Modelling the information seeking and searching behaviour of users with impairments: Are existing models applicable?

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Abstract

Purpose

A substantial number of models have been developed over the years, with the purpose of describing the information seeking and searching of people in various user groups and contexts. Several models have been frequently applied in user studies, but are rarely included in research on participants with impairments. Models are purposeful when developing theories. Consequently, it might be valuable to apply models when studying this user group, as well. The purpose of this study was to explore whether existing models are applicable in describing the online information seeking and searching of users with impairments, with an overall aim to increase the use of models in studies involving impairments.

Design/methodology/approach

Six models were selected according to the following criteria: the model should address information seeking or searching, include the interaction between users and systems whilst incorporate assistive technology. Two user groups were selected from each of the categories cognitive, sensory and motor impairments, namely dyslexia, autism, blindness, deafness, paralysation and Parkinson's. The models were then analysed based on known barriers reported for these cohorts.

Findings

All the selected models had potential to be applied in user studies involving impairments. While three of the models had the highest potential to be used in the current form, the other three models were applicable either through minor revisions or by combining models.

Originality/value

This study contributes with a new perspective on the use of models in information seeking and searching research on users with impairments.

Keywords: Information seeking, information searching, user models, users with impairments

Article classification: Research paper

Introduction

In the field of information research, there was a change of perspective at the end of the 1970s and beginning of 1980s, which entailed a shift of focus from systems to users. Researchers developed models on various aspects of user behaviour, such as different contexts, activities and stages of information seeking and searching. These models have later been applied extensively (Wilson, 1999). Over the last decade, attention has increasingly been directed towards the information seeking and searching of users with impairments (Hill, 2013, Berget and MacFarlane, 2020). Studies on users with impairments, however, rarely include any models of information seeking and searching (Berget and MacFarlane, 2020).

There are only a few examples where models have been included in studies on people with impairments. Baker (1998) applied Sense Making theory (Dervin et al., 1981, Dervin, 1992) to investigate the information needs of people with multiple sclerosis. Williamson et al. (2000) used the Ecological model by Williamson (1998) for studying the information-seeking behaviour of users with visual impairments. This model has also been applied in a study on elderly people (Williamson and Asla, 2009). Beverley et al. (2007) discussed whether two models, namely the Revised model by Wilson (1999) and the model of social information need by Moore (2002), could be used to describe how people with visual impairments search for information. Beverley et al. (2007) concluded that both these models could be purposeful in studies of people with visual impairments, but should be investigated further in other contexts. Sahib et al. (2012) applied the model by Marchionini and White (2007) in their study of the information seeking behaviour of people with visual impairments.

According to Bates (2005b), there is great value in models for developing theories. Models may also be useful for researchers and system developers, to predict and describe the behaviour of users. Consequently, it is purposeful to model the information seeking and searching of people with impairments, although it is rarely done. Beverley et al. (2007) claim that there is a lack of both models and theories that sufficiently include important characteristics related to impairments. The purpose of this study is to investigate this topic further. The research question is as follows:

> *RQ: How can established models be used to describe the online information seeking and searching behaviour of users with impairments?*

To answer the research question, six models will be discussed in the context of cognitive, sensory and motor impairments. The paper is structured as follows: First, there is a clarification of concepts addressing the distinction between theories, frameworks and models, followed by a classification of impairments. The next section presents the inclusion criteria for selecting models and summarises common barriers related to the chosen cohorts. In the subsequent section, the models are shortly introduced and analysed. Finally, there is a discussion regarding the potential of the models to be applied in the context of impairments. Models vary in their level of description. While some models are conceptual or abstract, others are more specific. The overall purpose is therefore not to compare them directly with each other, but rather explore their potential in describing the information seeking or searching of people with impairments.

Clarification of concepts

Theories, models and frameworks

According to Case and Given (2016), theories are general statements that try to explain the relationship between phenomena. These relationships are typically testable (Baker and Pettigrew, 1999). Vakkari (1998) relates the growth of knowledge in science to an increasing number of theories, entailing that the scientific community has accumulated more empirical evidence.

Models might vary in nature. Bates (2005b) claims that models are most purposeful when describing a phenomenon and trying to predict stages, while the theory is the proper explanation of the phenomenon. Consequently, Bates (2005b) claim that the distinction between the theory and model addressing the same phenomenon is not always clear. Both Wilson (1999) and Bates (2005b) state that models proceed formal theories. A model is typically more specific than a theory because it addresses a certain context, but is still related to theories (Wilson, 1999). According to Nilsen (2015), models can be defined as "*theories with a more narrowly defined scope of explanation*". Models are therefore regarded as more descriptive compared to theories, which are usually more explanatory. Case and Given (2016) claim that models are often easier to grasp than theories because they are typically depicted in diagrams.

In addition to theories and models, frameworks are also applied in research. The term *framework* is often used almost synonymously with *model* (Wilson, 1999, Beaulieu, 2000, Fisher et al., 2005). A framework, however, is often broader than a model, and differs from the model in that it typically does not provide explanations. Frameworks often consist of descriptive categories such as variables or concepts, and are often used to describe empirical phenomena by placing them into a set of categories (Nilsen, 2015). Theories models and frameworks can also be applied to impairments. It is to this subject we turn to next.

Classification of impairment

The terms *impairment* and *disability* are often used synonymously. Nevertheless, there is a crucial difference between the two concepts. According to the medical model, disability was regarded as something medical, and individual treatment was the key measure. In the 1970s, the Union of Physically Impaired Against Segregation (UPAIS) stated that people with impairments were oppressed due to disabling barriers in the society (Union of Physically Impaired Against Segregation and Disability Alliance, 1976). This movement encouraged a new way of looking at disability, and resulted in what Mike Oliver in 1983 referred to as *the social model of disability* (Shakespeare, 2013). According to this view, it is claimed that a person is not disabled, but disability is a concept created by society through barriers (Oliver, 1996).

In later years, the gap model has become the most common way of looking at disability. According to Shakespeare (2004), this model should not be regarded as an alternative to the social model, but rather another type of social model. The gap model states that disability occurs when there is a mismatch between the person's abilities and demands from society. This gap, however, can be reduced by either strengthening the individual, changing the society or both (Shakespeare, 2004). Consequently, a person is not disabled, but there might be disabling barriers in society, which causes disability. This paper is situated within the gap-framework, and will therefore apply the term "person with impairment" rather than "person with disability" or "disabled people".

