Designing Search User Interfaces for Visually Impaired Searchers: A User-centred Approach

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Thesis submitted for the degree of Doctor of Philosophy

at Queen Mary, University of London

October 2013

Declaration of originality

I hereby declare that this thesis, and the research to which it refers, are the product of my own work, and that any ideas or quotations from the work of other people, published or otherwise, are fully acknowledged in accordance with the standard referencing practices of the discipline.

The material contained in this thesis has not been submitted, either in whole or in part, for a degree or diploma or other qualification at the University of London or any other University.

Nuzhah Gooda Sahib

17 October 2013

Acknowledgements

Alhamdulillah for this thesis for it has led to amazing things and great people.

I have waited a long time to write this part of the thesis and I hope I do justice to everyone who is mentioned. Firstly, I thank my supervisors Anastasios Tombros and Tony Stockman for their advice, encouragement and support throughout my PhD. Tassos, who has known me since I was a first year undergraduate, always knew when something was not going quite right and Tony has always had time for discussions and for giving me feedback on my work.

The residents of CS 437 (Miguel, Marco, Sirvan and Yihan) have been great in providing interesting conversations ranging from politics to cakes and Hany Azzam, who is missed for his grumpiness, is fondly remembered for his help and advice. My friend, Samia, has been encouraging throughout this journey, providing many opportunities for lunch and hushed conversations in the corridors.

The most important people in my life reside on the other side of the world but without their unwavering support, this PhD would not be the same. I therefore thank my parents, Rassid and Khatijah for teaching my siblings and I all the right things in life. They have been inspiring and incredible role models. I am grateful that my sister, Najla, did not listened to me and embarked on a very successful PhD journey of her own. She has always been there to protect me from the world. My brothers, Irfaan and Isfaaq are probably my greatest fans and are continuously very proud of me. Last but not least, I thank my best friend, Nadeem, for always believing in me and for being a reliable companion on this PhD journey.

Thank you to everyone who has taken part in my studies.

Without you, this thesis would not have been the same.

Abstract

The Web has been a blessing for visually impaired users as with the help of assistive technologies such as screen readers, they can access previously inaccessible information independently. However, for screen reader users, web-based information seeking can still be challenging as web pages are mainly designed for visual interaction. This affects visually impaired users' perception of the Web as an information space as well as their experience of search interfaces. The aim of this thesis is therefore to consider visually impaired users' information seeking behaviour, abilities and interactions via screen readers in the design of a search interface to support complex information seeking.

We first conduct a review of how visually impaired users navigate the Web using screen readers. We highlight the strategies employed, the challenges encountered and the solutions to enhance web navigation through screen readers. We then investigate the information seeking behaviour of visually impaired users on the Web through an observational study and we compare this behaviour to that of sighted users to examine the impact of screen reader interaction on the information seeking process.

To engage visually impaired users in the design process, we propose and evaluate a novel participatory approach based on a narrative scenario and a dialogue-led interaction to verify user requirements and to brainstorm design ideas. The development of the search interface is informed by the requirements gathered from the observational study and is supported through the inclusion of visually impaired users in the design process. We implement and evaluate the proposed search interface with novel features to support visually impaired users for complex information seeking.

This thesis shows that considerations for information seeking behaviour and users' abilities and mode of interaction contribute significantly to the design of search user interfaces to ensure that interface components are accessible as well as usable.

List of Publications

Gooda Sahib, N., Tombros, A., and Stockman, T. (201X). Evaluating a search interface for visually impaired users. Journal of the American Society for Information Science and Technology. *Accepted for Publication*.

Gooda Sahib, N., Tombros, A., and Stockman, T. (2013). Investigating the behaviour of visually impaired users for multi-session tasks. *Journal of the American Society for Information Science and Technology*. In Press.

Goosa Sahib, N., Stockman, T., Tombros, A., and Metatla, O. (2013). Participatory design with blind users: A scenario-based approach. In *Human-Computer Interaction INTERACT 2013*, Lecture Notes in Computer Science, pages 685–701. Springer Berlin Heidelberg.

Gooda Sahib, N., Al Thani, D., Tombros, A., and Stockman, T. (2012a). Accessible information seeking. In *Proceedings of Digital Futures*, Aberdeen, Scotland.

Gooda Sahib, N., Tombros, A., and Stockman, T. (2012b). A comparative analysis of the information seeking behaviour of visually impaired and sighted searchers. *Journal of the American Society for Information Science and Technology*, 63(2):377–391.

Gooda Sahib, N. (2011). Investigating the information seeking behaviour of blind searchers on the web. In *Proceedings of the BCS Conference on Human-Computer Interaction (Doctoral Consortium)*, pages 558–560, United Kingdom. British Computer Society.

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Chapter 1

Introduction

1.1 Introduction

Online search has become one of the most popular activities that people carry out on the Web. By democratising access to a wealth of information, the Web has benefitted many people and has been a particular blessing for people with disabilities such as visually impaired individuals. Prior to the Web, visually impaired people had access to a limited amount of written resources as they had to wait for information to be converted in a format (Braille or audio) that was accessible to them and any information that was available in a computerised form, was hard to distribute.

Nowadays, with the Web and assistive technologies, visually impaired users can have instant access to information, for example, a newspaper, as soon as it is published without having to wait for a transcription (Pernice and Nielsen, 2001). Therefore, the Web has had a "liberating" effect among the visually impaired population (Pernice and Nielsen, 2001) as it has widened independent access and helped to combat social exclusion (Craven, 2004).

However, despite being originally conceived for a text-based interface, web pages have now become the embodiment of graphical user interfaces (Di Blas et al., 2004) and thus, when accessed via assistive technologies such as speech-based screen readers, the Web is perceived in a significantly different way. While the contents of a web page being accessed visually and through the auditory sense remain the same, from the point of view of user experience, the interaction is not equivalent (Shinohara and Tenenberg, 2009). As a result, web pages and applications are perceived differently by sighted and visually impaired users (Stockman and Metatla, 2008) and this is likely to have an impact on the way visually impaired users navigate and search the Web.

In fact, searching is a mentally intensive task (Hearst, 2009, p. 1) and can become more challenging when the search task is complex. Contrary to a simple search task (for example, finding the capital city of a country), a complex search task requires a high level of engagement from searchers (Fowkes and Beaulieu, 2000; Shiri and Revie, 2003, 2006) as it may require several search sessions to complete or the searcher may not fully understand the requirements of the task due to limited knowledge of the search domain. Examples of complex searches include: planning travel to a previously unvisited country (the searcher needs to find out how to travel there, when is the best time to travel, where to stay and things to do etc. which would require several decision-making stages) or gathering information on a medical condition (the searchers may be unaware of the causes, the symptoms and possible treatments etc. of the disease). For visually impaired users accessing search interfaces through assistive technologies, performing complex search tasks on the Web can therefore be particularly challenging as they have to divide their cognitive energy between the search task, the search interface, the web browser and the screen reader (Theofanos and Redish, 2003).

Therefore, in this thesis, our focus is on designing search interfaces to support visually impaired searchers for complex information seeking. We employ different user-centred techniques to ensure that the target users are correctly represented through out the design process, from requirements gathering to prototype evaluation. As web navigation through screen readers affect the way visually impaired users perceive the Web as an information space, we first seek to understand the information seeking behaviour of visually impaired users. Knowledge of the information seeking behaviour of visually impaired users can inform the design of search interfaces that provide effective support to visually impaired searchers during their information seeking activities on the Web. However, to truly make the user the centre of the design process, we also propose a novel technique based around scenarios and a dialogue-led interaction to engage visually impaired users in the early stages of design in order to verify user requirements, to critique proposed plans for design and to brainstorm design ideas. Lastly, we implement and evaluate a search interface with novel features to support visually impaired users for complex information seeking activities and hence, we provide further insights into the behaviour of visually impaired searchers for complex search tasks on the Web.

The term *visually impaired* is usually employed to denote both individuals who are partially sighted and those who have no vision. In this thesis, our focus is on users who have very little or no vision and who rely on speech-based screen readers to interact with a computer and to access the Web. Thus, in the rest of this thesis, unless otherwise mentioned, visually impaired users refer to screen reader users who have very limited or no vision.

1.2 Motivation

There are several works (Leporini et al., 2004; Andronico et al., 2006b) outlining the accessibility challenges faced by visually impaired users when using search interfaces. Leporini et al. (2004) proposed a set of guidelines for designing accessible search interfaces and Buzzi et al. (2004) reported how visually impaired searchers perceive and use search engines and the difficulties they encounter. Additionally, Andronico et al. (2006b) adapted the Google interface to improve accessibility. These previous works, among others, thus address visually impaired users' interactions with search interfaces in terms of browsing and navigation. While this perspective is essential, it is also important to consider how visually impaired users interact with search interfaces on a higher and broader level in a similar way as it has been done for sighted users. In fact, much previous research (Bates, 1989; Kuhlthau, 1991) has focussed on capturing the information seeking behaviour of sighted users to inform the design of search interfaces. For example, previous works (Belkin, 2000; Jansen et al., 2000) revealed the difficulties encountered in translating an internally represented information need into a keyword-based query. As a result, search interface designers have included dynamic query suggestions, which are suggested queries which dynamically appear in a drop down list as searchers type their queries, to assist searchers during query formulation and this support feature has rapidly spread on interfaces on the Web (Hearst, 2009, p. 105). Therefore, the design of this component of the search interface was informed both by an understanding of the information seeking process from the users' perspective (the broader higher level task) as well as an understanding of how sighted users visually interact with search interfaces (the more detailed low level aspect of interaction).

In a similar way, for visually impaired users, there is a wealth of previous works on the low level interaction with search interfaces in terms of the strategies used for navigation, the difficulties encountered and the solutions proposed to enhance browsing. This level of detail is essential to be able to support higher level tasks, but in order to effectively support visually impaired users, it is also important to understand the broader and higher level tasks. Therefore, in this thesis, our focus is on the broader and higher level task of information seeking and we particularly focus on complex searches as they are challenging and cognitively intensive (Campbell, 1988). We investigate how to design search interfaces for visually impaired users taking into consideration not only issues of technical accessibility, but also the context in which visually impaired searchers use such interfaces. Our aim is therefore to examine visually impaired users' interactions with search interfaces from an information seeking perspective, to complement the wealth of knowledge that already exists as far as the low level interactions concerning browsing and navigation. In the following section, we describe the different components of work carried out in this thesis and outline the contributions that each make to research.

1.3 Research Contributions

The work presented in this thesis covers aspects of various research areas including information science, participatory design, accessibility and search interface design. In fact, to design a search interface for visually impaired users through a user-centred approach, we had to address several questions such as the information seeking behaviour of visually impaired users, the most accessible techniques for engaging visually impaired users in the design process as well as the types of interface components that are accessible and usable for users of speech-based screen readers. Therefore, in this section, we outline the different components of the work reported in this thesis and we also describe the contributions that each component makes to research in the above-mentioned disciplines.

- We conduct an in-depth review of how visually impaired users navigate the Web using speech-based screen readers. We outline the strategies employed by visually impaired users for navigating and browsing web pages and we discuss the difficulties encountered while doing so. In addition, we examine the different solutions that have been proposed by previous research to enhance web navigation for screen reader users. We also discuss specific instances where making part of a system accessible only from a technical perspective can prove to be of limited value to screen reader users. Therefore, we advocate for usable accessibility and propose that a wider consideration of the context of use needs to be taken into account when designing accessible interfaces.

  Contribution: This review contributes to work on accessibility as it gathers, collates and discusses published work from different forums to provide a comprehensive overview of how visually impaired users access the Web through speech-based screen readers. It also highlights the gap that currently exists between usability and accessibility.

- We carry out an exploratory observational study to investigate the information seeking behaviour of visually impaired users on the Web. We focus on complex search tasks and compare the information seeking behaviour of 15 visually impaired and 15 sighted searchers to examine how screen reader interaction impacts on information seeking behaviour.
  Contribution: This exploratory study addresses the gap in information seeking literature regarding the information seeking behaviour of visually impaired users as to the best of our knowledge, there have been no previous investigations of the behaviour of visually impaired users when searching the Web. The comparison between visually impaired and sighted users also provides insights into the impact that interaction via screen readers has on the stages of the information seeking process.

