequence of the changing attitudes towards disability. Universal design is based on the notion that it is impossible to design for an "average person" because of human diversity. Instead, one should design products and environments that are usable by all people, without the need for adaptation or specialized design (Center for Universal Design, 2008).

The purpose of universal design is to provide a tool for reducing barriers in society. However, to design systems that are usable for all types of users, it is important to understand human diversity, variations in input and output preferences, and the use of assistive technology. The counterpart to universal design is accessible design, which refers to design that accommodates the requirements of people with specific impairments, something that is often achieved by specialized,

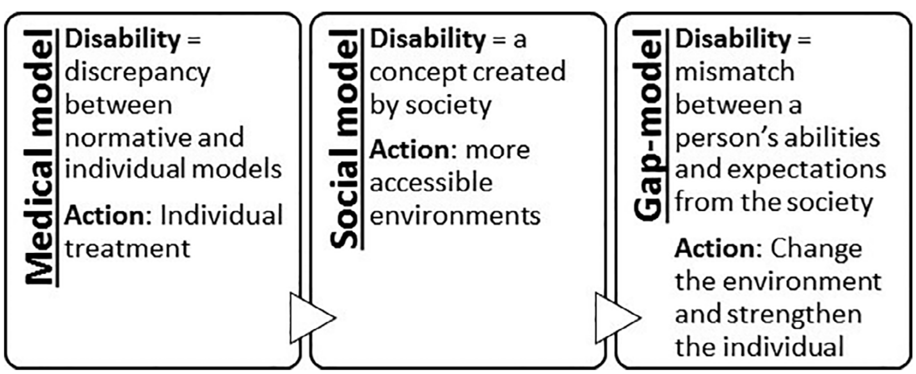

FIG. 1. Perspectives on disability.

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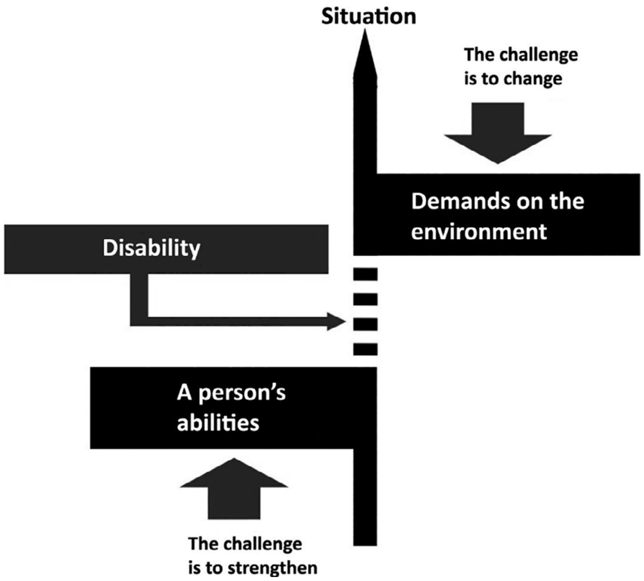

FIG. 2. The gap model, translated reproduction based on Sosial-departementet (2003).

separate solutions, often resulting in stigmatization of certain user groups (Iwarsson & Ståhl, 2003).

Classification of Impairments

The International Classification of Functioning, Disability and Health (ICF) is often used to classify and describe disabilities (WHO, 2001). According to ICF, disability is an umbrella term for participation restrictions, activity limitations, and impairments. Based on ICF's definitions (WHO, 2011), disabilities may be classified using various criteria, for instance, body functions or body structures. ICF applies a highly detailed classification scheme (WHO, 2011). However, this classification is too detailed for the purpose of this survey and is more suitable for medical contexts.

In a content analysis on impairments and accessibility in the library and information science literature, Hill (2013) applied the following categories: visual, learning, physical, auditory, multiple, and nonspecific general impairments. In this survey three broader categories are applied: cognitive, sensory, and motor impairments. The category cognitive impairments includes not only learning impairments, but also, for instance, autism spectrum disorder and Down syndrome.

A person may have several impairments concurrently, and consequently be included in more than one category; for instance, a person with visual and cognitive impairments. However, organizing the review according to three main categories seems consistent with the classification applied in the reviewed articles; for instance, Liang, Xue, and Zhang (2017). These categories are also used in other fields of research, for instance, Edwards (1995) and Hutton and Pharoah (2002), and in general descriptions of human abilities in the context of universal design (Story, Mueller, & Mace, 1998).

Definitions

For the purpose of clarity, an overview is first provided of what is meant by information seeking and searching. A frequently used term in this field of research is information behavior, which according to Wilson (2000, p. 1) is "the totality of human behaviour in relation to sources and channels of information." Moreover, Wilson (1999) suggested a division of information behavior models into three levels, namely, information behavior, information seeking. and information searching (see Figure 3). In Wilson's nested model, information seeking is a subset of information behavior, mainly concerned with the different methods people deploy to find and gain access to information sources. Information searching is a subset of information seeking, addressing the interactions between computer-based information systems and users, including both directed and undirected search (also referred to as browsing). Both of these inner levels are covered in this review.

Information seeking and searching involves various activities, such as choice of sources, query formulation/revision, inspection of results lists provided by the query, and choice of documents to inspect from that results lists. Other activities include browsing, monitoring the search process, accessing specific sources, keeping a record, and information use and sharing. Every activity has its own distinct characteristic, and impairments will affect each of these activities in various different ways. In each of the sections below the impact of each impairment is highlighted, with a focus on the two inner levels of Wilson's nested model (Wilson, 1999).

Directed search can be understood as a task that utilizes all these activities, and is driven by a specific user need, for instance, searching specific information to complete a work task. Undirected search, in contrast, is a task that is driven by more exploratory needs and does not necessarily involve the submission of queries and inspection of hit lists, but will involve the navigation through linked

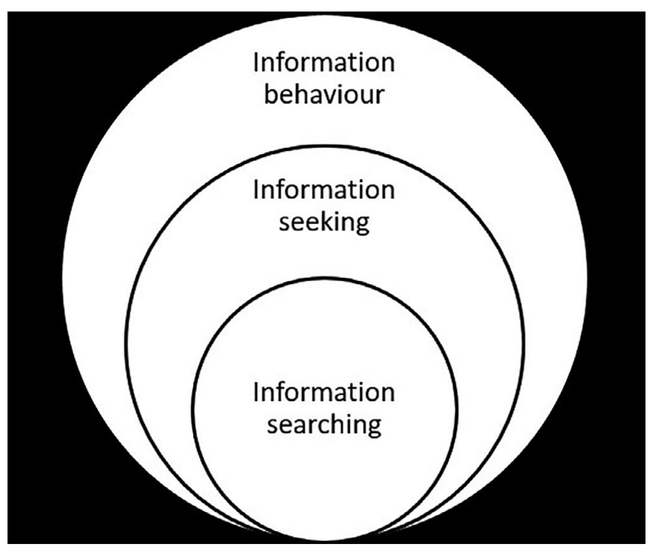

FIG. 3. Wilson's nested model (1999).