The World Health Organization (WHO) applies a Classification of Function, Disability and Health (ICF), with the purpose of providing a common language for description of health. According to WHO (2001), the organization wants to remove the view that disability starts where health ends, and thus avoids placing people with impairments in a separate category from "other people". Consequently, WHO (2001) has changed focus from emphasising impairments to addressing level of health , and refers to disability as "*a universal human experience*". ICF comprises four main categories, namely body functions, activities and participation, environmental factors and body structures (WHO, 2017). This classification is very detailed, and has a more diagnostic and medical perspective than was regarded as purposeful for this study. Consequently, three broader categories of impairments are applied here, namely cognitive, sensory and motor impairment. This classification has been used in previous studies in medicine (Hutton and Pharoah, 2002), information behaviour (Liang et al., 2017,

Berget and MacFarlane, 2020), human computer-interaction research (Abascal and Nicolle, 2005) and in general descriptions of human abilities within the universal design paradigm (Story et al., 1998).

Methods

In this study, the methodology initially focused on establishing selection criteria for models and impairment types. When these were defined, each model was analysed based on a set of user characteristics typically affected by the impairments. Each model was considered from a user perspective, system perspective and the ability to include assistive technology.

Inclusion criteria

An extensive number of models have been introduced over the years in various versions and revisions. Due to the large number of models, a set of inclusion criteria was applied to narrow down the number of potential candidates.

The first criterion is a clarification of the research field, which comprises many overlapping and related terms. For instance, according to Xie (2017), information searching is sometimes applied as a synonym for information access, information seeking and information retrieval. Information retrieval is a quite broad term, related to both the retrieval and representation of information. Chu (2007) divides the dimensions related to retrieval into information seeking, searching and access. This study is situated within an information seeking and searching behaviour context, as defined by Wilson (2000). Information seeking is defined as "*the purposive seeking for information as a consequence of a need to satisfy some goal*", while information searching is "*the 'micro-level' of behavior employed by the searcher in interacting with information systems of all kinds*" (Wilson, 2000).Consequently, the models need to address one of these levels.

According to Xie (2017), much research on information seeking has contributed to research on information searching. Consequently, these levels of behaviour are closely related. Information seeking comprises a variety of activities, such as passive attention, passive search, active search and ongoing search (Wilson, 1997). Searching can be described at various levels, such as strategies, usage patterns, tactics and modes (Xie, 2017). Consequently, search models can be regarded as "*illustrations of patterns of information searching and the search process*" (Xie, 2017). Information searching can be categorized into different modes; among others based on how actively involved the user is in the search process. White (2016) applies four modes, namely two types of active search: searching (directed) and browsing (undirected), and two types of passive search: monitoring (directed) and awareness (undirected). This study directs primarily attention towards the active modes of information searching. Finally, information searching can be divided into various types. Two common types are known-item search and exploratory search. Known-item search typically refers to look-up searches, where one information item might be sufficient, while exploratory search comprises more complex search tasks that are often open-ended, multi-faceted and iterative (White, 2016). This study includes both of these types.

The second criterion regards the components of the model. Several studies have found that impairments may affect various aspects of information seeking and searching, causing a behaviour that differs from other users. Examples are the use of shorter queries by people with dyslexia who find spelling query terms challenging (Berget and Sandnes, 2015) or the use of longer, more expressive queries among users with reduced vision due to challenges navigating the result lists using screen readers (Sahib et al., 2012). Moreover, search user interface functionality may affect the choice of sources. For instance, people with various types of language impairments may prefer

systems with a high tolerance for errors (Berget and Sandnes, 2016). The models must therefore include both a user- and system- perspective.

The third criterion addresses the use of assistive technology, which is commonly applied by people with impairments, and have the potential of reducing limitations related to certain impairments (Levitt, 2017). Further, such technology may have an impact on how users solve information needs, and compatibility issues can create barriers towards information seeking and searching (Sahib et al., 2014). Consequently, it is preferable if the models also have included various types of interaction with information resources, which allows for identification of particular issues that can be addressed by appropriate assistive technologies.

Impairments, cohorts, characteristics and barriers

The three categories cognitive, sensory and motor impairments comprise a wide spectrum of conditions. In this study, two example groups were applied for each category to cover as many user characteristics and assistive technologies as possible.

Dyslexia and autism represent cognitive impairments, since they entail quite different characteristics and behaviours. While dyslexia typically affects reading and writing, short-term memory, concentration and rapid naming skills (Hatcher et al., 2002, Jeffries and Everatt, 2004), autism may impact language, communication and cause repetitive behaviour (Sandin et al., 2014). Blindness and deafness were included for sensory impairments, representing two main senses, namely vision and hearing. Paralysation and Parkinson's were included as examples of motor impairments. The first represents loss of muscle function, while the latter typically involves slowness of movement, shaking and rigidity (Hawkes et al., 2010).

Previous research has reported several barriers for the cohorts included in this study. Much work is done on dyslexia and visual impairments, while fewer studies have addressed the other impairment types (Berget and MacFarlane, 2020). Some of the main issues related to dyslexia are query formulation (Berget and Sandnes, 2015), result list and document assessment (MacFarlane et al., 2012) and a general lack of confidence (Burden, 2008). People with autism may also have challenges with query formulation (Harrysson et al., 2004), making selections from large amounts of text (Harrysson et al., 2004) and navigating vertical structures (Williams and Hennig, 2015), such as result lists. It has also been reported that this group is more exposed to risk (Chiner et al., 2017b) and often has limited access to the web due to overprotection (Chiner et al., 2017a). Moreover, many people with autism may be regarded as silent information seekers, where intermediaries do all the searching on their behalf (Bilal, 2010). Finally, a lack of confidence is also reported for this cohort (Sitbon et al., 2018).

For sensory impairments, studies on people with severely impaired vision have reported issues with query reformulation (Sahib et al., 2012), access to information (Xie et al., 2015) and keeping track of information found during search (Ivory et al., 2004). Moreover, navigating result lists (Sahib et al., 2012), assessing information (Xie et al., 2018) and multisession searching (Sahib et al., 2012) may be challenging. People who are deaf often experience inaccessible multimedia content (Karras and Rintamaki, 2012), challenges with query formulation due to writing impairments (Moeller et al., 2007) and accessing information in a second language (Saar and Artur-Okor, 2013).