- Many existing user-centred methodologies to involve potential users in the design process contain barriers to participation for visually impaired users. Therefore, we propose in this thesis, an accessible approach to engage visually impaired users in the early stages of design. Our approach is based on the use of a narrative scenario as a basis for a dialogue between the designers and the users in order to verify user requirements for a search interface, to identify limitations with proposed design plans and to brainstorm new ideas for design. We describe how the scenario-based approach was developed and its evaluation with 4 visually impaired users. We also reflect on the use of narrative scenarios for participatory design with visually impaired users and we outline the benefits, challenges and practical experiences of implementing and evaluating such an approach.
  Contribution: This scenario-based approach contributes to research on participatory design as it proposes a novel way through which visually impaired users can successfully be engaged in the design process. The proposed approach also has implications for inclusive user-centred design as it highlights the need for involving users with different abilities in the design process especially when the designers interact with interfaces using different senses than the target user population.

- After gathering and verifying user requirements with potential users, we design and implement a search interface to support complex information seeking. The interface components are motivated by the user engagement sessions we carried out using the scenario-based approach and we ensure

that all interface features are not only accessible, but also usable for interaction with speech-based screen readers. We focus on supporting complex search tasks especially to assist visually impaired users in keeping track of encountered information throughout the search process.
Contribution: The proposed search interface includes novel features to support visually impaired users for complex information seeking activities and highlights the importance of usable accessibility for a positive user experience.

- We evaluate the proposed search interface with 12 visually impaired users to study whether the interface components support them in their complex information seeking tasks. We also investigate whether the difficulties observed in the exploratory observational study have been effectively addressed to improve the user experience of visually impaired users.
  Contribution: This user evaluation shows the impact of the novel features on the information seeking behaviour of visually impaired users especially when managing encountered information during the search process. It also illustrates the difference that user-centred approaches can make on users' experience of an interface following the re-design of interface components to ensure usable accessibility.

- In order to simulate a multi-session search task, the search interface evaluation process was structured so that each participant took part in two evaluations sessions separated by several days. Therefore, we were able to provide insights into the behaviour of visually impaired users for multi-session search tasks and we were able to observe how the proposed interface features supported users in managing their search across different sessions.
  Contribution: This component of the thesis contributes to information seeking research as it enhances the understanding of the information seeking behaviour of visually impaired users for complex search tasks. This enhanced understanding of the behaviour of visually impaired users has implications for search interface design in order to ensure that appropriate features can be designed to effectively support visually impaired users when completing complex search tasks.

1.4 Thesis Outline

In this section, we outline the structure of this thesis and describe the contents of each chapter.

Chapter 1: Introduction.

This chapter introduces the work we present in this thesis and outlines the contributions that the different components of this thesis make to research in several disciplines including information seeking, participatory design, accessibility and search interface design.

Chapter 2: Background Material.

In this chapter, we provide background information on the different components of this thesis namely, information seeking, participatory design and the design of accessible interfaces.

Chapter 3: Navigating the Web using a Screen Reader.

This chapter provides a comprehensive overview of web navigation via speech-based screen readers. We describe the strategies employed by visually impaired users, the difficulties encountered and the solutions proposed to enhance web navigation for screen reader users.

Chapter 4: Methodology

In this chapter, we outline the methodology used to conduct user-based studies throughout this thesis. Therefore, we describe the design of the user studies, the instruments used in terms of search tasks and search systems, the recruitment of participants and the data that was gathered and analysed. We also discuss the ethical considerations for the user studies.

Chapter 5: The Information Seeking Behaviour of Visually Impaired Users.

This chapter presents an exploratory observational user study that investigates the information seeking behaviour of 15 visually impaired users. We study the behaviour of visually impaired users at different stages of the information seeking process and we also conduct a comparative analysis with the information seeking behaviour of 15 sighted searchers.

Chapter 6: Using Scenarios to Engage Visually Impaired Users in Design

This chapter describes a scenario-based approach that we propose in this thesis to engage visually impaired users in early stages of the design process. The type of feedback gathered from potential users in a small scale user study are presented and the benefits, challenges and practical experiences of the approach are outlined.

Chapter 7: Search Interface Design

In this chapter, we describe the implementation of the search user interface that we designed to support visually impaired users during complex information seeking. We outline the design rationale for the proposed search interface and we describe each interface component discussing the reasons for their inclusion on the interface in light of the observations made from the exploratory study in Chapter 5 and the user engagement sessions in Chapter 6.

Chapter 8: Search Interface Evaluation.

In this chapter, we describe the evaluation of the proposed search interface, focussing on how visually impaired users interact with the interface features. We also discuss the impact that the search interface had on the information seeking behaviour of visually impaired users.

Chapter 9: The Behaviour of Visually Impaired Users for Multi-session Tasks

We examine the behaviour of visually impaired users for multi-session search tasks in this chapter. We provide insights into the strategies employed by visually impaired users to resume search tasks and manage encountered information across different search sessions.

Chapter 10: Discussions and Conclusions

In this chapter, we provide an overview of the work carried out as part of this thesis and describe the contributions that each component makes to research. We also outline the limitations of this thesis and discuss the avenues for future work that exist in the different disciplines that the work in this thesis spans.

Chapter 2

Background Material

2.1 Introduction

The work presented in this thesis covers aspects from different research areas such as information science, participatory design, accessibility and interface design. Therefore, in this chapter, we present selected background information from these research areas for their relevance to the different components of this thesis. In designing search interfaces, a knowledge of the information seeking process is essential as it allows designers to understand the information seeking behaviour of searchers. In section 2.2, we describe the information seeking process including a discussion on search tasks and search strategies.

In this thesis, we also develop a participatory approach to engage visually impaired users in the design process. Therefore, in section 2.3, we explore participatory design and highlight the different methods that have been used by previous research to include visually impaired users in design. There are many approaches to make interfaces accessible for visually impaired users ranging from compliance with accessibility guidelines to the use of audio to convey information. In section 2.4, we discuss how accessibility guidelines and auditory interfaces have contributed to the design of interfaces for visually impaired users. Overall, this thesis aims to make search interfaces more accessible to visually impaired users by employing a user-centred approach towards design with considerations for the information seeking behaviour of visually impaired users and for the usable accessibility of interface components. Nevertheless, previous works discussed in section 2.5, which have addressed the accessibility of search interfaces for visually impaired searchers have some relevance to the work presented in this thesis.

2.2 Information Seeking

Information seeking is defined as "*a process in which humans purposefully engage in order to change their state of knowledge*" (Marchionini, 1997, p. 5) and "*a fundamental and high level cognitive process often part of learning or problem solving*" (Marchionini, 1997, p. 6). During the information seeking process, which is usually a human activity that is part of a larger life activity, people carry out a set of activities in a progressive and iterative way (Marchionini and White, 2007). The information seeking process can be very diverse, however, previous information seeking frameworks (Bates, 1989; Ellis, 1989; Kuhlthau, 1991) have shown that the sub-activities of the process are very similar. In this section, we describe search tasks and search strategies as they impact the behaviour of users during information seeking and we also outline the stages of the information seeking process.

2.2.1 Search Tasks

Search tasks are fundamental to the search process as they define the searcher's information need. (Marchionini, 1997, p. 36) argued that the search task is what drives information seeking actions as it is a manifestation of the searcher's problems. This conceptualisation of the information need into a search task can represent numerous things, for example, the searcher's knowledge of the search domain or how the searcher's information need is evolving etc.

Previous research (Broder, 2002; Kellar et al., 2006) have found that people perform a diverse set of tasks on the Web ranging from simple fact-finding tasks (finding the capital city of a country) to more complex information gathering and browsing (planning a trip abroad or finding medical advice). In this thesis, our focus is on complex tasks such as multi-session search tasks as they affect the performance of all types of users (Bell and Ruthven, 2004) because they are challenging and cognitively intensive tasks.

Complex Search Tasks

The definition of task complexity has varied in previous research: Campbell (1988) argued that task complexity results from the task's objective attributes and places high cognitive demands on the user, whereas Byström and Järvelin (1995) defined a complex task from a subjective perspective. They showed that the user's understanding of the complexity of a task is impacted by how certain the user is about the task. However, researchers agree that the complexity of search tasks significantly affects the search process. Fowkes and Beaulieu (2000) found that complex topics required a higher level of engagement from users and Shiri and Revie (2003, 2006) observed that the number of physical and cognitive moves performed by users were high for complex tasks.

There are numerous factors contributing to task complexity such as a lack of structure in the task definition which results in the user having an ill-defined mental model of the search task. This model can become more incomplete if the searcher lacks domain knowledge (Marchionini, 1989). Furthermore, when faced with complex tasks, users may not be able to establish a goal hierarchy, that is, they may not be able to identify which goals need to be accomplished to reach a solution (Paas and Van Merriënboer, 1994). Thus, intrinsic task characteristics such as uncertainty and vagueness can further impact on the cognitive load associated with the search task (Sweller et al., 1998). Complex tasks may also require searchers to perform multiple searches to gather information from different sources. Searchers then have to analyse and compare the information found to make a decision on how to use relevant information. These steps, also part of general problem solving activities, require significant cognitive effort from the searcher. All these factors contribute to task complexity and in turn affect performance and effectiveness (Bell and Ruthven, 2004). In this thesis, we use the above-discussed previous works and describe the following set of criteria to define complex search tasks:

- Lack of structure in search task definition.
- Include task characteristics such as uncertainty and vagueness.
- Lack of prior knowledge on search domain.
- Require several search iterations.
- Information from multiple sources has to be aggregated.
- Involve a decision-making stage after relevant information has been compared and analysed

Multi-session Search Tasks

There are different types of information needs, some result in a quick search while others are longer-term, requiring successive searches over a period of time (Spink et al., 1998). Shneiderman [cited by (Hearst, 2009, p. 82)] described the differences as a "1-minute" search and "1-week to 1-month" search. A multi-session search task is not usually a routine task, it is one which requires more than one web session to complete and has a specific goal and a defined point when it is completed (MacKay and Watters, 2008a). For example, planning a vacation can be a multi-session search task. The user is likely to search for different aspects of the trip (flights, hotels and things to do) and there is a goal (go on vacation) and a defined completion date (when the trip is over or the idea abandoned).

Multi-session tasks are complex and often include multiple sub-tasks which may be dependent upon one another or they can be carried out in parallel (Liu and Belkin, 2010). However, apart from the nature of the task itself, multi-session search tasks can also occur as a result of external interruptions which means that a search task cannot be completed in one sitting (Morris et al., 2008). Therefore, multi-session tasks can be expected or unexpected, that is, from the outset, users know the task will require multiple sessions or they find out while they are completing the task that it will span multiple sessions maybe due to unanticipated task complexity or interruptions (MacKay and Watters, 2012). This type of task is challenging as users have to be supported in resuming the task after the interruption. Searchers have to be able to re-access previously encountered information and they also have to re-acquire the context of their searches to successfully progress with the task (Rose and Raju, 2007). Therefore, for multi-session tasks which are complex and often cause large memory and cognitive demands, there is a need for additional support for searchers. Several tools can assist searchers during multi-session search tasks, for example, note taking can bridge the gap between sessions (Aula and Russell, 2008) and history mechanisms can help users to re-acquire the context of their task (Rose and Raju, 2007; Morris et al., 2008).

2.2.2 Search Strategies

When faced with information seeking tasks, searchers employ certain search tactics and strategies to complete the task. Bates (1979) defined a search tactic as a move made to further a search and identified 29 such moves grouped in four categories, namely, *monitoring*, *file structure*, *search formulation* and *term tactics*. Fidel (1985) complemented the concepts of tactics and strategies by describing "moves" that users make during their search activities to identify two types of searchers, namely, operationalists and conceptualists. Operationalists aim at precise retrieval but they only modify the formulation of their search problem to change the retrieved set but not the concept that it represents. Conceptualists are primarily concerned about recall, but throughout the search process, they broaden or narrow down their problem formulations to reflect different concepts. The operationalist and the conceptualist model (Fidel, 1984) has also been observed in (Oldroyd and Citroen, 1977).

The concept of a search strategy was reported by (Markey and Atherton, 1978) and was also described in (Bates, 1979) as a plan for the whole search. For example, one search strategy could be that the user initially wants to navigate to the relevant part of the information space by issuing a broad query and then after viewing results, they reformulate their queries to specifically find what they are looking for. This is a common strategy for complex tasks such as exploratory search because of the uncertainty faced by users in the initial stages of the search process.

Search strategies have been widely studied in the literature, but not always in the context of online searching. Many studies that deal with search strategies were carried out at a time when online searching was not a daily activity but was a service that had to be paid for. Fenichel (1979) and many others have expressed their concerns about the effect that the cost of searching had on the search strategy of searchers, especially for experienced searchers. Therefore, studies of search tactics and strategies have to take into consideration the current context surrounding the searching activity. Technology also affects how people search, especially on the Web, as the amount of information available and the number of devices used to access the Web are increasing. In this section, we discuss two search strategies namely the orienteering strategy (O'Day and Jeffries, 1993) and the teleporting strategy (Teevan et al., 2004) for their relevance to the work presented in Chapter 5 of this thesis.