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documents; for instance, web navigation or browsing. Information seeking is the general task of finding information to fulfill an information need that will involve both directed and undirected search, plus other activities, for instance, inspecting library shelves. The focus on information seeking in this article is purely on the directed and undirected search tasks.

Sampling Process and Inclusion Criteria

The sampling process for this literature review included extensive searching with queries containing various synonyms and different spellings referring to impairments, such as "impairment," "impairments," "impaired," "disability," "disabilities," and "disabled," to mention a few. Categories such as sensory, motor, and cognitive were also added in different versions and with synonyms. Finally, specific impairments and diagnoses were used as query terms, for instance, "autism spectrum disorder," "down syndrome," "blind/blindness," "dyslexia," "adhd," "cerebral palsy," "paralysation," and "deaf," to name a few. These terms were searched together with synonyms such as "information seeking," "searching," "information retrieval," and "libraries." Citation analyses were conducted, and citations were used to identify further studies. A variety of commonly used bibliographic databases were searched; for instance, Springer-link, Elsevier, and Web of Science, in addition to the library systems at a British and Norwegian university library, Google Scholar, and Google. All the articles included in the review were written in English.

Articles included in this review address information seeking in general, or more specific activities related to information searching (both directed an undirected search). Where appropriate, studies from human computer interaction research which identify similar themes to ones found in the survey are included. All types of impairments are represented. Studies related to mental illness are excluded. Further, elderly users in general are not discussed, although they may share some common needs with people with impairments; for instance, reduced mobility or impaired vision.

An interpretive reading and a categorical indexing was applied to each article. According to Mason (2002), this method may be used to provide an overview of text-based data and can give a clearer idea of coverage and scope.

Survey Findings

A total of 69 documents are included in the review. The articles are presented in the sections below and cover a selection of core topics in research on information seeking and searching (see Figure 4). Most articles were published from 2000, but some studies from the 1990s are also included (see Figure 5).

The review section is organized as follows: First, the category cognitive impairments will be discussed, starting with dyslexia and succeeded by other cognitive impairments. This is followed by sensory impairments, where vision is discussed first, then hearing. Finally, motor impairments are presented.

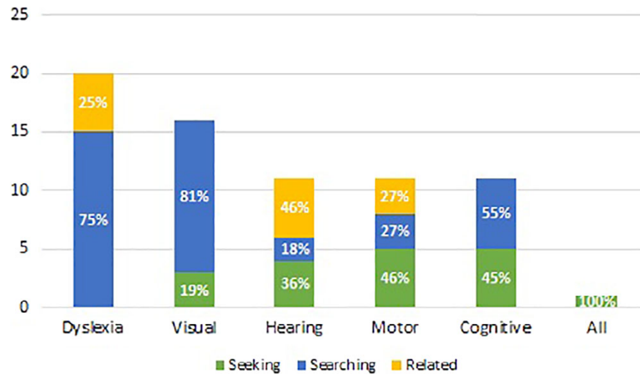

FIG. 4. Distribution of reviewed articles according to impairment type and topic (related refers to relevant articles in human-computer interaction, which does not directly address searching or seeking). [Color figure can be viewed at wileyonlinelibrary.com]

Each category starts with the more general information seeking, succeeded by the sublevel information searching addressing both directed and undirected search. For each category some future work is suggested. In addition, there is a more general discussion at the end of the survey.

Impairments in General

During the sampling process, several articles that addressed impairments in general were retrieved. However, the focus of these articles was primarily on web guidelines; for instance, W3C (2018) and library polices (Australian Library and Information Association, 1998; Burgstahler, 2018; Canadian Library Association, 2016; Irvall & Nielsen, 2005), an area where there is a substantial body of work to draw on. However, this review addresses user behavior. Consequently, these articles are out of scope, and are therefore not included.

The only general study on impairments included here investigated access to information after the natural disaster hurricane Katrina. Spence, Lachlan, Burke, and Seeger (2007) surveyed 554 people and found differences in the information seeking between people with and without impairments. Users with impairments were less likely to engage in information seeking than people without impairments. However, there were

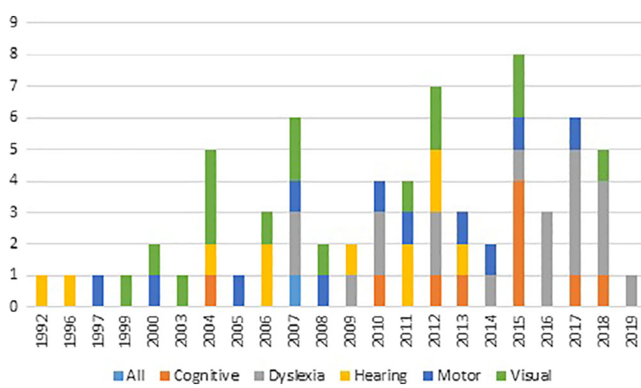

FIG. 5. Distribution of reviewed articles according to impairment type and publication year. [Color figure can be viewed at wileyonlinelibrary.com]

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no differences in the sources used for acquiring information. The main conclusion was that more attention must be paid to people with impairments in the context of risk messages and the communication of such information to people with impairments, which is an important topic to address further.

Impairments often manifest differently; for instance, through reduced vision or reading difficulties, which may result in variations in input and output methods and the use of assistive technology. Consequently, it is reasonable to assume that it is not purposeful to address a number of impairments in one study, but rather focus on one type at a time, which may explain the few articles addressing users with impairments in general. Consequently, it does not seem like there is a gap in the research here that needs to be filled.

Cognitive Impairments

Cognitive impairment is a category that covers a wide spectrum, from mild reading difficulties to severe autism. Such impairments may cause very different challenges concerning information seeking and searching. Users with cognitive impairments are therefore studied in various contexts in the research literature, from potential challenges with query formulation to the use of personal assistants. Studies included in this review typically focus on either dyslexia or other cognitive impairments, such as developmental impairments. This research is reviewed and categorized accordingly in this section, starting with dyslexia.