Little work has been done on users with motor impairments. It has been found, however, that brain computer interfaces are useful for people unable to use manual input devices (Nuyujukian et al., 2018) and word completion features increase typing rates (Nuyujukian et al., 2018) for people with

paralysation. For Parkinson's, gestural commands and use of touchscreens may resolve challenges with point and click interactions (Hollinworth, 2009).

Table 1 provides a summary of the most important issues to consider for each impairment type. (A more detailed summary of what is known about users with impairments and information seeking and searching is presented in Berget and MacFarlane (2020).) The table is the starting point for the analyses of the models. The characteristics in Table 1 should be regarded as a description of "the most typical case". Huge variations occur, and it is important not to generalize for all individuals. For modelling purposes, however, a set of characteristics are needed as a starting point, keeping in mind the potential diversity within these cohorts for each condition.

Impairment type	Condition	Characteristics affected
Cognitive	Dyslexia	- Spelling - Reading / writing - Short-term memory - Attention - Rapid naming skills
	Autism	- Language development - Reading / writing - Short-term memory - Uneven skill development - Social skills (- Motor skills) (-Sensory skills)
Sensory	Blindness	- Vision
	Deafness	- Hearing - Written language - Reading
Motor	Paralysation	- Movement
	Parkinson's	- Rigidity - Tremor - Postural instability

Table 1: Characteristics that might affect information searching

A key topic related to all types of impairments is the use of assistive technology. Although not all users do apply assistive technology, they might be purposeful and support users in various ways (Levitt, 2017). Some examples are spell checkers or voice input for people who find spelling challenging. For users with reading challenges, screen readers may be useful. For people who cannot see, screen readers and braille displays may be purposeful, while sign language avatars may be applicable for users who are deaf. For people with motor impairments, there are various input devices that replaces the mainstream keyboard and mouse, such as head mouse, gaze interaction and brain computer interaction.

Analysing the models

Before selecting models and impairment types, all relevant previous research regarding information seeking and searching of people with impairments was retrieved, analysed and summarized in a review paper (Berget and MacFarlane, 2020). Then, comprehensive literature searches and reading were conducted to identify potential models that were in accordance with the selection criteria. While a number of models were looked at, discussed and found potentially suitable, six models were

eventually selected due to space limitations (see Table 2). Consequently, Table 2 does not show the only models that complied with the criteria. The main reason for inclusion of each model are presented in Table 2.

Model	Main source	Level	Main reason for inclusion
Revised model of information-seeking behaviour	(Wilson, 1997)	Seeking	Applied in previous studies on users with visual impairments (Beverley et al., 2007)
Ecological model	(Williamson, 2005)	Seeking	Applied in previous studies on users with visual impairments (Williamson et al., 2000)
Information Seeking Framework	(Marchionini and White, 2007)	Seeking	Applied in previous studies on users with visual impairments (Sahib et al., 2012)
Berrypicking	(Bates, 1989)	Searching	One of the most cited models, and includes the potential complexity of search processes (Xie, 2017). Applied to other vulnerable groups e.g. refugees (Fisher, 2018)
Search situations and transitions (SST)	(Pharo, 2004)	Searching	Explicitly combines information seeking and searching features to model how users' characteristics influence their interaction with information systems (Toms and Freund, 2009).
Integrated Information seeking and Retrieval (IS&R)	(Ingwersen and Järvelin, 2005)	Searching	Heavily cited model, which describes how cognitive characteristics of users interact with the search system environment and associated factors (Xie, 2017).

Table 2: Selected models for analysis

Regarding inclusion criterion 1, three of the models described information seeking, while three addressed information searching. Inclusion criterion 2 required that the model had both a user and system perspective. All the six models included complied with this criterion. Finally, inclusion criterion 3 addressed assistive technology. Although none of the models had specifically applied this term, they had elements that allowed for potentially including such technology.

The information seeking models (Revised model of information-seeking behaviour, Ecological model and Information Seeking Framework) were selected because they had been applied in previous studies on visual impairments (Beverley et al., 2007, Williamson et al., 2000, Sahib et al., 2012). Consequently, it was purposeful to continue this work by exploring other impairments types, as well. In addition, three models on information searching were included (Berrypicking, SST and IS&R).

The foundation for the analyses comprised various papers and books presenting the original work, in addition to some empirical studies that had applied the models. Some of the models have been presented in different forms. The main source used for the analyses are included in Table 2. Both figures and text were used in the analyses. Table 1 was used as a starting point regarding user characteristics, in addition to the overview of potential assistive technologies applied by users with various impairments. The models were looked at both in terms of strengths and weaknesses.

The analyses were directed at the models as a whole in the context of the impairments identified, and through the literature in information seeking and searching for each impairment. Each model was carefully studied in terms of which components of the model that might be affected if the user had one of the selected impairment types. Moreover, the models were looked at in terms of which parts that could be used to explain potential user characteristics affected by the impairment types,

e.g. spelling skills, vision and short term memory capacity (see Table 1). Further, the models were examined in context of assistive technologies. All the analyses were checked by all the authors to ensure that all the analyses were conducted in the same way.

Models

In this section, the selected models will be analysed based on the general characteristics of the six impairment types (Table 1). The information seeking models are presented first, chronologically, followed by the information searching models. These will be discussed according to the user perspective, system perspective and assistive technology.

Revised model of information-seeking behaviour

The Revised model of information seeking-behaviour (Figure 1) , hereby referred to as Revised model, was developed by Wilson (1997). It was considered relevant since it addresses barriers encountered during the search process (Wilson, 1999). The starting point is the person with the context of an information need. Between the user and the various types of information seeking behaviour, there are several potential barriers. These barriers were originally referred to as 'intervening barriers' in an earlier version of the model, but were reframed as intervening variables in the Revised model (Wilson, 1997). Wilson related the need for information seeking to stress/coping theory and associated risk/reward theory with the decision to apply information sources.