Orienteering Strategy

O'Day and Jeffries (1993) described orienteering as a search strategy in which searchers use the information they encounter at their current stage to determine how to proceed with the search process. Orienteering behaviour has been reported in many previous studies (Bates, 1979; Hertzum and Frøkjær, 1996; Teevan et al., 2004) where searchers have been observed to adopt an incremental strategy of starting with short queries, inspecting the results and then modifying the queries to reflect their new state of knowledge. Therefore, orienteering as a search behaviour can be likened to the well-established technique of "breaking a big problem into smaller, more manageable problems" which is very productive for general problem solving. In the search context, an orienteering behaviour involve searchers breaking their complex information need into simple short queries and using them as steps to dynamically move closer to satisfying their information need. There has been speculation by (Teevan et al., 2004) that orienteering as a search strategy is cognitively less taxing (Hearst, 2009, p. 80). Orienteering as a search strategy has not been investigated in light of the most recent developments in search technology, for example, fast retrieval algorithms. However, it is likely that faster algorithms would enhance an orienteering approach towards searching as searchers are able to obtain search results more rapidly for their queries and thus can engage in a more dynamic search behaviour.

Teleporting Strategy

Teleporting is a goal-oriented search strategy where searchers try to directly jump to their information target (Teevan et al., 2004). In the context of information seeking, teleporting occurs when searchers attempt to solve their information problem by using one long, complex and overly specific query to represent their complete information need. As a result, searchers tend to submit queries more often to locate information on the Web (Alhenshiri et al., 2013) and believe in the 'perfect' query which the search system would use to retrieve the 'perfect' set of results. However, current search engines do not support effective teleporting (Teevan et al., 2004). For example, when searchers submit overly specific queries, many keyword search engines fail to retrieve relevant information matching the exact query and in those cases, searchers often have to resort to adopt an orienteering approach using shorter and broader queries to reach the information of interest or by following links on webpages to find and gather information (Alhenshiri et al., 2013).

2.2.3 Stages of the Information Seeking Process

There have been several models and theories capturing the information seeking process, but most identify similar stages such as query formulation, results exploration and query reformulation etc. In this section, we discuss the stages of the information seeking process and use the work of (Marchionini and White, 2007) to structure the discussion. Marchionini and White (2007) did not propose a new information seeking theory, instead they defined the information seeking process and organised the process as consisting of different sub-activities as shown in Figure 2.1 to discuss existing support for each stage.

Marchionini and White (2007) also identified some stages of the information seeking process that take place outside the search system. These involved **recognising** the problem, **accepting** it as well as being able to **formulate** it. The stage of problem formulation can be challenging as users often struggle to convey their information needs in the same context as they arise. Nevertheless, this stage of the information seeking process is important as it often determines the effectiveness and performance of the search. There have been numerous attempts to leverage contextual information from users through user

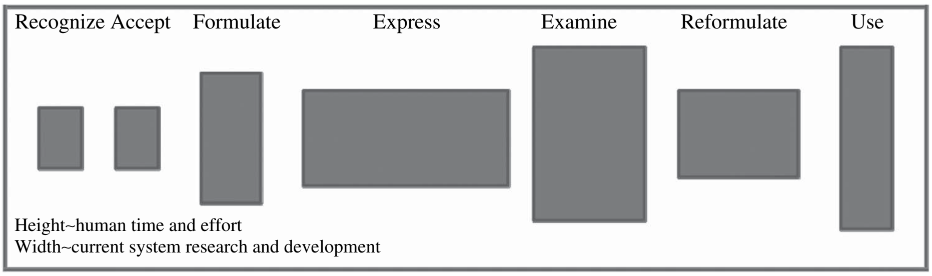

Figure 2.1: The information seeking framework defined by (Marchionini and White, 2007).

interfaces either by looking at their search history (Shen et al., 2005) or by explicitly asking searchers for contextual information (Kelly et al., 2005).

Once the user has formulated their information need in their minds, they have to **express** their understanding of the problem to the search system, mostly in the form of a query. This stage of the information seeking process poses a number of challenges as queries expressed by the user can be ambiguous for the system or can differ in vocabulary from that of the system's (Furnas et al., 1987). Therefore, the system returns results which might not satisfy the information need and the user only finds out about this during the results exploration stage.

Searchers spend most of their time **examining** results returned by the system (Marchionini and White, 2007). A common strategy is to quickly scan the list of results before deciding which results to follow. There has been much work in literature that has addressed this part of the information seeking process, focussing on how to present search results to users. While the most common way of displaying results is in a relevance-ordered list, others have proposed content-rich interfaces (White et al., 2003), clustering (Zamir and Etzioni, 1999) (results are grouped depending on their content), overviews and previews (Greene et al., 2000) among others as alternative ways of presenting retrieved search results.

The next stage of the information seeking process, according to (Marchionini and White, 2007) is the problem **reformulation** stage. This is when the searcher uses the set of retrieved documents to decide how well the expressed query has performed. If the user is not satisfied with the results retrieved by the system to match their internal information need, they can choose to modify the query by adding or removing terms or they can replace the query to better represent their information need. Marchionini

(1997) argued that the process of deciding when and how to iterate is fundamental to the information seeking process as it requires the user to understand how the information retrieved is useful for the overall task. Given the importance of this process, techniques such as relevance feedback (Salton and Buckley, 1990), query expansion (Efthimiadis, 1996), search history (Komlodi et al., 2007) and search assistants (Anick and Kantamneni, 2008) have been incorporated into many search systems to support searchers during the query reformulation stage.

The information seeking process often ends when searchers are satisfied with the information retrieved and **use** it to complete their tasks. Marchionini and White (2007) argued that the decision to stop searching is often satisfactory rather than optimal, that is, searchers think they have "good enough" results that satisfy their information needs. Therefore, the information need is fundamental and drives the information seeking process to a great extent.

2.2.4 Models of Information Seeking

An individual initiates the process of information seeking usually due to a trigger, for example, lack of prior knowledge in an area of interest. Over the years, a number of research endeavours [see (Wilson, 1999) for a review] have tried to capture the information seeking behaviour of searchers to develop models that correctly represent how individuals seek information. In this section, we describe three models of information seeking for their pertinence to the work presented in this thesis namely, the berry-picking approach (Bates, 1989), the information foraging theory (Pirolli and Card, 1995) and the six-stage model of the information search process by Kuhlthau (1991) which incorporates the affective and cognitive differences displayed by searchers.

Berry-picking Model

Bates (1989) described information seeking as analogous to picking berries in the woods, where one does not expect to find all the berries in one spot. Similarly, searchers do not expect to find one result set that satisfies their information needs completely, but they expect to pick bits of information during their search interaction to match their dynamic information needs. It is proposed that as searchers encounter information in the initial stages of the information seeking process, their information needs evolve and as a result, they change their queries and priorities as some sub-tasks become more important than others.

Information Foraging Theory

Inspired by the optimal foraging theory which was developed to explain animal foraging behaviour in finding food, Pirolli and Card (1995) described searchers as 'informavores' who move around the information space deciding what kind of information they want and which site or path to follow to acquire that information. The theory assumes that humans are able to use their transferable food-finding instincts when finding information (Pirolli, 2007). It is proposed that searchers continuously weigh the costs and benefits of a piece of information before deciding whether the benefits they will gain from it will outweigh the effort required to explore and make sense of that piece of information. To do this, searchers rely on '*information scents*', that is, cues and hints that help them decide on the content of the material (Chi et al., 2001). Effective information scents can therefore improve information foraging and hence, searchers can be better supported in exploring their information space (Hearst, 2009, p. 77).

Kuhlthau's Information Seeking Process Model

Following numerous field studies, Kuhlthau (1991, 2004) proposed a model for information seeking to capture the information behaviour for complex tasks. The stages that searchers go through both in terms of their knowledge and their attitudes towards the task are considered. Kuhlthau highlighted that at the beginning of the process, searchers may display signs of uncertainty due to a lack of domain knowledge or vagueness of the task. However, as the search task progresses, the uncertainty may be replaced by feelings of confidence as searchers become more focussed in their tasks. The stages of Kuhlthau's model are outlined in the following:

- **Initiation:** recognise the need for information.
- **Selection:** identify the topics related to the information need and decide on the approach to pursue.
- **Exploration:** investigate available information on selected topics to understand the information need.
- **Formulation:** focus on selected topics and resolve conflicting information.
- **Collection:** gather information on the focussed topic.
- **Presentation:** complete the search and use gather information.

2.3 Participatory Design

User engagement in the design process has been the driving force behind user-centred design (UCD) approaches and is essential if the final product is to meet users' needs and expectations. UCD encompasses design approaches that involve target users so that they can influence the design of the final product. In interface design, UCD approaches such as participatory design (Muller, 2007) change the focus of the design work. Instead of emphasising exclusively on functional specifications of the interface, designers using UCD methods ensure that they fully understand how people will use the interface so that their designs support users in their tasks (Carroll, 2000b, p. 51). There are several ways to ensure participatory design, but in section 2.3.1, we focus on scenario-based design as they form an important component of the work we present in Chapter 6 of this thesis.

Additionally, when designers and target users interact with interface using different senses, it is crucial for the designer to make sure that their understanding of the problem is aligned to what the users experience, as in those cases it can be very hard for the designer to correctly imagine the needs of the users and to conceptualise their interactions with the system. Engaging users with disabilities in the design process can be challenging as the designers have to ensure that the method employed for user involvement is appropriate to effectively communicate design ideas to the users to obtain valuable user feedback. For example, when designing for visually impaired users, designers cannot easily use participatory design techniques such as paper prototypes as they contain barriers to participation for the user group.

Similarly, when designing for other non-standard populations such as the elderly or people with low literacy, designers have to be considerate about the methods employed for user involvement in the design process. Therefore, previous works have reported several methods for user engagement in the design process. For example, Vines et al. (2012) used workshops with users who they identified as "extraordinary users" (those aged over 80) in the design of a payment method to augment paper cheques as an electronic means of payment and Lindsay et al. (2012a) discussed how people with dementia have been included in the design process through exploratory meetings, discussions and personally tailored prototypes. While outlining the benefits that these methods contribute to the design process, Vines et al. (2012) and Lindsay et al. (2012a,b) have also highlighted the challenges faced when involving non-standard groups in design and discussed how they can be addressed.

The majority of tools used for early stage prototyping contain barriers to participation for visually impaired users. Therefore, designers have to devise alternative techniques that are accessible so that visually impaired users can contribute to the design of artefacts that are tailored to their needs and abilities. In section 2.3.2, we discuss how previous works have included visually impaired users in design and in Chapter 6, we propose a scenario-based approach to address this challenge.

2.3.1 Scenario-Based Design

Scenario-based approaches have been a particularly successful way of engaging users in the design process as scenarios are easy to understand and help users to envision a yet to-be-constructed product (Carroll, 2000a). Scenarios have also been described as the necessary vocabulary for exchanging design ideas and they have been used for numerous purposes in different disciplines such as requirements engineering, software engineering and human-computer interaction [see (Filippidou, 1998) for a review about designing with scenarios]. In requirements engineering particularly, scenarios have been used for eliciting, envisioning, analysing and evaluating requirements to ensure that artefacts are designed to meet the expectations of different stakeholders (Holbrook, 1990; Carroll and Rosson, 1992; Carroll, 1994).

The use of scenarios in early stages of the design cycle usually involves designers using a description of people (actors) and their activities (goals) to help potential users to envision an interface that will be developed in the future (Carroll, 2000b, p. 46). Scenarios consist of a plot, including a sequence of actions and events which help to emphasise and explore the goals that a user might adopt and pursue. They thus allow users to immerse themselves in the context of the scenario and to imagine how they would interact with the proposed artefact.

Scenarios enable rapid communication among different stakeholders and make scenario-based design approaches iterative and lightweight for envisioning future use possibilities (Rosson and Carroll, 2007). Thus, designers can work through ideas rapidly, obtaining feedback and refining their ideas to make quick progress. In scenario-based design, scenarios focus the design efforts on use, that is, what people will use the interface for and how they will use it (Jarke et al., 1998). This compels designers to maintain a consideration for people and their needs.