Dyslexia

Dyslexia typically has an impact on word processing, and usually affects accurate and/or fluent word recognition, spelling, and decoding abilities (Lyon, Shaywitz, & Shaywitz, 2003; Peterson & Pennington, 2012). However, users exhibit a wide range of effects, which also include challenges with short-term memory (Perez, Poncelet, Salmon, & Majerus, 2015), concentration, and rapid naming skills (Lervåg & Hulme, 2009). Dyslexia therefore describes a spectrum of characteristics rather than one common cognitive profile. The cohort size is significant, estimated to be around 7% of the world's population (Peterson & Pennington, 2012).

Several studies on information searching were found, but no relevant articles on information seeking of people with dyslexia. Below is the literature on query formulations, result list/document assessment, and undirected search reviewed, activities that are strongly related to reading, writing, and short-term memory. A common feature for these studies is a focus on barriers rather than solutions.

Information Seeking

The overall issue regarding dyslexia is that information-seeking behavior as whole is poorly understood, and work is required to resolve this gap by examining seeking behavior of users with dyslexia in context. One way of doing this would be to take one model, for instance, Ellis (1989) and undertake a full-scale study of the impact of dyslexia on each aspect of information seeking (for instance, starting, monitoring, chaining, differentiating, extracting, verifying, and ending). There is a clear and urgent need for the community to tackle this issue.

Information Searching

The first potential barrier for users with dyslexia during search is query-formulation, which is closely connected with spelling. Berget (2016) compared the search behavior of 20 students with dyslexia with the search behavior of 20 students in a control group during query formulation in the Norwegian academic library system Bibsys Ask. This system had no query-building aids and a low tolerance for spelling errors. Users with dyslexia took significantly longer searching the library catalog than the control group, primarily due to more spelling errors, causing a higher number of queries per task (Berget & Sandnes, 2015). The negative impact of the user interface design on dyslexia found in the library catalog was not present in Google, a search system with query-building aids and a high tolerance for errors (Berget & Sandnes, 2016). Based on these two studies, Berget (2016) concluded that well-designed search systems could counteract or entirely remove the potential barriers. An example of this is the impact of inaccessible user interfaces on activities related to query formulation for users' with dyslexia. Examples of potential changes in the search user interface design was, for example, a higher tolerance for errors, better-developed query suggestion functions, and implementing more advanced spell checkers. A limitation in this study was that only students were included, thus excluding people with more severe dyslexia who might formulate queries differently, causing a potential bias.

Cole, MacFarlane, and Buchanan (2016) compared the search behavior of seven participants with dyslexia with a control group of seven users without dyslexia in a qualitative study and found differences in choosing keywords, spelling, and refining/forming complex queries. The evidence in this study on spelling confirms the evidence produced above, and also reported problems breaking down large topics (that is, from a textual description) to identify appropriate keywords. People with dyslexia were much less effective when using drop down keyword suggestions. Using complex Boolean search strategies combining AND and OR operators proved to be problematic, but there was some evidence that various tactics such as wildcards and filters could be used effectively.

Multimodal interaction and query aids have also been investigated. In a survey of web searching, Morris, Fourney, Ali, and Vonessen (2018) found that users with dyslexia often utilized voice search on mobile phones as a query aid—this could potentially help many users on the desktop also, but may be a result of the difficulty entering queries on a small compact interface. The study also found that 66.3% of users placed a heavy reliance on autocomplete when forming queries, which may help to reduce errors in this initial stage. This contradicts the findings of Berget and Sandnes

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(2016), who, in an eye-tracking study, compared the search behavior of 20 people with dyslexia and 20 users in a control group searching Google, and concluded that people with dyslexia did not utilize the autocomplete function much, because their eyes were fixated on the keyboard during query input. However, that study was conducted using a desktop computer and a regular keyboard. It seems purposeful to include more studies on different devices, since the studies above suggest that, for instance, the size of the keyboard and/or screen might result in different behavior and various needs for query aids.

More empirical research on query formulation and people with dyslexia is needed, because it seems likely that well- developed search aids may remove barriers for information searching (Berget, 2016). However, in user studies identifying potential barriers and user behavior, it is necessary to include control groups. This has been done in several studies reviewed above, but not all. Otherwise, the researchers may draw erroneous conclusions based on mistakes from the general user, which might not be the same as users with dyslexia.

While most of the studies above addressed barriers, a few studies have focused on solutions. For example, Sitbon, Bellot, and Blache (2007) introduced a method for automatic revision of sentences inputted by people with dyslexia, and found that the word error rate declined from 60% to 22%. Another attempt to make useful search aids for users with dyslexia is the Fuzzy String Matching Model (Onifade, Thiéry, Osofian, & Duffing, 2010) that can assist users who input characters in the wrong order during query formulation. Overall, there has been a limited focus on spelling skills in the context of query formulations, and future research should investigate further the effect of short-term memory, concentration, and rapid naming skills on query formulations.

Other related research within the field of human–computer interaction (HCI) may be applied to explore these issues further, and there is a substantial amount of work to build on; for instance, guidelines on web accessibility and web readability (Miniukovich, Angeli, Sulpizio, & Venuti, 2017; Santana, Oliveira, Almeida, Cec, & Baranauskas, 2012; Venturini & Gena, 2017), using games to improve spelling skills (Rello, Bayarri, Otal, & Pielot, 2014), and including people with dyslexia in the development teams (González, 2017). Based on the existing research, it seems purposeful to explore these issues further, since spelling correction and string-matching methods might reduce the impact of spelling errors in an information searching context. This is especially important, because people with dyslexia often make spelling errors that differ from other users (Moats, 1996). Consequently, the spell checkers implemented today might not be sufficient for this user group.

The second potential barrier to users with dyslexia is access to results lists and retrieved documents, where there is evidence of the impact of short-term or working memory on searching behavior. MacFarlane et al. (2010) used the experimental retrieval system Okapi to compare the information searching of five users with dyslexia and a control group of five people. Users with dyslexia exhibited fewer search iterations, took more time on each search, and assessed fewer documents than the control group. This pilot study in terms of search interactions was not conclusive, as there were too few users in the experiment, but it did provide some useful pointers for a second experiment reported in MacFarlane, Albrair, Marshall, and Buchanan (2012). In that study a larger group of users was recruited, comparing information searching among eight people with dyslexia and a control group of eight participants. There were two significant findings from this experiment: users with dyslexia judged many view documents as irrelevant (this was statistically significant) and a correlation between short-term memory capacity (based on the digit span method) and the ratio of documents classified as irrelevant was found. This demonstrated that there was a key relationship between the reduced working memory of people with dyslexia and search interactions for the first time. Further evidence was provided by examining the eye-tracking data from the 2010 study (MacFarlane, Buchanan, Al-Wabil, Andrienko, & Andrienko, 2017). These data was much richer, with over 600 k fixations to examine. Using visualization techniques on the eye tracks, evidence of more backtracking by users with dyslexia was found, as they made more vertical eye movements (up and down) than the users in the control group. The number of horizontal movements (left and right) was proportionally the same. This finding supports specific evidence of a reduced short-term memory effect, with, for example, users with dyslexia forgetting content and having to navigate upwards to reread text.