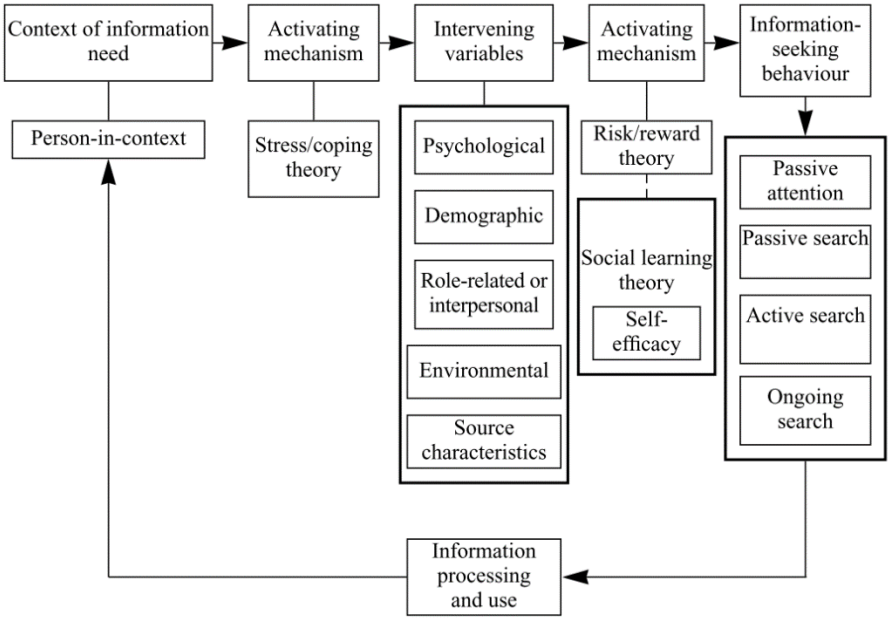

Figure 1: Revised model,
reprinted from Wilson (1999) with permission.

The model's intervening variable concept is a key advantage and can be applied to any element of the model represented in Figure 1. The intervening variables (or barriers) can be related to each of the impairments identified in Table 1. Cognitive impairments can be matched to the psychological variables, where those particular personal characteristics have an impact on information searching. For example in dyslexia (MacFarlane et al., 2012)and autism (Bilal, 2010), limited working memory is evident. For both sensory and motor impairments, environmental or situational variables are more prominent in terms of users' interactions with systems during information searching. Spatial-temporal characteristics are strong determinants of information seeking behaviour in those cohorts. Other parts of the model can also be useful for examining the impact of impairments on information

searching e.g. poor self-efficacy is reported as being a significant issue for users with dyslexia (Burden, 2008), and this can be a significant barrier to successful activation of seeking (Cole et al., 2016). In terms of systems however, it is less easy to see how the model impacts on information searching as concepts such as active and passive search are quite high level, and not sufficiently detailed in their own right to examine particular issues with any impairment type.

Appropriate assistive technologies can be identified using barriers from intervening variables. For users with cognitive impairments, technologies such as memory aids can be provided. For users with sensory impairments, assistive technology provide alternative access via other functioning senses, e.g. braille devices for query formulation and screen readers for browsing and navigation to help users with visual impairments. Signing Avatars could be used to help hearing impaired users with browsing, whilst machine vision could be used to detect users' sign language to support query formulation. Users with motor impairments may rely on specialist input devices (accessible keyboards) or voice recognition software for query formulation.

Ecological model of human information seeking and use

The Ecological model of human information seeking and use (Figure 2) was developed by Williamson (1998). The model emerged from a study of elderly participants (Williamson and Asla, 2009) and has also been applied to people with visual impairments (Williamson et al., 2000). One of the main purposes was to show the relationship between information seekers and systems, and the model includes sources such as family and friends (Williamson, 2005). Another important factor is the inclusion of social and biological constraints among users.

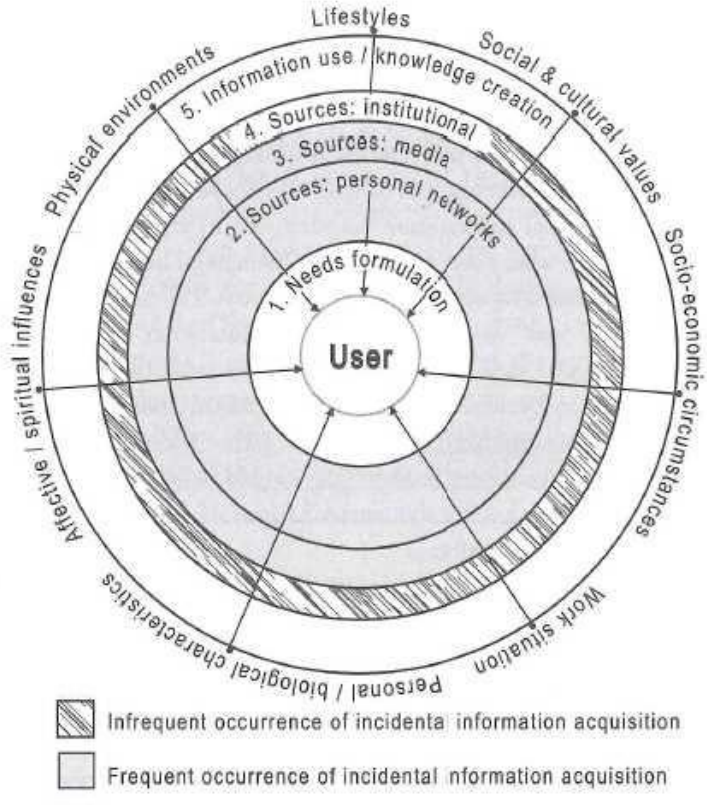

Figure 2: Ecological model, adapted from Williamson (2005), reprinted with permission.

This model is quite general and does not address any distinctive phases or activities. The Ecological model regards users as both socially constructed and individual entities, and is therefore claimed to fit well in the context of people with impairments (Williamson et al., 2000). This view is also in

accordance with the predominant view on disability, namely as constructed by societal barriers (Shakespeare, 2013), thus affecting individuals with impairments in various ways. These barriers can also be related to the category physical environments, that are often claimed to have a noteworthy effect on the inclusion level of the society, for instance through universal design (Steinfeld and Maisel, 2012).