Apart from their use in framing the design rationale, scenarios have been used in human-computer interaction for other purposes, namely, for planning and evaluating test tasks and to specify usability goals. Bødker (1999) described three ways of using scenarios in usability work and design namely to generate ideas during field studies, as a starting point in design workshops and for usability testing of prototypes. The author thus demonstrated how scenarios could be used at different times with different purposes. Scenarios also have a natural and inherent ability to support participatory design as they allow users to identify themselves as the actors in the scenario and to reflect on their own ideas and their implications in the context of design. In this way, scenario-based approaches provide a common language for design discussions among users and designers (Jarke et al., 1998).

The *descriptiveness* of scenarios refers to the medium in which the scenario is defined and may include text in natural language, images, graphics and videos etc. In Chapter 6 of this thesis, given our domain, we used textual narratives as they were most suitable for users of screen readers to use to envision our proposed interface and its features. As discussed by (Carroll, 2000b, p. 54), the written narratives of scenarios evoke an image of people pursuing goals by performing activities and therefore, the scenario works well because the human mind is adept at overloading meaning in narrative structures. As a result, the scenarios stimulate the imagination (Jarke et al., 1998) and provoke new ideas (Bødker, 1999) and are thus well suited for use in participatory approaches to engage users early in the design process.

Newell and Gregor (2002) have suggested that for older and disabled users, design methods should be presented using scenarios in the narrative form as a story-telling approach can help to gather information about accessibility issues. In fact, scenarios have been used successfully with other user groups, for example, Marquis-Faulkes et al. (2003) used scenario-based drama to elicit user requirements in the design of a fall detector for elderly people. The authors developed four scenarios which were performed by a theatre group and filmed. These videos were then used to engage elderly people in the design process by provoking discussions about the usage of the system. Also, the use of a scenario-based approach was proposed in (Bhatia et al., 2006) in the design of a location-based feedback notification system for users with mobility impairments. While the authors concluded that the scenario-based development process helped them to manage and understand user requirements, they did not describe how exactly scenarios were used in the implementation of this system. In a further example, in the design of digital technologies for older users, Lindsay et al. (2012b) used video prompts of a scenario about the problem domain for participatory design with users who were in the 65+ age group.

2.3.2 Participatory Design with Visually Impaired Users

Participatory design with visually impaired users can be challenging as designers have to ensure their methods of communicating design ideas with users are appropriate and effective to gather useful feedback. Okamoto (2009) discussed a workshop where scenarios were used between visually impaired and sighted students to discuss products being designed to enhance the day-to-day activities for visually impaired users. However, no details of the implementation of the scenario-based method were given, so it is difficult for readers to understand how scenarios were used in that context.

Workshops have been successfully used with visually impaired users to involve potential users in the design process. Metatla et al. (2011) conducted a workshop to encourage users to discuss and share experiences about using diagrams in the workplace to inform the design of a collaborative cross modal diagramming tool. Eight participants took part in the workshop and the activities ranged from round table discussions to demonstrations of early audio and haptic prototypes for diagramming systems. As a result, Metatla et al. (2011) were able to identify the diversity of diagrams that the group of visually impaired users come across as part of their professional activities as well as the coping strategies they employ to access diagrams in the workplace.

Prototyping is also a common way of brainstorming design ideas with users, but for obvious reasons, visual prototyping techniques are not appropriate for visually impaired users and therefore, alternatives have been proposed namely, haptic paper prototyping (Magnusson and Brewster, 2008) and tactile paper prototyping (Miao et al., 2009). Haptic paper prototypes, often built using cardboard mockups, are used to simulate haptic interactions early in the design process. Tanhua-Piiroinen and Raisamo (2008) have reported on two types of haptic mock-ups used with visually impaired children which consisted of cardboard models (Patomäki et al., 2004) and plastic artefacts with Braille labels (Saarinen et al., 2006). Visually impaired children understood the interface well with cardboard models which were also cheap and easy to modify. However, the plastic Braille-labelled artefacts had to be prepared with special equipment and therefore could not be modified. As for tactile paper prototypes proposed in (Miao et al., 2009), they included Braille and tactile graphics used to verify requirements before implementing graphical user interfaces. In fact, the authors attempted to convey to visually impaired users the spatial layout of user interfaces by mapping graphical user interfaces into tactile displays (Schiewe et al., 2009).

Simple models using cardboard are beneficial to introduce new ideas to a target group in a participatory design setting, as it can take a considerable amount of time before the designers of haptic interfaces have the earliest prototypes to show to potential users (Brewster, 2008), due to the amount of code that needs to be written before the simplest haptic prototypes can be interacted with. Therefore, to address these difficulties, Forrest and Wall (2006) developed a haptic prototyping tool, ProtoHaptic, to allow designers to construct simple haptic scenes using drag and drop techniques in order that basic haptic interfaces can be quickly created to support effective user-centred design.

However, techniques such as haptic and tactile prototypes can be time-consuming to set up and changes are not easy to make in response to feedback. Additionally, both methods proposed in (Miao et al., 2009) and (Tanhua-Piiroinen and Raisamo, 2008) exclude the significant proportion of the blind population who are not Braille readers and are only suitable to prototype haptic interaction as opposed to speech-based screen reader interaction. Also, the cardboard and plastic abstract models such as those used in (Tanhua-Piiroinen and Raisamo, 2008) have a possible drawback of not allowing users to fully conceptualise the application as a whole, since users only interact with individual artefacts at a time. Therefore, there is a clear need for new user-centred design techniques or for existing ones to be adapted so that they can be effectively employed with visually impaired users for user engagement early in the design process.

2.4 Designing Accessible Interfaces for Visually Impaired Users

In many countries, there are legislations in place to ensure that people with disabilities have the same access to goods and services. In the United Kingdom, the Equality Act 2010[1] (replacing the Disability Act 1995) makes provisions to guarantee equal opportunities for people in the workplace and in the wider society and thus, website developers are encouraged to design web pages which are accessible to users with disabilities such as visually impaired users. Hence, there have been several initiatives to make web applications accessible for visually impaired users. While some advocate following established guidelines such as those proposed by the World Wide Web Consortium (W3C)[2], others are more in favour of using the auditory or haptic sense for interaction. In this thesis, we do not discuss haptic interfaces as they are beyond the scope of the work we present. In section 2.4.1, we discuss accessibility guidelines and in section 2.4.2, we describe the use of audio in designing for visually impaired users.

[1] http://www.homeoffice.gov.uk/equalities/equality-act/

[2] http://www.w3.org/

2.4.1 Accessibility Guidelines

Regarding accessibility, the W3C is the major source of information, guidelines and resources. It has established the Web Accessibility Initiative (WAI)[3] which provides a set of guidelines such as the Web Content Accessibility Guidelines (WCAG)[4]. The WCAG 2.0, published in December 2008, include more advanced technologies and seek to facilitate the automated testing and human evaluation of web pages. The WCAG 2.0 consist of 12 guidelines which are grouped under four principles, namely, **perceivable** (information and interface components must be presented to users in a way that they can perceive - it cannot be invisible to all their senses), **operable** (the interface should not require an interaction that the user cannot perform), **understandable** (the content and operation of the interface should be understood by the users) and **robust** (the content should remain accessible as technologies and user agents evolve).

The WAI has also developed the Accessible Rich Internet Applications (ARIA) suite that defines how to make dynamic content and advanced interface controls more accessible to people with disabilities. More specifically, the ARIA suite addresses concerns that arise with AJAX, HTML, Javascript and related technologies and proposes alternative ways in which functionalities developed using Web 2.0 technologies can be made accessible to assistive technology (Web Accessibility Initiative, 2011). Most website designers are aware of these guidelines (Lazar et al., 2004) and can check for compliance through automatic accessibility validation tools such as WAVE[5]. However, there are concerns that designers rely excessively on compliance to these guidelines and therefore do not focus on the real usability of the artefacts they design (Theofanos and Redish, 2003; Takagi et al., 2004). Over reliance on guidelines and the importance of usable accessibility are further discussed in section 3.7 of this thesis.

2.4.2 Auditory Interfaces

Screen readers process the content of web pages sequentially, outputting every component of the web page out loud in computer-synthesised speech. However, the visual experience of a web page and the audio experience differ significantly (Di Blas et al., 2004) and therefore accessibility initiatives to produce auditory interfaces should not focus on completely replicating a visual interface (Edwards, 1989a). Mynatt and Edwards (1992) argued that many features of the graphical user interface do not need to be

[3]http://www.w3.org/WAI/
[4]http://www.w3.org/TR/WCAG/
[5]http://wave.webaim.org/

modelled in an auditory interface and thus proposed to carry out a translation at the level of the interface components to create auditory alternatives. This idea was implemented in the Mercator Project (Mynatt and Edwards, 1992, 1995) which was designed to translate X Windows applications while they are running, into auditory interfaces for blind and visually impaired users.

Visually impaired users rely significantly on speech output through their screen readers to interact with user interfaces. However, other types of sounds can also be used to convey information of varying complexity (Edwards, 1989b). Brewster (2003) argued that speech sounds are slow and can overload short-term memory whereas non-speech sounds which are shorter, can be heard and understood more rapidly once they have been learnt. In fact, non-speech sounds can help to enhance access to non-visual interfaces as they reduce the burden caused by speech information (Brewster, 1997; Mynatt, 1997) and thus improve the usability of auditory interfaces (Brewster, 1997).

In this thesis, our focus is on the use of non-speech sounds to convey additional information to speech-based screen readers and therefore, in this section, we review different types of non-speech sounds that can be used in auditory interfaces. Auditory icons (Gaver, 1986) are informative sounds that have a semantic link to the object they represent, for example, the sound heard when a file is sent to the trash can. Such sounds are easy to learn and to remember (Brewster, 1997) precisely because the sounds relate directly to the artefact they represent in the user interface. In contrast to auditory icons, earcons are abstract and synthetic sounds that inform a user about an object, an operation or an interaction (Blattner et al., 1989). For example, short beep-like sounds which are heard as confirmations of specific actions such as saving a file. Earcons and their meaning must be learnt so that users can map the sound to the correct action. Between the two extremes of speech sounds and abstract earcons are spearcons, which are sounds created by speeding up a spoken phrase so that the resulting sound is short and not recognisable as the original spoken phrase (Walker et al., 2006).

Auditory icons and earcons have been used for a long time, in many types of interfaces for blind and visually impaired users, to convey varying types of information. In the context of web navigation, Donker et al. (2002) used sounds to represent different elements on a web page to address the difficulties faced by screen reader users when interacting with layout features (headings, links, paragraphs etc.) that have a semantic purpose. A 'torch metaphor' was used to illuminate a web page so that users hear the sounds closest to where their focus is on the page and thus, they have an indication of the layout of the web page. Murphy et al. (2010) used auditory cues to enhance the accessibility of mathematical components for visually impaired users so that the ambiguities caused by spoken mathematics can be avoided. A combination of earcons and spearcons were used to represent mathematical material such as brackets, fractions and superscripts. These were evaluated with visually impaired users to gather feedback on the choice of sounds for specific mathematical functions. Encelle et al. (2011) has also used earcons in combination with speech synthesis to enhance the understanding of videos. Earcons were used to convey spatial information to visually impaired users by indicating when there is a change in sets, that is, when the action changes from one place to another. Thus, these previous works have shown how non-speech sounds can complement the use of speech-based screen readers to convey different types of information.

2.5 Search Interfaces for Visually Impaired Users

There are several works (Leporini et al., 2004; Andronico et al., 2006b) outlining the accessibility challenges faced by visually impaired users when using search interfaces. Leporini et al. (2004) proposed a set of guidelines for designing accessible search interfaces which were based on preliminary testing with automatic validation tools and a survey questionnaire (Buzzi et al., 2004). Despite their methods not allowing the researchers to capture real time human interaction with search engines, they helped in gathering data about the use of search interfaces, the difficulties encountered by visually impaired users and their general knowledge of search interfaces. The questionnaire was distributed to 52 users, but only 25% were visually impaired. However, a number of challenges were identified, for example, 46% of visually impaired searchers had difficulties in reading results retrieved by search engines.

Andronico et al. (2006b) adapted the Google interface to improve accessibility while ensuring that the visual appearance of the pages was the same as the original page. The underlying code was restructured to group the most important parts of the interface in order to reposition them on the interface. The authors also added shortcuts to enhance navigation and introduced sounds to alert users about important events. The modified interface was evaluated with 12 visually impaired users and data collected through questionnaires showed that a majority found the interaction with the modified search interface simpler. The search process was also considerably less time consuming with a clearer and easier to use interface.