These results have been confirmed by the following two qualitative studies: Morris et al. (2018) and Kvikne and Berget (2018). These studies suggest that short-term memory capacity seems to be an important component during information searching, and this part of the cognitive profile should receive more attention in other user groups who share problems with short-term memory. However, these studies were small in scale, and larger studies to understand the precise role of short-term memory in reading both results lists and documents, and the interaction between both, are required. The results so far in this area are not conclusive, but are indicative. Knowledge about more accessible results list design would be useful for search user interface (UI) designers.

Morris et al. (2018) reviewed design implications based on their studies using multimodal interaction methods (use of images and audio, as well as text). They applied decluttering, simplified pages and extra features such as reading level and page structure in the results presentation algorithm. Further work by Fourney, Morris, Ali, and Vonessen (2018) identified features in web pages that could associate readability with relevance, such as average line length and sentence text ratio. There is much scope for taking this work further in different scenario's, for instance, professional search tasks on systems such as ProQuest Dialog.

The undirected search of people with dyslexia has also been addressed. In a qualitative exploratory study with 10 users, Al-Wabil, Zaphiris, and Wilson (2007) identified barriers people with dyslexia may experience when searching

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online information, showing different patterns of navigation. For instance, users with visual processing challenges chose the search box, while users with short-term memory issues navigated back and forth between pages. This fed into an exploratory eye-tracking study with two users with dyslexia and five in a control group, with a number of navigation tasks to carry out (Al-Wabil, 2009). This experiment indicated that people with dyslexia had more and longer fixations on a page than the control group, indicative of challenges navigating through linked structures.

Two further eye-tracking studies were carried out by Al-Wabil (2009) to build on these exploratory studies, both with the same 30 participants: 15 participants with dyslexia and 15 in a control group. The first experiment showed that users with dyslexia spent more time on tasks and were more easily disorientated, suggesting that short-term memory, phonological process, and visual stress all may have an impact. The second experiment demonstrated significant differences between the two groups in their page-viewing behavior in unconstrained viewing of text-heavy web pages. This research together with MacFarlane et al. (2017) shows that users with dyslexia may easily get lost both during directed and undirected search, and this area needs more attention.

In terms of information searching, there is an understanding of various aspects of the search process, such as the impact of spelling challenges on querying and the impact of reduced short-term memory on scanning results lists. However, there is very little work on how to deal with these issues, apart from work done on assisting the user with spelling when entering a query. There is a need to also take a closer look at result lists assessment, since this seems to be a difficult part of the search process for this category of user.

A further key issue with the work done so far is the issue of diagnosis. The studies by MacFarlane et al. (2012) and Berget (2016) used standard psychological tests to fully examine the differences between participants with and without dyslexia. In all other studies, the participants with dyslexia were self-diagnosed and researchers did not have access to the original psychologists' report. In order to build a stronger body of knowledge in this area, more studies should use dyslexia screening tests and other psychological tests, to ensure that participants with dyslexia and the control groups are clearly distinguished. Further, the cognitive profiles can be analyzed with search statistics to better understand how dyslexia affects search behavior (Berget & MacFarlane, 2019).

Other Cognitive Impairments

The literature on cognitive impairments other than dyslexia is present, but research is not as well developed. This category comprises a wide range of users, with very different degrees, from specific learning difficulties (SpLD) to Down syndrome and autism. Some users might need support in certain functions, but not all, while others might need personal assistants to conduct everyday tasks. The research so far has focused on either one cognitive impairment or on several simultaneously—those that concentrate on the latter have severe limitations given the differences between cohorts with different cognitive profiles. However, key aspects of search in querying and results assessment have been investigated, as well as providing some evidence of this diverse community in terms of undirected search and information seeking.

Information Seeking

There has been some work done on information seeking and needs, but more research in this area is required. Hanson-Baldauf (2013) examined the information needs and practices of users with intellectual impairments, and identified barriers on several levels that could cause challenges, namely, intrapersonal (for instance, reduced literacy skills or memory capacity and difficulties comprehending abstract concepts), physical (for instance, limited access to transportation or technology, which could lead to print-only sources of information), economic (limited job training), social (for instance, discrimination, learned helplessness, or lowered expectations of ability), and institutional (limited curriculum or segregation in school). Hanson-Baldauf (2013) concluded that an understanding of end users' everyday life is important to better understand information needs and practices. More work is needed to understand how to reduce or remove barriers, for instance, by emphasizing cognitively accessible information.

Harrysson, Svensk, and Johansson (2004) investigated the navigation of people with developmental impairments. Users found it demanding to make selections when presented with large amounts of text, and absorbing information due to reading abilities. A more recent study by Sitbon, Bayor, Bircanin, Koplick, and Brereton (2018) used Marchionini's information seeking framework to examine 12 users with intellectual impairments. The key finding of this work was that, while participants may have appropriate seeking and searching skills, the lack of confidence in these users represents a real barrier regarding access to information and users will often require help to resolve their needs. A simple solution could be the use of information literacy programs specifically focused on giving users the confidence to utilize their search skills to the full. One example is the study by Markey and Miller (2015), who found video-modeling to be successful in teaching students with autism spectrum disorder (ASD) information literacy skills.

In some cases, the degree of cognitive impairment may be so severe that users are not able to access or seek information unassisted, which results in mediated information needs. The use of assistants may particularly apply to impairments such as ASD or Down syndrome. According to Bohman and Anderson (2005), the more severe the cognitive impairment is, the higher the probability for the user needing a personal assistant for accessing web content. Bilal (2010) investigated the mediated information needs of children with ASD, and concluded that children with autism were silent information seekers, where others did all the information seeking for them. Their parents utilized a variety of information resources to accommodate the children's needs, both for academic and everyday life. Mediated information seeking is also an area that requires closer scrutiny, especially for adults with cognitive impairments, to ensure that their information needs are adequately solved. Moreover, there is a need to investigate how mediated information seeking can be made more inclusive, to ensure that the user has direct control, both by being informed by the mediator during the information seeking and being more involved in decisions.