The category personal and biological characteristics comprises topics such as health, age, stage of disease and affective issues (Williamson, 2005). This is a broad category comprising both physical and cognitive characteristics. In this context, the model works well to display all the impairment types included in this study. Moreover, it provides room for modelling how various stages of diseases or conditions may affect the information searching. It has been reported that people become less rationale as impairments or diseases become more severe, which might affect result list assessment (Liang et al., 2017). Consequently, this is an aspect of impairments that might also be relevant to include.

The model has many advantages in modelling the user. There is, however, a need to model the system itself. In the Ecological model, point 2-4 refers to sources. Category 2, 'Personal networks', may be particularly important for people who rely on intermediaries, such as people with autism (Bilal, 2010). Other users, e.g. people with intellectual impairments, may have reduced access to sources due to overprotection (Salmerón et al., 2019). The next category, 'Media', can relate to both system features such as query building aids or compliance with assistive technology, and can thus be related to various aspects of impairments.

Information seeking framework

The Information Seeking Framework by Marchionini and White (2007), builds among others upon previous work by Marchionini (1995). The model includes a figure showing the set of activities undertaken during search (Figure 3). Moreover, the various forms of system support are discussed, such as query suggestions, which fits quite well with users who might rely on such features. The size and shape of the squares in the model relates to human and system effort.

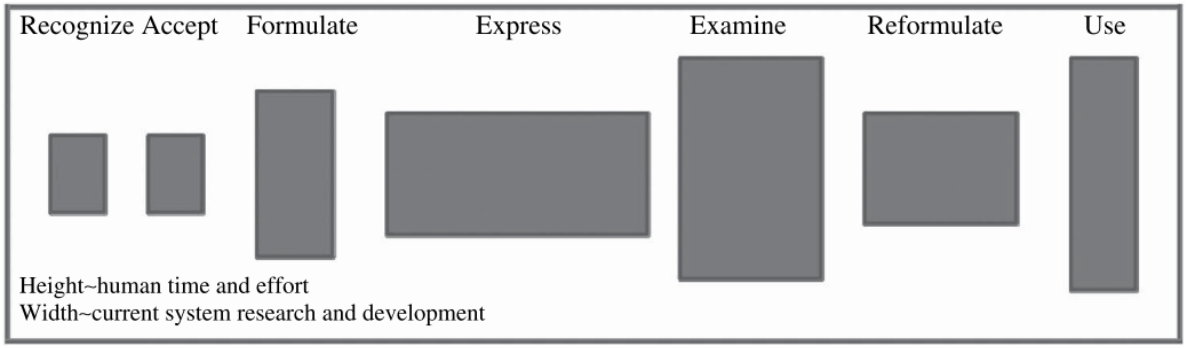

Figure 3: Information Seeking Framework (Marchionini and White, 2007).

One advantage with this model is the specific focus on each phase of the information seeking, which makes it easier to identify where in the search process potential problems may arise. Marchionini and White (2007) argue that search systems perceived as effective and easy to use will result in people accepting more information needs, and that this phase is related to time constraints. This can be clearly related to people with impairments, who have been reported to take longer when using certain systems e.g. people who are blind (Craven and Brophy, 2003) or users with dyslexia (Berget and Sandnes, 2015).

According to Marchionini and White (2007), the express phase is constrained by the search user interface and search facilities. This argument is also purposeful when addressing people with impairments. This phase is related to both semantic and action mapping. The first is especially related to vocabulary, and can be applicable to many types of users e.g. people with reading impairments (Norton and Wolf, 2012), aphasia (Boyle, 2011) dementia (Emery, 2000), or people with developmental impairments (Meilleur and Fombonne, 2009). Action mapping may potentially be related to input challenges experienced by people with motor impairments.

Marchionini and White (2007) describe result list assessment as the need to quickly make sense of the result list and then scan full objects, which has been reported to be challenging by people who are blind, people using screen readers (Sahib et al., 2012) and people with dyslexia (MacFarlane et al., 2012). This activity may potentially also affect people who are deaf, who often have challenges with reading (Moeller et al., 2007). The final two phases are followed by possible reformulations and use.

The inclusion of both human effort and system support makes this model quite useful when describing the information seeking and search of people with various impairments. Although assistive technology is not included, it seems likely that the model could be revised by making several of the boxes wider, thus increasing system support and making them lower, reducing the human effort.

Berrypicking

Bates' Berrypicking model (Bates, 1989) depicts how information searching is not always performed in "*a one query/one use way*" (Bates, 2005a). This model (Figure 4) shows how queries might evolve and change during the search process, and that users apply "a bit-at-a-time-retrieval", referred to as 'berrypicking'. Bates also describes the thought process during search, the use of a variety of search techniques, and the application of different sources. The Berrypicking model has therefore incorporated both a user and system perspective.

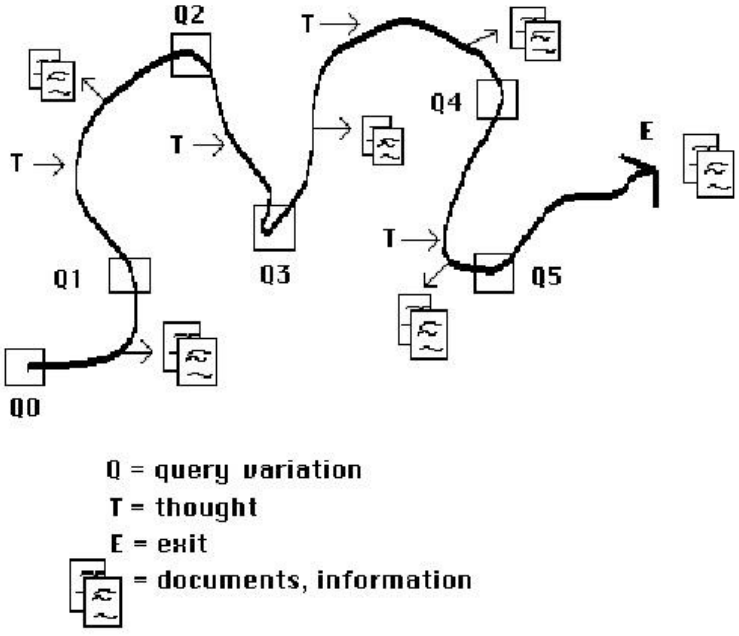

Figure 4: Berrypicking model, reprinted from (Bates, 1989) with permission.