Yang et al. (2012) also modified the Google interface to design an accessible interface for blind users with improved functionalities. The authors thus designed the Specialised Search Engine for the Blind (SSEB) to improve blind users' efficiency in searching. Additional functions on SSEB include alternatives to visual content, ability to sort search results, bookmarks and the ability to modify the display options for search results (displaying only title and summary of results instead of title, summary, URL, date etc. on Google). SSEB was evaluated with 12 participants with 8 visually impaired users and 4 sighted users wearing eye shades having to perform a task on SSEB and Google. It was reported that the mean search time on SSEB was significantly lower than on Google and that participants reported a higher level of satisfaction with SSEB (Yang and Hwang, 2007; Yang et al., 2012).

2.6 Chapter Summary

In this chapter, we described selected background information from different research areas for their relevance to the work presented in this thesis. Hence, we outlined previous information seeking theories and described the stages of the information seeking process which will be the focus of our investigation in Chapter 5. We also explored participatory design and reviewed previous work that has successfully involved visually impaired users in the design process. We focussed on scenario-based design as it is an important component of the approach we propose in Chapter 6. Finally, we discuss different initiatives to design accessible interfaces for visually impaired users including the use of audio, as it is relevant to the work we carry out in Chapter 7 when designing a search interface to support visually impaired users for complex information seeking. In the following chapter, we conduct an in-depth review of how visually impaired users navigate the Web using screen readers.

Chapter 3

Using Screen Readers to Navigate the Web: An Overview of Strategies, Difficulties and Solutions

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3.1 Introduction

There are millions of people around the world who have a form of visual impairment that prevents them from using traditional computer displays (estimated at 6 million by (Ghaoui et al., 2001)). Therefore, visually impaired users employ various assistive technologies that provide alternative means of input and/or output to suit their particular needs. Assistive technologies break accessibility barriers and allow their users to access information and services that are available to the wider population. Previous research has shown that the majority of visually impaired users who are employed use computers in their work and some of the assistive technologies that they use include: alternative keyboards and pointing devices, speech recognition, eye tracking, Braille displays and screen readers (Paciello, 2000). Despite these multiple alternatives, screen readers are the most popular assistive technology for both blind and partially sighted users (Lazar et al., 2007). Low Braille literacy [estimated at 20% for blind users (Lazar et al., 2007)] has contributed in making speech output popular among visually impaired users (Zhao et al., 2008). In this chapter, we focus on web navigation through speech-based screen readers. We describe the strategies employed by visually impaired users to explore and navigate web pages using screen readers. Additionally, we discuss the difficulties encountered during screen reader navigation and outline the solutions that have been proposed by existing research to address those challenges.

3.2 Motivation

The aim of this chapter is to provide an overview of how visually impaired users access the Web using speech-based screen readers. Previous works addressing this topic are often published in different forums including conferences and journals which can be from the research areas of accessibility, interface design, human-computer interaction etc. Therefore, significant effort is required for any researcher to have an overview of web navigation through screen readers. To the best of our knowledge, there are no published reviews concerning the ways screen reader users access the Web.

A comprehensive review of web accessibility has been conducted in (Harper and Yesilada, 2008), which is a collection of chapters authored by different researchers focussing on different types of impairments, evaluation methodologies and application areas. In comparison, the review we propose in this chapter has a much narrower focus, emphasising on visually impaired users and their interaction with the Web via screen readers. Thus, in this chapter, we gather and collate published research from different forums to provide an in-depth review of how visually impaired users access the Web using speech-based screen readers. Additionally, apart from reviewing existing work, we also discuss the importance of usable accessibility when designing accessible interfaces. We advocate therefore that screen reader accessibility should implicitly mean that interface components are usable and intuitive to access through screen readers to ensure a satisfying Web experience.

Most importantly however, in the context of this thesis, the aim of this review is to understand how visually impaired users understand the Web through screen readers and the mental models that they create for web-based interactions, as this impacts on their information seeking behaviour on the Web and consequently on our studies in this thesis. Hence, the contributions that this chapter makes to this thesis are the following: firstly, it allows us to identify a gap in the literature concerning the information seeking behaviour of visually impaired users and secondly, it contributes to our knowledge and understanding of how the Web is interpreted through speech-based screen readers to inform the design of any search interface that we design for visually impaired users.

The rest of this chapter is structured as follows: in section 3.3, we describe speech-based screen readers and outline the strategies employed by users of screen readers for navigation in section 3.4. We discuss the difficulties posed by screen reader navigation in section 3.5 and we review in section 3.6, previous research aiming to enhance browsing and navigation for visually impaired users. In section 3.7, we discuss how ensuring technical accessibility with screen readers is not sufficient for a positive user experience and thus, we advocate for usable accessibility to be given greater consideration in the design of accessible solutions for users with disabilities. We conclude this chapter by discussing the need for further exploration beyond screen reader accessibility, in order to fully support visually impaired users in the tasks they perform on the Web, for example, web-based searching.

3.3 Speech-based Screen Readers

Screen readers are software packages that allow visually impaired users to interact with computers and other devices such as mobile phones and tablet computers. The screen reader acts as an intermediary between the user and the application by reading what is displayed on the computer screen out loud in computer-synthesised speech. Therefore, the screen reader helps visually impaired users to independently interpret what is present on the interface when otherwise, they would always need support and assistance from others (WebAIM Survey, 2010).

As well as providing the user with the content in a speech format, the screen reader often can also output the content on a Braille display (Andronico et al., 2006a). Braille displays provide access to the information that is on computer screen by electronically raising and lowering different combinations of pins in Braille cells (American Foundation for the Blind, 2012). They are available in different sizes and can display up to 80 characters. As the user moves the cursor on the screen using command keys or screen reader commands, the refreshable Braille display is updated by displaying what is on the computer screen at the new cursor position.

However, given the low Braille literacy among visually impaired users (Lazar et al., 2007) and the relatively high cost of Braille displays, most users prefer the screen reader's output to be in the form of speech. Therefore, over the years, many screen readers have been developed to support visually impaired users to interact with computers and other devices. The commercial screen reader Job Access with Speech (JAWS)[1] has undergone years of development (Lazar et al., 2007) and remains the most popular (64% of users in the most recent WebAIM survey (WebAIM Survey, 2012)). Nevertheless, Non

[1] http://www.freedom-scientific.com

Visual Desktop Access (NVDA)[2], an open source screen reader, is quickly gaining popularity among the visually impaired population (WebAIM Survey, 2012). Other screen readers for the Windows platform include Window-Eyes[3], System Access[4] and ZoomText[5]. For Apple Mac users, the operating system includes a built-in screen reader called VoiceOver[6]. The inclusion of VoiceOver as part of the Apple OS X operating system has stimulated interest among visually impaired users as it avoids the need to purchase an external screen reader as is the case for JAWS and Window-Eyes. In addition, the presence of VoiceOver in Apple mobile platforms such as the iPhone, iPod and iPad means that visually impaired users can use the same screen reader on personal computers and mobile devices.

On mobile devices, VoiceOver allows users to use simple gestures to interact with items on the screen and therefore, compared to other screen readers, it provides users with more contextual information. For example, if the user touches the upper right corner of the screen, VoiceOVer outputs which item is at that location. Thus, users have a true sense of the layout of the screen, rather than just descriptions of the objects present. The VoiceOver mobile platforms also have a feature called a rotor which enhances navigation for visually impaired users. The rotor works like a physical dial and users operate it by flicking up or down. On web pages, the rotor contains a list of common elements such as headers, links, form elements and images etc. Users can select a setting, for example, headers, and then by flicking up or down, navigate to the previous or next occurrence of that item on the page. Given these additional functionalities, VoiceOver is quickly becoming the most popular mobile screen reader (WebAIM Survey, 2012). However, it is likely that systems of this type will become increasingly popular as the technology develops and becomes available on other platforms such as Android.

Despite their popularity and years of development, screen readers are not easy to use as at the beginning, the user has to invest significant efforts to learn about the features and how to use the screen reader practically. A problem that arises with the learning curve of the screen reader is that the time spent in learning how to use the software does not directly contribute to completing the end user task. However, for any end user task to be performed, the user has to first learn at least the basics of how the screen reader functions. But once this is done, the user is often reluctant to invest more time learning about additional functionalities unless these functionalities provide very clear and relevant benefits (Andronico et al.,

[2]http://www.nvda-project.org
[3]http://www.gwmicro.com/Window-Eyes
[4]http://www.satogo.com
[5]http://www.aisquared.com/zoomtext/
[6]http://www.apple.com/accessibility/voiceover/

2006a). Some users are professionally trained and thus can become rapidly skilled to access information with reading rates of up to 300 words or more per minute (WebAIM Survey, 2010).

3.4 Screen Reader Navigation Strategies

When visually impaired users navigate to a web page, the screen reader provides them with a page summary, that is, an overview of the web page including components such as the page title and other page statistics such as number of headers, frames, forms, links and tables etc. The summaries convey the number of different types of objects on the page, but this is of relatively little value to visually impaired users, other than giving an overall impression of the page complexity. This type of summaries omit any information about the ordering of objects, the overall page layout and the density or placement of text which may be helpful in conveying to screen reader users, an overview of what is contained on the page. Therefore, such summaries fall a long way short of providing an overview like the equivalent of what a sighted user will obtain from scanning a web page for a few seconds. As a result, to cope with the linear access imposed by the screen reader software, visually impaired users employ different strategies during web navigation. In this section, we provide an overview of the navigation strategies used by speech-based screen reader users to access the content of web pages.

3.4.1 Skip Links

To follow accessibility guidelines, web designers often add hidden links, also known as *skip-to-main-content links*, to their web pages to allow users to directly navigate to the content of the page in order to avoid repetitive irrelevant information such as banners and links (Borodin et al., 2010). However, skip links are often ignored by users as they are often broken links which are not maintained (Borodin et al., 2010). In the most recent WebAIM survey (WebAIM Survey, 2012) of over 1000 participants, 28% of the participants used skip links sometimes while 14% claimed to never use them. Those who do not use skip links often base their decisions on lack of control, that is, they do not know where the links will take them and they are also anxious about skipping some important content (Borodin et al., 2010).

3.4.2 Heading Navigation

This strategy is the most popular navigation strategy for screen reader users (WebAIM Survey, 2012) who use HTML heading tags (<H1>to <H6>) to browse through the content of a web page (Borodin et al., 2010). For this strategy to work, website developers need to ensure they use HTML headings instead of just using Cascading Style Sheets (CSS) to format elements on the page. Therefore, a well-structured page that uses headings properly helps screen reader users to navigate efficiently and during online search, when faced with web pages that contain a lot of information, visually impaired users can use headings to navigate to the relevant section of the page.

3.4.3 Link Navigation

Navigation by links is similar to heading navigation, but instead of using headings, screen reader users use the links on a page to browse the content. The 'tab' keys are used to jump from one link to another on the page or some screen readers have functionalities to provide their users with a list of links on the page (Yesilada et al., 2007). This strategy can speed up navigation, but it can also be cumbersome and frustrating on pages which have a high number of links. In those cases, sequentially accessing links can lead to users spending large amounts of time hearing about links which are irrelevant to their goal.

3.4.4 Keyword Search

Also known as the '*find feature*', this is a popular and useful strategy to access the main content of web pages, especially when searchers know what they are looking for (Borodin et al., 2010). This strategy is like using the equivalent of the Ctrl+F command to search for keywords or phrases on a web page. However, this strategy can also cause several problems as it only works for exact string match. Therefore, users can feel disoriented in case of no match (Mahmud et al., 2007b) and in case of a match, users might still have to sequentially read through the text immediately before and after the match to understand the context in which the keyword or phrase occurs.

3.4.5 Sequential Navigation

Using this strategy, screen reader users let the software continuously read through the content of the web page or they use the down arrow key to sequentially access all components on the page (Borodin et al., 2010). This strategy is not common among screen reader users with an advanced proficiency (WebAIM Survey, 2012) as it is very inefficient and time-consuming. It is more likely to be used by beginners or when all other navigation strategies have failed.

Screen readers also provide means to navigate sequentially forward and backward by other types of page element, such as by frame, form, checkbox or radio button. Visually impaired users, especially experienced screen reader users, typically employ multiple strategies to explore a web page. Most of the time, they adopt a trial and error approach whereby they will try an alternative strategy in case their current one is not working (Tonn-Eichstädt, 2006). For example, a screen reader user may be trying to navigate through headings but in the absence of headings on the page, they will switch to keyword search or navigation by links. Navigation strategies also vary with users' experience and proficiency (Yesilada et al., 2007) as experienced users with advanced proficiency are more likely to employ strategies to scan the page rather than having the content read to them as is common with novice users.