Information Searching

Query input has been investigated by several researchers, addressing both challenges with spelling and the possibilities of alternative input methods to typing on keyboards. Harrysson et al. (2004) studied how seven users with mild to moderate developmental impairments navigated the web. There is no mention of type of impairment included in this study, but a focus on functionality, where four people could read and write simple sentences, two could read and write simple words, and one who was unable to read or write. The study showed challenges when inputting text in search boxes and address bars. Moreover, the users had very limited Internet experience. A question to investigate further is whether the lack of experience may also have an effect. Moreover, it would be interesting to see whether the participants with the least reading and writing abilities could have solved the tasks through multimodal interfaces or speech or whether assistive technology could be helpful.

Nour (2015) compared two forms for input during search in Google, namely, typing and voice searching in a study including six participants with different types of cognitive impairments (Down syndrome, ADHD, autism, Turner syndrome, and Traumatic Brain Injury). Nour (2015) concluded that some participants preferred voice searching, while others liked typing better, and advocated a flexible approach in search UI design. The lack of coherence between participants is not surprising, since the participants comprised several different user groups, where some might have challenges with speech while others might experience spelling difficulties. Similar studies should be conducted with one user group at a time to potentially get some clearer results regarding preferences, or to confirm the variations in preferences.

Voice searching was also investigated by Rocha, Carvalho, Bessa, Reis, and Magalhães (2017), who studied the interaction between 20 users with intellectual impairments and two search engines: Google and SAPO. They concluded that speech recognition can be useful, but must be precise and robust enough to handle atypical word pronunciation, a particular issue with some people in this user group. Technology such as spell checkers might also be helpful, but would need to be targeted to the needs of the particular cohort.

Based on the available research, result list assessment can also cause barriers for users with cognitive impairments. Harrysson et al. (2004) found problems with result list assessments and extracting useful content, and related this barrier to reading abilities. There is also evidence that directed searching is more purposeful than undirected searching for this user group according to Kumin, Lazar, Feng, Wentz, and Ekedebe (2012) based on a small study of 10 users. This result is in accordance with Hu and Feng (2015) in a larger study with 23 participants with various cognitive impairments (mainly Down syndrome, but also cerebral palsy and neurological impairment) searching in a specially designed website called "Mini-Library," including a customized Google search box. The participants were more efficient when using search via keyword than browsing through the structures. This is most likely because a simple text box is easier for users with intellectual impairments to use than text-heavy pages. Consequently, mechanisms should be developed to support users who find reading challenging, particularly when presented with text-heavy documents and pages.

Undirected searching has also been addressed. Williams and Hennig (2015) investigated different architectures to assist users with learning impairments, suggesting that horizontal browsing structures may be more useful than vertical ones—the latter being prevalent in search systems. The study included 56 participants who were mostly classified with minor learning difficulties. Users were presented with lists of standard words in both horizontal and vertical layouts. Although no statistical significance was found, it is argued that scrolling may have added an extra dimension that needs investigation and that vertical presentations interfere with text presented on the page, whereas horizontal menus place important content at the top and are self-contained. Separating text and menus for users with reading difficulties may be appropriate. Clearly, a full-scale navigational experiment to examine these issues further is required.

Sensory Impairments

The articles on sensory impairments were divided into two subcategories: vision and hearing. The literature on visual impairments is fairly well developed, but users with hearing impairments have not been addressed in any depth to date.

Visual Impairments

Visual impairment is often defined as the inability of the human vision system to process light. People may have a mild loss of vision, which may be solved by the use of glasses, or have more severe problems caused by deformation, neurological damage, disease, or accidents. According to Ackland, Resnikoff, and Bourne (2017), around 253 million people in the world have a visual impairment; 36 millions of these are blind. Although different measures such as better healthcare and medical technology have reduced the number of people with visual impairments over the years, a growing aging population has caused an increasing number of people who are blind, which is a serious issue that must be considered by the research community.

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For visual impairments, the literature has mainly been directed towards potential difficulties during the search process and problems with inaccessible search systems. An accessible search user interface is a premise for access to information and this emerges as a key problem for users with visual impairments.

Information Seeking

Williamson, Schauder, and Bow (2000) found that the information seeking of visually impaired people resembled the behavior of older people, both in the types of needs and sources used, because many elderly users experience loss of sight. Lessons learned with the latter user group can be utilized to inform the needs of the former. Jeong (2007) studied the emotions of completely blind users when seeking information, and argue that the information needs of blind people should be regarded as completely different from other users, among others due to frustrations experienced in everyday life and suppression of technological needs. The evidence from this body of work is that an understanding of context is required to tailor systems and services to the needs of the visually impaired.

Beverley et al. (2007) examined the information behavior of people with visual impairments looking for health and social care information. They found that existing models on information behavior should include an additional intervening variable, related to the visual impairment in terms of type, length, and degree of impairment, since these factors seem to affect information behavior. For instance, one would expect people who have been blind for a long time to have more experience using assistive technology, and the search process would probably manifest differently whether a person has severely reduced sight or is completely blind.

Information Searching

Craven and Brophy (2003) addressed the information searching from web-based resources in the context of blind or visually impaired users, and also made recommendations regarding, among others, web page design and user training. Visually impaired people had to spend more time searching than people without impairments; for instance, nearly five times longer inspecting web pages, which frustrated users who ended the information searching process early, thereby missing relevant information.

Xie, Babu, Castillo, and Han (2018) explored the interaction between users with visual impairments and digital libraries. Three main areas were particularly affected by the impairment: assessment and evaluation of information and utilization of help functions. Several design implications were discussed, among others the need for better assistance to solve unsuccessful searches, automatic removal of search terms after a search has been submitted, and offering contextual information for search results.

A typical information searching scenario is for users to spread searches over a number of sessions for their given task. Sahib, Tombros, and Stockman (2014) in a study with 12 users found that multisession searching is difficult for users with visual impairment, as the lack of persistence in screen readers puts a heavy load on short-term memory, a clear indication that the use of accessible technology as part of a user interface needs to be thought about carefully. There is clearly an issue with the design of user interfaces for this group, but it is also clear that UI design impacts the search process as well; for instance, forming queries and navigating search results lists, and pages are also problematic.