A key disadvantage of the model is that it focuses on a process rather than individual user characteristics – the model can therefore be classified as impairment agnostic. From the point of view of each of the impairments, there are no distinguishing elements that would on the surface allow the study of a particular set of issues given users characteristics. However, this is compensated by the ability of the model to identify issues at each stage of the process from query formulation to browsing results lists and documents, by directly observing user behaviour in each step. These directly observable activities can be studied and issues for all impairment categories identified.

Functionality of systems is a key output of the Berrypicking model, which allows easy identification of barriers and workarounds as the user's search evolves given their journey - picking up relevant 'berries' and moving to areas where more can be found. In terms of query formulation or variation, the behaviour of users with dyslexia can be empirically studied with the model, where it has been demonstrated that users change query terms to address spelling errors, avoiding words that might be difficult to spell (Berget and Sandnes, 2015). A different set of problems is associated with browsing, which often requires access to and significant navigation through substantial quantities of information. A good example for this part of the model is the problems visually impaired users encounter. Users issue expressive queries to reduce the number of interactions in the browsing phase (Sahib et al., 2012). This is because visually impaired users often have challenges with browsing and navigation as they rely on screen readers to read out content, and the linear nature of this interaction inhibits easy scanning of information (Sahib et al., 2012). Particular issues for a given part of the process can therefore be identified for cognitive and sensory impairments given evidence from the literature. Despite the lack of research into motor impairments the key behaviours exhibited by such users will be subject to the same level analysis through the Berrypicking process model.

The model can identify the given barrier and an appropriate workaround together with an appropriate assistive technology at appropriate points in the Berrypicking process. For users who require assistance with the formulation of queries such as people with dyslexia, query building aids with spell checkers and word suggestions can be designed. For visually impaired users, assistive technology that address browsing and navigation are essential, and thoughtful design of screen readers is required to meet user needs.

Search situations and transitions (SST)

The Search situation and transition (SST) method schema (Figure 5) was first presented in Pharo (2002). The conceptual framework of the method schema constitutes the model presented in Pharo (2004). The model was derived from a literature study and empirical studies of students searching the Web to find information for writing their bachelor theses.

The model depicts information searching processes as alternations between searcher-system interaction with meta-level resources ('transitions') and real information resources ('situations'). The process is influenced by several factors, including characteristics of the searcher's social and organizational environment (e.g. domain, colleagues, policies) as well as characteristics of the individual searcher (e.g. knowledge, motivation, attention, cognitive style). Pharo (2004) points out that the list of characteristics is not fixed, and that the researcher should pick attributes relevant to the research problem. This could e.g. include searchers' physical characteristics.

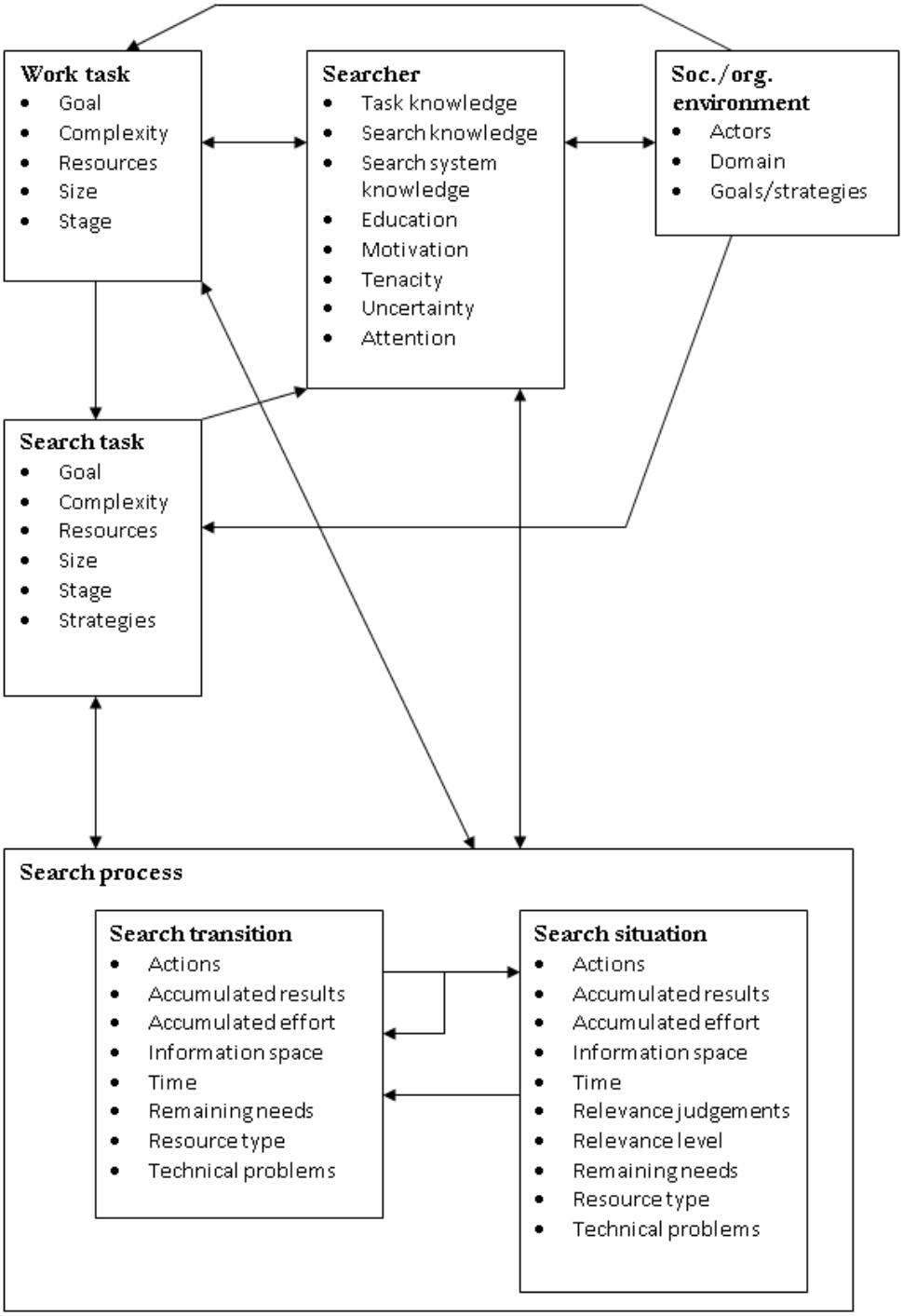

Figure 5: The SST model, reprinted from (Pharo, 2002) with permission.