3.5 Navigation Difficulties with Speech-based Screen Readers

Graphical user interfaces including web pages and web applications have been designed with sighted users in mind. Interface components are strategically placed at specific parts of the screen to draw the attention of the user thereby making screen 'real estate' an important consideration when designing graphical user interfaces. In this section, we focus on the difficulties experienced by screen reader users when accessing applications which have been designed to be visually interacted with. These difficulties arise because the screen reader software is an audio interface which changes the way graphical user interfaces are rendered and understood. For example, the structure and layout of the interface, which would be considered important by those who interact with the interface visually, would become irrelevant when being accessed using a screen reader. This is why visually impaired users' perception of web pages are significantly different from that of sighted users (Stockman and Metatla, 2008). Therefore, web browsing and navigation can be challenging and in this section we identify the difficulties that are encountered when using speech-based screen readers to access the Web. These navigation difficulties have been highlighted in various forms in previous works (Buzzi et al., 2004; Leporini et al., 2004; Leporini and Paterno, 2004, 2008) and thus we categorise and discuss them in the following:

3.5.1 Linear Processing

The screen reader processes a web page linearly from the top left to the bottom right of the page by serialising its content, that is, the screen reader works with the page source with no consideration for positions that might have been assigned by CSS properties (Leporini and Paterno, 2008). This often constrains the users to access the content of pages sequentially which is time consuming, inefficient and fatiguing especially for the less experienced users (Murphy et al., 2007). For example, in the context of information seeking, this means that the screen reader user has to listen to the list of search results linearly before being able to make an informed decision about the search result page to visit. For sighted users, the equivalent process would be to quickly scan the page and make a decision which requires a few seconds. This is why visually impaired participants using search engines have been reported to take twice as long to scan search results and three times as long to explore web pages in (Ivory et al., 2004). Previous work (Takagi et al., 2007) has also shown that during online shopping tasks, blind users can take up to ten times longer. These are the major reasons for which accessibility guidelines recommend the structuring of web pages in meaningful sections with appropriate headings which can enhance navigation for visually impaired users.

3.5.2 Aural Perception

The differences between the information conveyed by visual layouts and aural rendering are significant as secondary information provided by the use of colour, positioning or other formatting features are not conveyed to screen reader users (Leporini and Paterno, 2008). For example, a web page with two side columns and a main column is clear for the sighted user but for the visually impaired user, it is rendered in a linear way, so there is a top, a middle and a bottom section which in itself is a completely different representation of the page (Yesilada et al., 2007). The purpose of visual elements is often just to improve the aesthetics of the web page, but they also ease access to the content of the page by providing visual guidance (Wright, 1981) which visually impaired users cannot benefit from. The differences in how different users interpret web pages have lead to suggestions for the contents of web pages to be partitioned and structured so that screen reader users can access the desired information more quickly without excessive sequencing (Leporini and Paterno, 2004, 2008). This is important during online search as searchers often have to navigate through a vast amount of information to identify what is relevant.

3.5.3 Information Overload

Screen readers process web pages sequentially with little or no content filtering which can cause information overload (Mahmud et al., 2007a). Static portions of web pages which contain items such as banners, advertisements and copyright information do not tend to vary between pages and therefore, visually impaired users often have to listen to repeating information which does not benefit the progress of the task being completed. Despite screen readers providing users with the ability to skip blocks (skip links) of text or to navigate to specific parts of the web page (heading navigation), in non-visual browsing, visually impaired users still have to listen to or skip through a substantial part of the page to get to the required information (Mahmud et al., 2007a). Thus, they are overloaded with unrelated information which can contribute to the load on working memory (Leporini and Paterno, 2004; Murphy et al., 2007).

3.5.4 Lack of Context

When visually impaired users access web pages using speech-based screen readers, irrespective of their navigation strategies, information is read to them in small portions. Therefore, it is up to the users to progressively build a mental model of the page. This requires a high level of cognitive effort and can lead to difficulties in understanding the overall context of the page (Leporini et al., 2004; Leporini and Paterno, 2004). Gaining an overview of a web page is a challenging problem (Murphy et al., 2007) and visually impaired users often tackle this by trying to memorise the structure and layout of pages that they regularly visit, for example, whether information are displayed in tables etc.

Visual scanning is very efficient for sighted users as the overall layout and structure of a page can enhance recall whereas screen reader scanning is time consuming and tedious and results in visually impaired users having a totally different perception of a web page (Stockman and Metatla, 2008). In a study of the causes of frustrations among 100 blind users, Lazar et al. (2007) found that one of the biggest causes of frustration was page layout; users reported being lost and disoriented and not knowing where they were on the page. Therefore, the contextual information that sighted users can grasp within seconds is, to some extent, inaccessible to visually impaired users. During search tasks, this can have a significant impact as users do not always know what their current focus is and they have less immediate access to the contextual information that could help them in refining their information need.

3.5.5 Lack of Persistence

Screen readers, like all speech user interfaces, lack persistence (Gilbert and Zhong, 2003), that is, users only hear one piece of information at a time and once they have navigated away from that interface component, the information is lost (Teixeira et al., 2009). This is not the case when interfaces are accessed visually as any part of the content is considered as being persistent and is only 'a glance away'. The equivalent of this for a screen reader user would be to navigate back to the interface component and re-access that part of the content. This is time consuming and requires more effort than a quick glance. This lack of persistence, coupled with sequential access, is responsible for many of the navigation difficulties encountered by speech-based screen reader users during web navigation. As mentioned previously, several previous works have discussed these navigation difficulties and thus, this area has received considerable research attention. As a result, there have been several proposals as to how speech-based screen reader navigation could be enhanced for visually impaired users and we discuss these in the following section.

3.6 Enhancing Browsing and Navigation with Screen Readers

There have been numerous solutions proposed to enhance browsing and navigation in order to ensure universal access to information. To address the problems identified in section 3.5, researchers have proposed diverse solutions varying from specialised browsers (Borodin et al., 2007; Mahmud et al., 2007b) to navigational aids based on the Semantic Web (Salampasis et al., 2005; Kouroupetroglou et al., 2007). In this section, we group the proposed solutions under different headings namely, non-visual browsers, dynamic updates, travel metaphor, semantic web and information scent and we discuss how they support screen reader users in browsing and exploring web pages on the Web.

3.6.1 Non-visual Browsers

Since the late 1990's, research has been carried out to implement non-visual browsers. Asakawa and Itoh (1998) implemented the Home Page Reader which consisted of a text-to-speech engine to convert HTML tags into voice output and users could navigate using only the numeric keypad. The system was evaluated with 20 Japanese blind users who had to perform tasks such as moving between pages in the history depending on their level of computer experience, that is, whether they were beginner, intermediate or advanced users. The users found the system to be novel which allowed them to access information on the Internet without depending on others to transcribe it first.

More recently, the non-visual browsers HearSay (Borodin et al., 2007) and CSurf (Mahmud et al., 2007b) have used context-aware browsing to allow visually impaired users to avoid listening to web pages from the beginning, thereby avoiding repetitive information such as banners and advertisements. Instead, CSurf (Mahmud et al., 2007b) which has its roots in HearSay (Borodin et al., 2007), analyses the content of the page and uses topic detection to partition web pages into segments which are semantically related. Therefore, navigation is enhanced as relevant sections of a page are read when users move from one page to another. The browser can be used in two modes: the verbal mode and the earcon mode. Earcons are played when specific HTML elements are encountered so that this type of information can be separated from the typical content-related feedback that is given by the browser. For example, an earcon played when a link is found can be distinguished from the word 'link' in the content of the page. The work proposed in HearSay (Borodin et al., 2007) and CSurf (Mahmud et al., 2007b) addresses the problems caused by information overload and linear access.

Mahmud et al. (2007b) evaluated the CSurf browser with 30 sighted students by measuring the time taken to find the desired information after a link was followed and 3 visually impaired users were solicited to provide qualitative feedback. It was reported that the student participants took 66% less time when browsing with CSurf than with state-of-the art screen reader JAWS. The visually impaired users also found that context-aware browsing was a significant improvement over regular browsing when using screen readers and therefore, the conclusions were that context-directed browsing could improve browsing efficiency for screen reader users.

3.6.2 Dynamic Content

Dynamic content has been at the forefront of Web 2.0 and new technologies such as AJAX allow web pages to update themselves with new information, content and layout in real time without the page being reloaded. This can cause confusion among screen reader users as they do not receive any feedback for their actions. This is because screen readers are only notified of changes when a page is reloaded and not when content is dynamically changed. For example, if a user clicks on a button expecting a new page to be opened but instead part of the page is updated as a result, the user can become disoriented and confused about whether they have correctly activated the control (Hailpern et al., 2009).

To allow visually impaired users to detect and directly navigate to dynamic updates on a page, Borodin et al. (2008) proposed Dynamo, a simple and intuitive interface, through which changes that have occurred on a page can be reviewed. A Dynamo-based prototype called HearSay-Dynamo (HD) was implemented using VoiceXML to notify users of dynamic content changes and to provide shortcuts to navigate to the updates. The prototype was evaluated with eight blind users against a baseline, HearSay-Basic (Borodin et al., 2007). The baseline system recorded the dynamic changes that occurred on web pages but users had to linearly search for the updates as they were not notified when the updates happened. During the evaluation, participants found HearSay-Basic frustrating due to inefficient access to page updates and found that their access to updates was improved with HearSay-Dynamo. Bigham et al. (2007) has shown that blind users are less likely to visit pages with dynamic content or those that issue AJAX requests. To ensure that visually impaired users can fully benefit from Web 2.0 technologies, screen readers are also being enhanced to support users in accessing dynamic content. For example, the Apple VoiceOver 'Hot Spots' feature allows users to create and monitor up to 10 hot spots on a page. When changes occur at any of the hot spots, the user is alerted and taken directly to the spot. However, for this to be an efficient strategy, users must know prior to navigation where changes are likely to occur and when browsing through new pages, this might not be completely apparent.

Additionally, to address the issues posed by dynamic content, the World Wide Web Consortium (W3C) has established a protocol called the Accessible Rich Internet Applications (ARIA) to define a way of making dynamic content and advanced user interface controls more accessible to people with disabilities. More specifically, the ARIA suite addresses concerns that arise with Web 2.0 technologies and proposes alternative ways in which information can be made accessible to assistive technology (Web Accessibility Initiative, 2011). ARIA metadata can be used in web pages to add semantic information to interface components. For example, ARIA attributes can be used to describe 'live' areas whereby designers can specify when updates should be announced to users by giving the live attribute values **off** (changes not announced), **polite** (changes announced after users have completed their current activity), **assertive** (user can be interrupted with changes but not immediately) or **rude** (user should be interrupted with changes).

Buzzi et al. (2009) used the ARIA suite to enhance the Wikipedia editing page and conducted a user evaluation with 20 visually impaired users to compare the original and the modified page. Participants performed two tasks which required them to insert a special character and to apply a formatting style on both pages. It was reported that participants were able to perform the tasks more rapidly using the

ARIA-enhanced page and also that performance was significantly higher.

3.6.3 Travel Metaphor

The idea of using the analogy of travel in the physical world to improve web accessibility was first discussed in (Harper et al., 1999). A journey on the Web has a lot in common to travel in the physical world as they both involve getting from one place to another and both share the common goal of reaching the desired location to accomplish the purpose of the journey (Goble et al., 2000).

A travel analogy is used in (Goble et al., 2000) to enhance navigation in the world of hypertext by proposing a framework for the identification of travel objects which can either be travel cues (helping travel) or travel obstacles (hindering travel) for blind users. The authors used the notion of travel in the physical space to encode the needs of the visually impaired users during web navigation and to offer design guidelines for web pages. They argued that on web pages, a maximum number of objects should be cues and obstacles should be minimised to enhance mobility. In addition, they advocated for a Mobility Index to enable comparisons between web browsers and also between combinations of web pages and they propose to include such a measure in the usability metrics of web design.

Similar to this travel analogy to enhance navigational support, TrailBlazer was proposed to use existing journey itineraries to support web navigation (Bigham et al., 2009). The system provided step-by-step instructions to guide screen reader users when completing web tasks. TrailBlazer exploited the how-to-knowledge from a repository of scripts which contained a list of steps that must be performed in order to complete a task. Users were offered suggestions of what to do next and the focus of the screen reader was automatically moved to the next correct action. The proposed system was evaluated with five experienced blind users who despite liking the concept of the next correct action being suggested, questioned the dependence on others for scripts that such a tool would require.