Sahib, Tombros, and Stockman (2012) compared the search behavior of 15 people with visual impairments and 15 people in a control group during online searching. The users with reduced vision formulated more expressive queries in an attempt to reduce iterations with search results pages (10.93 queries on average with 4.61 keywords per query compared with 4.47 queries each with 3.86 keywords per query for the control group). The difference was statistically significant. Furthermore, query-aids such as query and spelling suggestions were often ignored by the users with visual impairments, and advanced query operators (such as + and “”) were rarely used. In contrast, query suggestions were much utilized by the sighted searchers. There is some evidence that users with visual impairments have built sophisticated query formulation techniques that can be enhanced with appropriate techniques. A radical rethink on query support for people with visual impairments may be required, providing other studies can both confirm the results of the Sahib et al. (2012) study and provide more detail on how visual impairments affect query formulation techniques.

Another significant issue with this group is examining both results lists and documents. Sahib et al. (2012) also found that result list assessment took longer, and visually impaired users had to rely more on content than structure and layout simply because screen readers take time to read out the page to the user. This confirms earlier research which found similar problems. Oppenheim and Selby (1999) on a small qualitative study of four users reported that inaccessible search engine user interfaces represent a barrier to effective access to information, with visually impaired users becoming disorientated when examining search results due to repetition of speech outputs on search results. This is time-consuming and tiring for the user. Andronico, Buzzi, and Leporini (2004) concluded that, although people without impairments reported searching to be easy, 80% of the visually impaired participants found search tools hard to utilize, with particular difficulties reading result lists. Ivory, Yu, and Gronemyer (2004) studied the decision-making behavior of six visually impaired people during search, and found that users first process summaries, titles, and URLs before considering additional features to predict search result relevance. Users who were blind took twice the time as the control group when assessing search results, and three times more when exploring web pages. Solutions to the problems identified in terms of query formulation and results list/document assessment include the understanding of the user context, the design of appropriate UIs, and the use of assistive technology.

Understanding of the user context can help with user interface design. Yang, Hwang, and Schenkman (2012) built a

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modified version of Google specifically designed for users with visual impairments that included an adjustable display function, a results-showing function, and a bookmark function. This scheme reduced search times and resulted in higher user satisfaction, which suggests that allowing user-control over search user interfaces may be beneficial. Andronico et al. (2004) further suggested that interactivity can make more accessible search engine user interface design, by examining the features of a search engine and applying accessibility guidelines.

In a later study, Andronico, Buzzi, Castillo, and Leporini (2006) built on their 2004 study by establishing design guidelines to provide a more accessible search engine user interface for visually impaired users. The logical order of the page was changed to allow better access to elements by quick navigation, for instance, arrow and tab keys. The guidelines were to redesign the Google interface for integration with accessible technologies to meet accessibility needs and evaluate it with 12 totally blind users in Leporini, Andronico, Buzzi, and Castillo (2008), which confirmed the value of the design, as users found the revised interface was clearer and easier to use.

In Sahib et al. (2014) and Sahib, Tombros, and Stockman (2015), support for tagging and commenting on search trails was proposed and implemented in a tool called TrailNote. This tool includes the ability to tag relevant pages and to make notes on pages, addressing the problem with persistence in the accessible technologies identified above. In the 2015 study with 12 visually impaired participants, nonspeech sounds, which are used to indicate a particular event to a user, and spelling support functionality were redesigned. Usability testing showed that users clearly found the functionality useful, but they did not attempt a test to assess the time taken to undertake specific task such as inspecting documents—a critical issue for this use group (see above).

Users with print impairments were addressed by Dermody and Majekodunmi (2011) in the use of the assistive technology such as screen readers while navigating in three proprietary databases: CBCA Complete, Sociological Abstracts, and Expanded Academic ASAP. They found that the success rate of finding two readable articles was 55%. However, inaccessible pdf's and links that were inaccessible reduced this number to 32%. The participants reported frustration navigating the databases with a screen reader, and a need for a simplified search interface with more clearly placed text and links. Dermody and Majekodunmi (2011) also concluded that libraries can assist the users, among others with usability feedback to the vendors. This is a very important issue, since knowledge of users is key for product developers, who may not be aware of potential shortcomings in their systems.

Overall, it is clear that there is much further work to be done before visually impaired users information retrieval needs can be met. One specific issue was raised by Xie, Babu, Joo, and Fuller (2015), who investigated help-seeking of blind people in digital libraries, with a focus on information assessment. Xie et al. (2015) identified a gap between the needs of blind users and the design of the digital library in terms of using features such as advanced search and bibliographic record search. However, the bigger issue to be addressed is that the community does not yet have a full understanding of the information seeking and searching process of users with visual impairments.

What is required is a much more detailed investigation of the user context to provide a better idea of how to support activities such as querying, results navigation, accessing information, and keeping track of records. Such knowledge will inform better user interface designs and improved deployment of assistive technologies. The time taken to examine web pages is a particular problem (Craven & Brophy, 2003). The evidence from the literature is that searching by visually impaired users may be radically different from other users, and current systems are not designed to meet these needs. Rethinking the UI design is therefore essential for researchers, practitioners, and software vendors (Ivory et al., 2004) by focusing on the strengths in audio that this user group has.

Hearing Impairments

Approximately 6% to 8% of the world population has "disabling hearing loss," and the prevalence is far higher today than it was 20 years ago (Wilson, Tucci, Merson, & O'Donoghue, 2017). In addition to loss or reduction of hearing, this impairment may also affect other areas, causing delays of spoken language, lower literacy, social isolation, and psychological illness, among others due to problems communicating with others (Wilson et al., 2017).

Few studies were retrieved on the information seeking and searching of people with hearing impairments. However, from the general literature that is available on hearing impairments there is one clear stand out issue, namely, communication. Profoundly deaf users who have had a hearing impairment from an early age have sign language as their first language. This is distinct from spoken/written languages such as English. Different varieties of sign language exist, such as BSL (British Sign Language) and ASL (American Sign Language), which are also distinct from each other (Barnett, McKee, Smith, & Pearson, 2011). Deaf users are therefore accessing information in a second language. This factor is reported to be the biggest obstacle preventing equal access to information for deaf people (Saar & Artur-Okor, 2013). Consequently, studies on users with hearing impairments primarily focus on communication barriers due to either inaccessible audio content or the difficulties users with hearing impairments have communicating with people who do not understand sign language. Less attention has been directed towards information seeking and searching.