The model's *searcher* category can be expanded with characteristics associated with the impairments described in Table 1. Searchers' literacy skills (such as spelling and reading), e.g., can easily be modelled along with the current motivation, the same goes for all the other characteristics. Consequently, it should be possible to model dyslexia (Berget and Sandnes, 2015), Parkinson's (Hollinworth, 2009), deafness (Moeller et al., 2007) and other impairments and conditions.

The SST model does not explicitly model the search system, but contains three related components, specifically 'actions', 'resource type' and 'technical problems'. Actions denote searcher-search system interaction, including entering queries, following links, reading a document and other ways to

consume and manipulate the content. Resource types are different genre or types of content that can be stored in search systems, such as journal articles, metadata or interactive web resources. Resource type can also be used to specify different versions of the same content, tailored for specific user groups. Technical problems refer to problems caused by software, hardware or other parts of the technical infrastructure that hinder the user in the system interaction.

Assistive technology, including spell checkers and screen readers are less intuitively applied in the model. It can, however, be argued that the SST model implicitly supports the use of assistive technology, in the sense that effects caused by lack of assistive support is accounted for. Another option, which can be considered indirectly, would be to define the technology as a means for actions that the searchers perform.

Integrated information seeking and retrieval (IS&R) framework

The integrated information seeking and retrieval (IS&R) framework (Figure 6) as presented in Ingwersen and Järvelin (2005), is a revision of Ingwersen's model (Ingwersen, 1992, Ingwersen, 1996). The model features the cognitive and affective characteristics of the actors involved in information seeking and retrieval. These characteristics include both those actively directly involved in ISR processes (actors or searchers, who may collaborate in teams), but also characteristics embedded into the information objects (e.g. books, web pages or television programs), interfaces and information systems.

IS&R is based on several assumptions, for instance that algorithmic information retrieval cannot have any real meaning without including the interaction between the user and the system. The system context is on the left-hand side, while the socio-cultural organizational context is represented to the right.

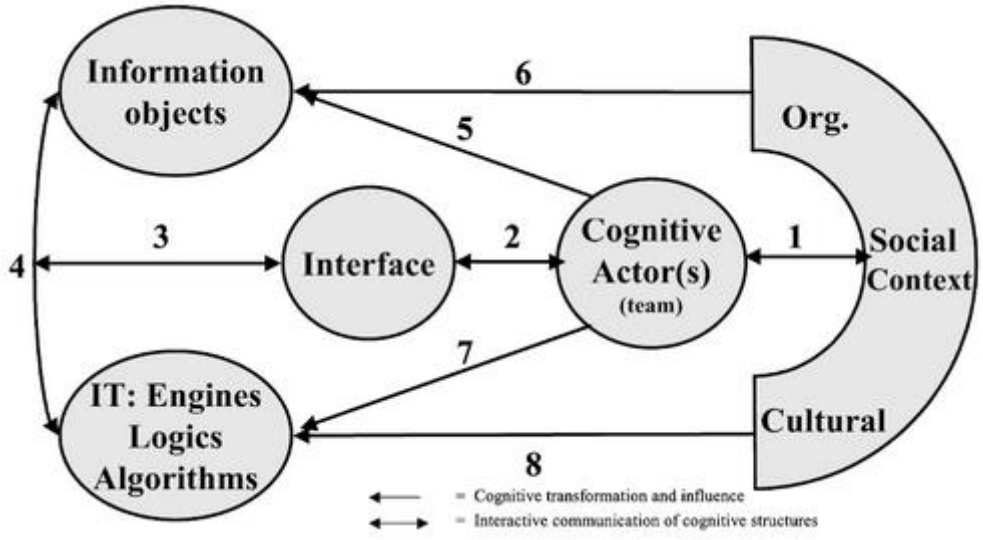

Figure 6: IS&R framework, reprinted from Ingwersen and Järvelin (2005) with permission.

In the IS&R Framework the searchers of information systems are modelled as cognitive actors acting in a context, where the contexts as well as the searchers' cognitive characteristics influence their information searching activities. The model's cognitive approach means that cognitive impairments, such as dyslexia (MacFarlane et al., 2010) and autism (Bilal, 2010), are adaptable in modelling the searcher. Its weakness is its 'cognitive' focus, which does not explicitly take into account sensory or motor impairments.

The core of the information system is constituted by the 'Information objects' and 'IT: Engines Logics Algorithm" components. The cognitive approach implies that solutions tailored for searchers with impairments may partly be embedded in these two components. Examples of this are books (information objects) available in Braille format or algorithms designed to rank documents in a predictive way for persons with autism (Akin and MacKinney, 2004), based on reading level for people with dyslexia (Kvikne and Berget, 2019) or access to multimodal content for people with sensory impairments (Karras and Rintamaki, 2012).

The interface between information system and the actor can consider specific requirements of the searcher, such as the need for assistive technology, but also human intermediaries that can help the searcher in system interaction (Bilal, 2010).

Discussion

Bates (2005b) claims that models have a great value when developing theories. For the application of models to be useful, however, the models must leave room for the relevant components involved in information seeking or searching, depending on the context of use. When modelling the information seeking and searching of people with impairments, the model should obviously contain the same elements as in all other user studies. In addition, there might be need for a few more user characteristics, since impairments may impact seeking and searching in different ways. For instance, query formulation may be influenced by impaired spelling skills (Berget and Sandnes, 2015), language skills (Harrysson et al., 2004) or impaired vision (Sahib et al., 2012). Result list and document assessment may be affected by short term memory (MacFarlane et al., 2012), navigation challenges (Williams and Hennig, 2015) or be related to problems in connection with second languages, such as speech versus sign language (Saar and Artur-Okor, 2013). The aforementioned characteristics are typically related to different types of impairments. Nevertheless, such characteristics would probably be relevant to include in all types of user studies. Attributes such as attention and short-term memory, for instance, might be affected by fatigue, stress or illness.