3.6.4 Transcoding and Annotation

The concept of a 'Semantic Web' is viewed as an opportunity to structure the Web and to produce websites that are understandable both by machines and humans (Berners-Lee, 1998). Given the different ways and devices that are used to access the Web, content adaptation methods such as transcoding can have a significant impact on the way web pages are viewed by users. Transcoding is the process of rendering the content of a page differently, taking into consideration the physical and performance constraints of the client device (Hori et al., 2000), be it mobile devices or voice browsers. The transcoding engine can be enhanced with annotations, that is, meta-information that augments a web page and allows the engine to make better decisions on how to adapt the content. Annotations can be as simple as assigning a level of importance to a page element or as complex as having alternative images depending on the display properties of the client device. Annotations are essential for semantic transcoding which is the process of adapting the content of a web page according by capturing the meaning of the elements on a web page. For example, if an element on a page is labelled as a menu in the source code, the transcoding system can manipulate the element appropriately according to its rules for menus and thus the content of the page can be correctly rendered. In this respect, annotations can be used to provide better support for audio rendering or for visual rendering on small screen devices (Bechhofer et al., 2006).

The use of annotations with transcoding can augment web pages for non-visual access by providing more context for page elements when navigating with screen readers (Asakawa and Takagi, 2000). Salampasis et al. (2005) proposed to augment the browsing process by using metadata to enrich web pages. As a result, a semantically enhanced voice web browser, SeEBrowser, was implemented which used ontologies to annotate web pages to semantically enhance browsing. Web pages were presented to users aurally and when the pages were properly annotated, users were provided with shortcuts to directly navigate to annotations thereby improving browsing within a page and across web pages (Kouroupetroglou et al., 2007). The browser was evaluated with six blind users in (Salampasis et al., 2005) to test whether annotated web pages were more usable than non-annotated ones. Half of the participants used non-annotated pages and the second group was given a set of questions to answer using pages which had been annotated for the existence of navigational bar, table of contents and a content element. This meant that users could directly navigate to those if needed. Marginal differences were observed in access times and number of keystrokes needed to complete tasks which were not statistically significant from the log analysis.

A similar idea was studied by Yesilada et al. (2007) who proposed Dante, an approach which required web pages to be annotated with semantic information. Dante also used the Web Authoring for Accessibility (WA*f*A) ontology to annotate travel objects and showed that by fragmenting pages and combining them with a table of contents (TOC), users can be provided with better mobility and travel support. With Dante, Yesilada et al. (2007) attempted to replicate how designers visually fragment a page using different columns or chunks of information to enhance page navigation with blind users. One of the aims of this framework was to evaluate whether semantically transcoded web pages support users better when they are ‘travelling’ on the Web. The user evaluation with 10 participants, using the NASA TLX measure (Hart and Staveland, 1988), showed that some tasks were more demanding to perform on the original page compared to the semantically transcoded version. The authors concluded that transcoding semantically improved the ease with which visually impaired users can navigate through web pages. The conclusions were that users had a better awareness of orientation and spatial layout and the TOC was useful to provide an overview of the page’s structure. The linear nature of the TOC was compatible with the way screen readers render a page resulting in participants finding that semantically transcoded pages were more organised and less cluttered.

The use of annotation to enhance browsing for visually impaired users has also been investigated in (Vigo et al., 2009) where the authors proposed to annotate links to target web pages with accessibility information. Links were annotated with a measure of accessibility level which was derived from two automatic evaluation tools, ACB (Vigo et al., 2007) and Magenta (Leporini et al., 2006). To test whether annotated links impacted the decision making process of blind users during navigation, a remote user evaluation was performed with 16 users carrying out a searching and browsing task. The conclusions were that despite a general tendency to browse pages with high accessibility scores, blind users do not tend to consider the score when making decisions of whether or not to follow a link. There were also no agreement on whether scores reflected the perceived accessibility of visited pages.

3.6.5 Improving Information Scent

The information foraging theory (Pirolli and Card, 1999) suggests that when deciding whether to visit a web page, people carry out a cost-benefit analysis to consider the benefits of following a path against the effort required to do so. If the benefits outweigh the costs, the user will visit the page or else they will abandon the page in search of something that is considered to have a better cost-benefit ratio. To make such decisions, users rely on *information scents* which are hints and cues that allow people to estimate how useful following a certain path will be (Pirolli and Card, 1999; Chi et al., 2001). Information scents thus play a significant role during web navigation and for visually impaired users, reliable information scents have the potential to improve efficiency and cause less frustration. For sighted users, information scents can exist in many visual forms such as formatting, layout and structure etc. whereas for screen reader users, they have to rely mostly on the content of the page and thus, understanding the components that provide information scents can have an important impact on their navigation strategies.

Takagi et al. (2007) observed that on online shopping websites, blind people used between one to five words to determine the scent and changed their navigation pattern to reflect this. Thus, they argued that for blind users, word-level design of content is important compared to page-level content for sighted users who used the full page content to determine the scent. In (Takagi et al., 2007), online shopping websites which typically do not contain a large amount of text, were under study. As product titles are usually short and concise, blind users used a small number of words to evaluate the information scents. As for sighted users, they can quickly scan the images of a list of products on a page to make a decision and thus, the full page content can provide information scents.

This difference was not observed in (Ivory et al., 2004) where there was no significant difference in the features blind and sighted searchers use to inform their exploration of search results. The summary, title and URL were mostly used to determine whether or not to explore a search result. Despite providing useful insights in the decision making process of searchers, in the user evaluation carried out by Ivory et al. (2004), searchers were shown one search result at a time and had to say whether or not they would visit that page. This setting does not reflect the real settings in which search is usually performed as other factors on the search results page such as, the position of the result and other search results could also act as information scents to influence the decision making process of whether or not to explore a web page.

Another type of information scents for visually impaired users have been in the form of dynamically generated gist summaries (Harper and Patel, 2005) which were proposed to enhance the decision making process during navigation. A gist summary is a short and concise summary of the page. It does not contain any superfluous information and is aimed at conveying what the page is about and to help users in deciding whether the page is worth being viewed. Harper and Patel (2005) created the gist summaries by parsing the XHTML code in the Document Object Model (DOM) and selecting the first sentence of each paragraph from the returned model. The summaries consisted of a maximum of four sentences: the first sentence of the page, the first sentence of the last paragraph and the sentence from the upper (75%) and lower (25%) quartiles of the page. Given their nature, gist summaries are very useful for visually impaired users as they can avoid wasting time and efforts. Therefore, gist summaries can provide strong information scents to visually impaired users during web navigation. Despite highlighting the importance of gist summaries for visually impaired web surfers, Harper and Patel (2005) did not include blind users in their evaluation of the Summate feature for the FireFox browser. Instead, they required six sighted participants to judge between different types of summaries and concluded that those generated with Summate was better at conveying the gist of a web page.

While the gist of an entire page can provide strong information scent about its content, individual components on a page can also be enhanced to provide information scent as in (Vigo et al., 2009) which annotated links on web pages with accessibility information. Enriching page links with the additional information of how accessible the target page is, supports visually impaired users in their cost-benefit analysis of whether a page is worth visiting. However, a remote usability study with 16 blind users showed that information scent in the form of an accessibility measure did not make a significant difference in the decision of which link to explore.

3.7 Beyond Technical Accessibility with Screen Readers

While the approaches described in Section 3.6 describe research investigating ways in which navigation with screen readers could be enhanced, in reality, website designers rely on conformance with guidelines such as the Web Content Accessibility Guidelines (WCAG) (Caldwell et al., 2008) from the W3C to ensure that their websites are accessible to users with disabilities. Developers are generally aware of design guidelines (64% of participants in a survey by Lazar et al. (2004) were aware of the WCAG) and rely on automatic validation tools such as WAVE[7] to check for compliance to those guidelines. However, despite being compliant to basic regulations, many websites still have serious usability issues (Theofanos and Redish, 2003; Power et al., 2012). For example, most regulations and guidelines suggest that images must be accompanied by alternative text so that they can be accessible to users with visual impairments. However, it is common for website developers to use vague and meaningless text to describe pictures (Takagi et al., 2004) and while most accessibility checkers can check for the presence of alternative text, they cannot check whether any text that accompanies an image conveys a correct representation of that image to the visually impaired user (Sloan et al., 2000).

Therefore, compliance with guidelines is not sufficient (Powlik and Karshmer, 2002; Schrepp, 2010; Power et al., 2012) and a website does not ensure a usable or satisfying Web experience just because its content is accessible (Hanson, 2004; Leuthold et al., 2008). It was reported in (Power et al., 2012) that only 50.4% of web accessibility problems that blind users encountered were covered by WCAG 2.0.

[7] http://wave.webaim.org

The authors also reported that there was no significant decrease in accessibility problems between non conforming websites and those that conformed with WCAG 2.0 at level A (the second highest level of conformance). Therefore, it was argued that upgrading to WCAG 2.0 from WCAG 1.0 did not have the expected impact on improving accessibility for blind users.

To support web designers in identifying usability issues, several tools and techniques have been proposed by previous works: Takagi et al. (2004) has developed the aDesigner (Accessible Designer), a tool to help web authors and auditors to visualise the usability of the Web as understood by visually impaired users. Two new metrics, navigability and listenability, were used to evaluate usability in aDesigner (Fukuda et al., 2005). Navigability is concerned with the structure and layout of the page, that is, whether headings and intra-page links have been correctly used to allow screen reader users to quickly access the main content of the page whereas listenability addresses the difficulties experienced with alternative texts for images and evaluates whether inappropriate or redundant text has been used to describe images. Similarly, Correani et al. (2004) proposed a set of 19 usability criteria for websites, grouped into three categories, namely, effectiveness, efficiency and satisfaction. The authors then developed NAUTICUS, a tool to support designers to check whether a website is usable for user's interaction via screen readers. The tool not only identified the usability problems but also provided suggestions for modifications to correct the problems which have been identified.

In fact, the categories used by Correani et al. (2004) are employed by the International Organisation for Standards to define usability as "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" (ISO 9241-11, 1998, p. 2). The concepts of effectiveness, efficiency and satisfaction are further defined by ISO as:

- *Effectiveness:* "accuracy and completeness with which users achieve specified goals". Therefore, an interface is effective if it supports users in completing specific tasks.
- *Efficiency:* "resources expended in relation to the accuracy and completeness with which users achieve goals". An efficient interface helps users to accomplish particular tasks with minimum waste, expense or effort (Kelly, 2009).
- *Satisfaction:* "freedom from discomfort, and positive attitudes of the user to the product". Satisfaction is often used as a measure for the users' experience of an interface. It determines the sense of fulfilment and contentment when users achieve a specific goal in regards to their task.

Additionally, Tonn-Eichstädt (2006) and Schrepp (2010) have addressed the efficiency criterion of usability by proposing to modify the well-established method employed in user interface design, Goals, Operators, Methods and Selection rules (GOMS) to model blind users' interaction behaviour. The proposed modified GOMS models have not been verified, but if they can be used to reliably represent the strategies that blind users employ when interacting via screen readers, designers will be able to estimate task completion times, analyse problems with user performance and evaluate the efficiency of interface designs (Schrepp, 2010). Usability issues such as poorly structured pages and redundant alternative texts occur for many reasons but Takagi et al. (2004) identified the following causes:

- Too much focus on compliance to guidelines, but not on real usability.
  Accessibility checkers focus too much on whether web pages comply with regulations, instead of checking whether accessible components are usable. An interface component that passes an accessibility guideline does not necessarily provide a good user experience (Henry, 2007).
- Relying on syntactic checking of web pages.
  The syntax of underlying web code is checked to detect issues with accessibility and therefore checkers are limited as they can only check web code underlying the pages.
- No attention to "time-oriented aspects" of user operations.
  There are no considerations for the way users navigate web pages; they almost never passively listen to the screen reader and instead, they employ different strategies as outlined in section 3.3 to create a mental model of the page to navigate to the information of interest.

Furthermore, usability problems also arise because developers assume that they can reproduce an audio experience only by reading out the content of a web page that was designed to be visually experienced. However, this is not the case as discussed by Di Blas et al. (2004) who suggested that the visual and the audio experience should be separated so that "*not all that is written or visualised must be read, not all that is read by the screen reader must be visualised on the screen*". Therefore, from the point of view of user experience, the replacement of an interaction mode such as the display of text on a screen with another interaction mode with the same functionality (speaking the text out loud) is not necessarily equivalent (Shinohara and Tenenberg, 2009).