Information Seeking

Barnett et al. (2011) reported that deaf people have limited access to health information, among others because information is not presented in sign language. Consequently, people miss out on information considered common knowledge among hearing people, which has a negative impact on health literacy. The lack of health literacy and the need for

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better access to information is also discussed by Smith, Massey-Stokes, and Lieberth (2012).

Karras and Rintamaki (2012) investigated online information seeking by deaf users looking for health information. Some deaf people used the Internet for information seeking, including instant messaging programs to discuss health issues with friends and family, but others avoided the Internet due to a fear of erroneous information. Difficulties using the Internet were also reported when service providers had not sufficiently considered the needs of deaf people, for instance, by presenting multimedia content with inaccessible audio. This issue is also addressed in general guidelines for web accessibility (W3C, 2018), and for people with hearing impairments in a library context (IFLA, 2000).

Information Searching

Few studies have investigated the information searching behavior of people with hearing impairments. Nevertheless, several of the studies reviewed in the dyslexia section suggest that reading and spelling abilities might affect both query formulation and result list assessment. Because severe hearing impairment has been reported to affect reading and writing (Moeller, Tomblin, Yoshinaga-Itano, Connor, & Jerger, 2007), these studies might have some transfer value to the context of hearing loss. There is also a need to provide effective and accessible bibliographic instruction (Jeal, de Paul Roper, & Ansell, 1996; Norton, 1992).

Overall, solutions to the communication problem are few and far between. There is little, if any, understanding of the communication differential between people with and without hearing impairments, and unfortunately support for users whose main language is sign language is currently very poor.

There is almost no understanding of the impact of communication barriers on the process of search; for instance, forming queries and reading results in a second language. Solutions could be digital assistants, which allows visual entry of queries in sign language, and access to results lists via a sign language avatar (El Ghoul & Jemni, 2009; Kipp, Heloir, & Nguyen, 2011). The underlying system would need to be able to handle translation to and from sign language, on a base language such as English. However, there are a significant number of users who are not fluent in sign language. For instance, around 8.3 million people are hard of hearing in the UK (Barnett et al., 2011), and these users will need different solutions. Around 24,000 people in the UK are dual sensory impaired, being both deaf and blind, so solutions using tactile interactions interfaces could potentially be more appropriate (Wall & Brewster, 2006). Others have suggested including more graphical user interfaces (Fajardo, Cañas, Salmerón, & Abascal, 2006; Petrie, Fisher, Weimann, & Weber, 2004).

Motor Impairments

There is a huge gap in the research regarding the information seeking and searching of people with motor impairments. The focus seems to be on more general guidelines and policies (Australian Library and Information Association, 1998; Burgstahler, 2018; Canadian Library Association, 2016; Irvall & Nielsen, 2005), with a focus on topics such as sufficient parking spaces and accessible toilets. However, in the context of information seeking and searching the research is sparse. Only a few articles are included in this survey, addressing both topics.

Information Seeking

Liang, Xue, and Chase (2011) looked at users with physical impairments related to neurological conditions, and addressed both information seeking and information use. They found that the level of disability seems to affect information seeking, where people are more likely to seek health information online as their physical function is reduced. However, the use of information did not increase with information seeking, suggesting that these two behaviors are not necessarily related and should be differentiated in user studies.

Liang et al. (2011) also related the disease process to information seeking, and found that people diagnosed with what they refer to as "a disabling disease" were more anxious about retrieving information related to the disease, while users in the chronic stage focused more on specific information. This finding implies that the disease process may play an important role in information seeking, and is a variable that should be taken into consideration when designing a research project. This statement supports Beverley et al. (2007), who discussed the same issue for people with visual impairments.

Liang et al. (2011) also emphasized that although certain people had a higher level of information seeking, they did not necessarily use more information. Consequently, one of the conclusions of this study is that physical impairment does not seem to affect the source evaluation, and that people with severe physical impairments would not easily fall victims of inaccurate or misleading information, unless they also have a cognitive impairment. The moderating role related to the individual's level of impairment was also confirmed in Liang and Xue (2013) and elaborated on in Liang et al. (2017), where it was suggested that people might be less rational as the impairment increases.

Abdulla et al. (2014) surveyed the information seeking of 106 patients with amyotrophic lateral sclerosis (ALS) and 100 caregivers, and found that the information-seeking process consisted of various sources, where most participants relied on more than one source. Moreover, a majority wanted to discuss web content with their physician, again confirming the need for reliable health information sources.

Source criticism may be particularly important for people with motor impairments, who may rely heavily on locating information by themselves (Fox, 2007) and not seek help using an intermediary such as a librarian due to reduced mobility. Moreover, high levels of physical pain might potentially affect the decision-making process. This area needs more research; for instance, by investigating the source criticism skills among this user group and how intermediaries or librarians best can accommodate remote users, as inaccurate or false health information can have serious, in the worst case fatal, consequences. Moreover, based on the work of Liang et al. (2011), it seems purposeful to include a number of variables in user studies, such as the stage and degree of the diagnoses, since these factors seem to affect the information seeking.

Information Searching

Edwards, Van Mele, Verheust, and Spaepen (1997) evaluated the user interface design of a library database. In a study including eight students with motor diseases such as muscle disease and central motor disturbance, the participants were interviewed about and conducted searches in a library catalog to reveal potential accessibility issues. The main finding was that there was a need to reduce the motor actions needed to interact with the search user interface and to provide consistency. Moreover, the main obstacle for people with motor impairments was scrolling. The issues with scrolling was also emphasized by Long (2000) in a study of how to improve subject searching in online public access catalogs (OPACs).

Sandberg, Gardelli, and Stubbs (2005) studied how the use of information and communication technology, including information search, can support the rehabilitation of 12 people with severe functional impairments. The conclusion was that the users felt a greater sense of empowerment and that quality of life was improved. The findings from this study confirm the need to ensure accessible ICT in general, and search user interfaces in particular.

Although there are few studies directly addressing the information searching of people with motor impairments, there are related HCI-studies focusing on the use of assistive technology, and this technology seems crucial for this user group to support input and output (Tai, Blain, & Chau, 2008). Moreover, it is likely that alternative input methods, such as voice input, gaze interaction, or brain–computer interfacing might be helpful for users who are paralyzed, have reduced movement or tremor, to name a few. However, according to Pasqualotto et al. (2015), brain–computer interfacing is still inferior to eye-tracking due to the higher cognitive load for people with ALS, an area that needs to be explored in future research. The advantages of eye-based pointing over head-based pointing has been addressed, but it has been emphasized that eye mice have been less popular due to usability issues that can be solved by adjusting the target size and training (Raya, Roa, Rocon, Ceres, & Pons, 2010).