The system perspective is also important. First, users with impairments may select search tools based on user interface components such as query building aids or a high tolerance for errors (Berget and Sandnes, 2016). Second, search systems might return inaccessible content, for instance multimedia that is not available for people with impaired vision (Xie et al., 2015) or hearing (Karras and Rintamaki, 2012). Finally, for other cohorts, overall access to information systems might be a challenge, due to overprotection (Chiner et al., 2017a). Finally, there must be room for the application of assistive technology.

The starting point of this paper was that few studies of people with impairments include user models (Berget and MacFarlane, 2020). Moreover, it has been claimed that existing models are not sufficient for describing characteristics specifically connected with the various impairments (Beverley et al., 2007). The purpose of this paper was therefore to explore this issue further. The analyses of the models in terms of the ability to describe user- and system characteristics in addition to the appliance of assistive technologies are summarised in Table 3. The different models in Table 3 are ordered from left to right according to in what degree they fulfil the criteria. It should be noted that there are variations in the abstractness and level of these models. Consequently, they cannot be compared directly and will often probably not be applicable in the same types of studies. The purpose with this study was to explore their potential in describing the information seeking or searching of people with impairments.

Category	Condition	Information seeking framework	Ecological model	SST	"Revised model"	Berrypicking	IS&R
User characteristics	Dyslexia	Yes	Yes	yes	yes	partly	yes
	Autism	Yes	Yes	yes	yes	partly	yes
	Blindness	Yes	Yes	yes	yes	partly	no
	Deafness	Yes	Yes	yes	yes	partly	no
	Paralysation	Yes	Yes	yes	yes	partly	no
	Parkinson's	Yes	Yes	yes	yes	partly	no
System perspective		Yes	Yes	yes	no	yes	yes
Assistive technology		Yes	Yes	partly	yes	yes	yes

Table 3: The models' ability to display general user-and system characteristics and assistive technology

The analyses of each model showed various abilities to describe the online information seeking and searching of people with impairments. Three of the models had been applied in prior studies on visual impairments. The revised model by Wilson (1999) had been used by Beverley et al. (2007) in the context of visual impairments. The authors concluded that the model should be explored for other cohorts, as well. Based on the analyses in this study, the model might also be useful for other impairment types. Williamson et al. (2000) applied the Ecological model (Williamson, 1998), while (Sahib et al., 2012) used the Information Seeking Framework (Marchionini and White, 2007) , also on people with visual impairments. Both of these models seemed appliccable to other cohorts.

Starting with the user characteristics, there are four models that accommodate all the six cohorts, namely the Information seeking framework (Marchionini and White, 2007) the Ecological model (Williamson, 1998), SST (Pharo, 2002) and Revised model (Wilson, 1997). Berrypicking (Bates, 1989) covers all impairments partly, while IS&R (Ingwersen and Järvelin, 2005) seems useful on studies on cognitive impairments only, such as dyslexia and autism. Regarding the system perspective, all the models except for the Revised model (Wilson, 1997) and is applicable. In context of assistive technology, the SST model (Pharo, 2002) covers that only partly.

The only models that seems to fulfil all the criteria are the Information seeking framework (Marchionini and White, 2007) and the Ecological model (Williamson, 1998). They include all the necessary components and consequently allows the researcher to describe a wide range of characteristics, both related to the user and the system. The second best model would be SST (Pharo, 2002). There is a limitation in the model's ability to fully cover assistive technology. Except for that, the models seems highly applicable in studies on users with impairments. The model was developed to be extended with additional factors that characterises its main components, thus the searcher can be extended with additional factors that represent different types of impairment characteristics. In the Revised model (Wilson, 1997), it might be possible to incorporate assistive technology by adding an extra element to the intervening variables component which would match appropriate technologies for each.

The Berrypicking model (Bates, 1989) relies on directly observable behaviours, and cannot take into account the specific aspects of impairments to identify appropriate assistive technologies. The main weakness of the integrated information seeking and retrieval (IS&R) framework (Ingwersen and Järvelin, 2005) is its explicit emphasis of cognitive features of users. For this reason, it is difficult to take into account how sensory and motor impairments characterise users' information seeking and searching.

As discussed above, one of the models, SST (Pharo, 2002), require only minor alterations to sufficiently describe the information searching of people with impairments. In this case, the modified

version is so similar to the original, that it does not really represent a new model. For others, however, the alterations would be more comprehensive e.g. Berrypicking (Bates, 1989) and IS&R (Ingwersen and Järvelin, 2005). A huge number of models exist, and the purpose of this study is not to develop new models. An alternative in these cases is to apply a combination of models, selecting models that may complement each other. For instance, while the Revised model (Wilson, 1997) is good on the user side, the Berrypicking model (Bates, 1989) is better on the system side. The could be combined by using the Revised model (Wilson, 1997) intervening variables to model specific impairments and identify appropriate assistive technologies, and use the Berrypicking model (Bates, 1989) to model observable behaviours.

The research question for this study was how existing models can be used to describe the online information seeking and searching behaviour of users with impairments. Some of the models analysed, however, were published before the Web was introduced. Nevertheless, that does not seem to be a limitation in the application on online searching, keeping in mind that bibliographic databases were available pre-web. Moreover, some of these models are quite general, and should therefore be robust enough to deal with technological changes. For instance, when the Berrypicking model was introduced in 1989, Bates pointed out that with the new, emerging technology, it was possible to design systems that accommodated the ways people actually searched (Bates, 2005b).

Conclusion

This study applied a wide variety of user studies of people with impairments as a starting point. The research question addressed the lack of models in such studies, and questioned whether existing models have the potential to be useful in studies involving various impairment types. The main purpose was not to directly compare all the models up against each other, but rather explore whether different types of models may be useful in context of impairments. Overall, three models seem to be particularly useful in this context, namely the Information seeking framework (Marchionini and White, 2007) the Ecological model (Williamson, 1998) and SST (Pharo, 2002). The remaining three models require more comprehensive revisions. There is, however, a potential for combining models, for instance the Berrypicking model (Bates, 1989) and the Revised model (Wilson, 1997).

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