Conclusion and Implications for Future Research

This review has summarized material covering a number of topics including information seeking and searching. A number of gaps were identified, which are elaborated on here. These gaps can be divided into two main types: gaps in areas where research has been carried out and areas in which little or no work has been undertaken. More general issues which apply to the area as a whole were also addressed.

In areas already addressed, there is more of a focus on information searching than seeking, both for users with cognitive and sensory impairments, with very little knowledge gained on seeking within the impairment category. There is a clear need to investigate information seeking as a whole and examine the impact of impairments on more than just the searching activity; for instance, by taking an existing model such as Ellis (1989) and explore what the impact is of the given impairment on the seeking process. In areas such as dyslexia and visual impairments, there is a body of knowledge in searching that can be used to inform information-seeking experiments.

All categories of impairments are represented in this study. However, dyslexia and visual impairments seem to have received the most attention by the research community. There is less research on certain cognitive impairments, such as ASD and Down syndrome. Furthermore, there are few studies involving people with motor impairments and reduced hearing.

Some issues within certain impairment categories with little work done on them have particular issues that need to be addressed. In the context of users with impairments, mediators are sometimes involved, namely, personal assistants, that is, helping people with motor impairments navigate wheelchairs or sign language interpreters assisting in communication. Consequently, mediators in information seeking is a potential highly relevant topic in this area of research. Nevertheless, only one study included in this review directly addressed this issue (Bilal, 2010), suggesting a gap of knowledge in this area, both regarding users with hearing impairments and cognitive impairments. A consequence of a lack of focus on people who need mediators may cause an underrepresentation of users with severe impairments, for instance, ASD or Down syndrome, who have received little attention in the field so far. However, these users also need sufficient services and access to age-appropriate information and material. According to Nour (2015), access to online information can provide tremendous support to users with cognitive impairments, but few studies have this focus, making a gap that needs to be filled.

Some impairments have not been investigated at all to the best of our knowledge. Throughout this article, links are provided to work done on developmental dyslexia, but other types of dyslexia such as acquired dyslexia (Coslett, 2003) have not so far been addressed. Acquired dyslexia occurs as the result of some kind of brain injury, through, for instance, stroke, dementia, or brain tumor. The results of acquired dyslexia can be very severe, with significant language impairments such as aphasia present.

Aphasia is a condition in which the ability to produce or consume information through language is impaired. Given the importance of language in information access and seeking, it is highly likely that an ability to find information using standard search engines or IR software is severely impaired. Clearly, these users have information needs, but there is as yet no understanding of their requirements, let alone their information-seeking behavior. These users often need helpers with speech and language therapy knowledge, particularly those with very severe aphasia (Galliers et al., 2012). It is therefore important to address the needs of these therapists, and to engage their help in the work, as they have significant subject knowledge of working with users with aphasia. The therapists can act as effective search intermediaries, if the behaviors of both stakeholders are understood. Moreover, therapists should be trained accordingly.

Based on this review, a common trend seems to be addressing different user groups separately in user studies on information seeking and searching. This makes sense, since users may have conflicting needs or dissimilar challenges. For instance, although blind users may have difficulties accessing the content in result lists (Andronico et al., 2006), people with dyslexia may find spelling terms correctly during query formulation more demanding (Berget & Sandnes, 2015) or have challenges related to reduced working memory (MacFarlane et al., 2012, 2017). Therefore, when addressing specific gaps in the literature identified above, researchers should pay attention to what is known about each impairment and design experiments accordingly. The impairment itself will determine what needs to be investigated and a clear analysis needs to be conducted before attempting research, preferably with advice from a professional with domain knowledge of that impairment.

There are a significant number of articles investigating information seeking and searching, which are typically represented by user studies. The aim of many of these investigations is often to identify barriers and/or provide solutions on how to develop more accessible systems. Consequently, the primary goal of this research is to make information retrieval systems more accessible for users with impairments. This focus adheres to international conventions and national legislation, and confirm our statement in the Introduction that access to information is regarded as essential by researchers and practitioners. Furthermore, various members of the community are actively involved in improving services to users with impairments.

One topic that is included in the various research reviewed here is the seeking or searching for health information. This is not unexpected, since it is likely that severe impairments cause a higher need for such information. However, there is also a need to address other types of information needs. More studies are needed in general on other types of information needs than health.

Impairments exist in various forms and degrees. Moreover, because impairments have different implications, there might be a huge variation in what types of barriers that are met during information seeking and searching, and also which barriers cause "the disability." Some of these barriers might be shared by several user groups, for instance, issues related to spelling or short-term memory, while others might be more closely associated with one or a few impairments, such as complete hearing loss. Moreover, users may also have conflicting needs. Although people who are blind rely on sound as an input channel, people with reduced hearing are dependent on visual content. Consequently, it does not make sense to design user interfaces that accommodate certain user groups, but rather to design systems that are flexible and robust enough to handle different types of barriers users may face when searching or seeking for information. This policy would also reduce the barriers and consequently the gaps that cause disability. This mindset is the core of the universal design paradigm, which is frequently applied in research and used as a framework for this review. Overall, research involving users should have as a goal to develop guidelines to support practitioners and developers, who may not be familiar with barriers or difficulties related to the diversity of users.

While universal design has been influential in the library world (Chodock & Dolinger, 2009; Samson, 2011), it is particularly important in terms of information access, seeking, and searching, since it provides key concepts for good practice for search engines of different types. Most of the topics addressed in this review are key issues for other users as well, without impairments. Some people might experience reductions in certain functions temporarily, for instance, breaking a leg or being exhausted after a tiresome day at work. Other situations might be caused by, for instance, very noisy surroundings, making it difficult to, for instance, apprehend a message at the train station or problems using smartphones due to heavy sunlight or rain. Moreover, it has been emphasized that information searching requires a huge cognitive load, making it a potentially demanding task for all types of users (Gwizdka, 2010).

Although universal design is a good ideal, it has been discussed whether this principle can actually be achieved in practice. The argument is that by addressing all types of needs in one design, the result is an interface that fits none (Harper, 2007). Consequently, one might argue that it might be purposeful to design systems where interfaces might be tailored by the users to comply with their personal requirements for interaction, for instance, by supporting both textual and verbal input in search boxes. More studies within the universal design paradigm are therefore recommended, but with an awareness of the immense diversity found in all types of user groups.

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