Therefore, compliance with guidelines and regulations only guarantees technical accessibility (Di Blas et al., 2004; Petrie and Kheir, 2007), that is, website components are designed to conform to the technical criteria that make them accessible via existing assistive technologies. Yet, to ensure that users with disabilities have an effective user experience, technical accessibility is not sufficient to ensure successful usage (Shneiderman, 2000). In this respect, it is suggested that accessibility should be treated as a branch of usability and Di Blas et al. (2004) and Petrie and Kheir (2007) have advocated for usable accessibility, that is, considerations for how usable accessibility solutions are and for accessibility criteria to be user-based. Similarly, Thatcher et al. (2003) proposed that accessibility should be considered as a subset of usability as accessibility problems are only a type of usability problems that hinder access for people with disabilities. Shneiderman (2000) has argued that it is necessary to ensure that the widest possible audience can use a product and that there are benefits in accommodating a broad spectrum of usage as researchers are forced to consider a wider range of design ideas which can lead to innovative designs that benefit all types of users.

In fact, there are differences between how users understand the severity of problems they encounter on websites and how these same problems would be rated using guideline ratings (Petrie and Kheir, 2007) and thus, by just ensuring technical accessibility, developers cannot guarantee that interface components would be usable and would ensure a satisfying experience. Similar observations have been made about other user groups such as the elderly in (Sloan, 2006) whereby the authors argued in favour of research-based guidelines as opposed to technical guidelines as the former allow designers to identify and acknowledge the problems faced by older users in the real world. It is only then that the real problems can be addressed to make sure that the users have a positive user experience. Power et al. (2012) argued that there is the need to move away from a problem-based paradigm, that is, when the focus is on eliminating problems encountered by users as is the case when proposing solutions to address the problems posed by screen reader navigation. Instead, the authors suggested that similar to usability research, web accessibility research should be based on user data, focussing on how users with disabilities use the Web in order to propose broader sets of guidelines that are user-centred.

Therefore, while it is undoubtedly important to ensure that any interface components to be designed are accessible with a screen reader, it is also essential to ensure that these components can be accessed with a screen reader intuitively so that the user can fully benefit from the interface. The aim of usable accessibility should be to ensure that technically accessible components also provide an effective user experience by complementing and not interfering with the mode of interaction and the mental model that users with disabilities create for websites or other artefacts. It is difficult to identify such usability issues through the exclusive use of automatic validation tools such as accessibility checkers and this is why, in this thesis, we adopt a user-centred approach to identify and verify user requirements, to design and evaluate a search interface for visually impaired users.

3.8 Chapter Summary

In this chapter, we described how visually impaired users access the Web through speech-based screen readers. We provided an overview of the strategies that screen reader users employ to navigate the Web and given that web pages are typically designed for visual interaction, we discussed the difficulties that visually impaired users encounter during screen reader navigation.

The design of screen readers is continuously evolving but they tend to lag behind the increasingly rapid developments that occur with web technologies. Therefore, there has been considerable research towards enhancing web navigation for screen reader users, such as research into voice browsers, semantic annotations and transcoding etc. as described in section 3.6. However, there are concerns that accessibility is exclusively being defined as compliance to guidelines with no consideration about how usable a web page is. Usable accessibility ensures that a user interface or any artefacts can be technically accessed with assistive technologies and at the same time, those artefacts can be used by users with effectiveness, efficiency and satisfaction.

Additionally, this chapter has shown that there is a wealth of work that tries to address the difficulties encountered by visually impaired users, but there are very few studies that take into account the context of use in order to design for the users' abilities. For example, in the context of the work in this thesis, there are several previous works that address the problems encountered during web navigation through screen readers, but none have studied how visually impaired users interact with search interfaces in a broader context and how their behaviour can influence the design of search interfaces. However, web browsing and navigation is often only a '*building block*' leading to a broader and more complex task on the Web, such as web search or online shopping.

In this thesis, we explore the wider information seeking process of visually impaired users on the Web to inform the design of search interfaces. We particularly focus on the impact that the mode of interaction has on the search behaviour of visually impaired users. Through out this thesis, we adopt a user-centred approach to design a search interface for visually impaired users and therefore, at different stages of the design process, we engage potential users to gather user requirements, to discuss design ideas and to evaluate proposed interface features.

Hence, a significant part of the work presented in this thesis is based on user involvement and in this respect, we conduct the following user studies: an exploratory study to investigate the information seeking behaviour of visually impaired users on the Web, a user evaluation of the scenario-based approach for participatory design with visually impaired users and a user evaluation of the search interface we propose in this thesis. Therefore, given the importance of user-based explorations and evaluations in this thesis, we discuss in Chapter 4, the methodology adopted to conduct the above-mentioned user studies. We describe the design of the user studies, the instruments used and the procedure that the studies followed. We also discuss in the following chapter, the methods used for collecting data from participants and the approach used for data analysis.

Chapter 4

Methodology

4.1 Introduction

The multi-disciplinary nature of this thesis implies that in conducting research related to it, we are able to draw on the practices from the different research areas it spans, for example, information science and human-computer interaction. Given the user-centred approach of this thesis, user studies play a significant role and are carried out for the following purposes: to gather user requirements, to engage potential users in the design process and to evaluate a proposed search interface.

User studies, as an empirical method, are common and can be characterised by the data they provide (qualitative or quantitative), by where they take place (lab-based or naturalistic) as well as the length of time they last (single session or longitudinal) (Kelly, 2009). Qualitative methods are increasingly being employed by HCI researchers (Adams et al., 2008) as such methods allow them to understand how groups of users experience and perceive usability issues. Therefore, qualitative data help researchers to understand the how and why of users' behaviour. Quantitative methods, however, aim to collect and analyse data mostly in a numeric form and thus, they mostly focus on hypothesis testing, data prediction and replication etc.

In this thesis, we design user studies to collect both quantitative and qualitative data. Qualitative methods such as observations and interviews allow us to understand the complexity of human behaviour during information seeking whereas quantitative data such as query length, number of search results explored etc. act as measures of performance when evaluating interface components. Thus, this combination of data provides a broad picture of the visually impaired users' performance, experience as well as preferences (Jay et al., 2008).

When designing interfaces for users with disabilities, Jay et al. (2008) has highlighted the need for user evaluations for the following purposes: to capture requirements, to identify and document existing accessibility problems, to define the desired solution, to design an accessible solution and to map the desired solution to the interface. In this thesis, we perform three user studies for similar purposes as discussed by Jay et al. (2008) and in the following, we describe those studies:

- **Study 1** is the exploratory observational study described in Chapter 5 where we compare the information seeking behaviour of 15 visually impaired and 15 sighted users for complex search tasks on the Web. The aim of this user study is to investigate the information seeking behaviour of visually impaired users especially to examine how interaction through speech-based screen readers impacts the search behaviour. Therefore, we gather requirements for a search interface for visually impaired users to support complex information seeking. Through this exploratory study, we also identify and document the accessibility problems observed among visually impaired users when interacting with web-based search interfaces.

- **Study 2** is conducted to evaluate the scenario-based approach described in Chapter 6. We carry out a user study with four visually impaired users to investigate whether the technique we propose for engaging visually impaired users in design, can be used successfully to verify user requirements and to gather user feedback in the early stages of the design process. This study therefore allowed us to define a desired solution to address the observations we made in Study 1 by collaboratively discussing design plans with potential users.

- **Study 3** is the user evaluation that is performed in Chapter 8 to evaluate the search interface we propose in this thesis. This study is carried out with 12 visually impaired users and is structured so that each participant takes part in two evaluation sessions which are separated by several days. Therefore, as well as observing how participants interact with the proposed interface, the evaluation structure also provides us insights into the information seeking behaviour of visually impaired users for multi-session search tasks.

In this chapter, we discuss the methodology for the user studies described above. In section 4.2, we describe the design of the user studies we carried out and explain our reasons for using a remote evaluation setting. We discuss the instruments for the user studies in section 4.3 with particular focus on the choice of search tasks and how they were constructed. The overall procedure for each user study is explained in section 4.4 and we describe the methods that we used to gather data in section 4.5. Finally, in section 4.6, we provide an account of how we analyse the gathered data and we highlight in section 4.7, the participant recruitment process and the ethical considerations taken into account throughout the user studies presented in this thesis.

4.2 User Study Design

For all the user studies that we performed in this thesis, we employed a remote evaluation approach. Remote evaluations represent situations where the evaluators and the participants in the user study "are separated in space and/or time" (Castillo et al., 1998). There are numerous ways to carry out remote evaluations, including synchronous approaches (evaluators and users are only separated by space) as well as asynchronous approaches (evaluators and users are separated by space and time).

We followed a synchronous strategy for our user studies by attempting to simulate a conventional laboratory-based study through live observation. We achieved this by using audio access and screen sharing via Skype[1]. Such observational studies, common in interactive information retrieval, involve the evaluators watching how users interact with search systems in their natural environment and therefore result in a deep understanding of naturalistic search behaviour (White and Drucker, 2007).

One of the ways to capture data during remote usability studies is through think-aloud protocols. However, in our case, we did not use think-aloud methods as visually impaired users, especially inexperienced screen reader users, can find it challenging to think aloud while using a screen reader (Chandrashekar et al., 2006). Previous research (Pernice and Nielsen, 2001) has also shown that visually impaired users can be reluctant to think aloud despite prompts as the verbal protocol seems to add to the cognitive effort that is required from them to perform computer-based tasks using a screen reader. Therefore, we did not ask the participants in our user studies to think aloud. Instead, we left it to the participants if they wanted to provide feedback during the task and we followed up on anything we observed either by asking

[1]http://www.skype.com

participants questions during or after the task depending on the urgency of the matter.

Our reasons for using a remote setting were motivated by the fact that we wanted to observe users in settings as closely related to those in which they carry out their day-to-day search activities. In addition, a remote user study allowed the participants to use their own equipment and assistive technologies at settings that they are familiar with. Given the known difficulties in recruiting users with disabilities (Petrie et al., 2006), through remote evaluations, we were able to access a more diverse set of users. With careful attention to design, remote evaluations do not compromise the users' experience of the system (Brush et al., 2004) but they can be time-consuming to set up both for the users and the evaluators and there can be several difficulties in re-establishing the setup if there are any hardware or software malfunctions (Dray and Siegel, 2004).

Such remote evaluations are common in studies of human-computer interaction [see (Andreasen et al., 2007) for a review] and are known to be as effective (Thompson et al., 2004) and to identify the same number (Brush et al., 2004), and in some cases, more usability problems as a conventional usability test (Andreasen et al., 2007). Therefore, depending on the type of remote evaluation conducted, the data gathered can also be impacted. Petrie et al. (2006) compared remote and local evaluations with disabled users and reported that the quantitative data collected is comparable whereas the amount and richness of qualitative data were different. However, remote user studies can also be beneficial for formative evaluations as users feel more comfortable to criticise a product thereby avoiding evaluator's bias (Bradner, 2004).

4.3 User Study Instrument

In this section, we describe the instruments that were central to the user studies we carried out, namely, the search task and search interface. These, especially the search task, are important because they significantly impact on the search behaviour of participants.

4.3.1 Search Task

The search task is central to the search process as it determines the direction of the search process and hence, the behaviour of the searchers. The goal of the search task is for evaluators to create the context for an information need for the participants so that they interact with the search system. Formulating an information need for a study can be difficult as assigned search tasks are viewed as artificial and do not provide the participant with a relevant context to perform the task (Kelly, 2009).

Hence, Borlund (2003) proposed *simulated work tasks* that allow researchers to create a context and motivation by generating a short story that leads to the creation of an information need for the participants in their studies. We created simulated work tasks for Study 1 and Study 3. However, given that we were designing search interfaces to support complex search tasks, we also had to ensure that our simulated tasks met the criteria we used in section 2.2.1 to define complex tasks. In Study 1, we also left the choice of task open to participants as the study was exploratory in nature, but we also provided participants with example tasks to assist them in choosing their own search task. We further discuss our reasons for doing so in section 5.3.2 and we list the example tasks for Study 1 in Appendix A.

Additionally, for Study 3, as we were evaluating the proposed search interface to investigate the behaviour of visually impaired users for multi-session tasks, we created work tasks that simulated circumstances for a search task that would require multiple sessions to complete. For this user study, we assigned a specific work task to participants as we were focussed on studying how they would interact with the components on the proposed interface. The tasks for Study 3 are presented in Table 8.3.2.

4.3.2 Search Interface

The purpose of the search interface is to allow users to interact with the search system in order to satisfy their information needs. Using a search user interface, searchers should be able to formulate queries, explore information spaces and keep track of the information they encounter during their search process (Hearst, 2009, p. 1). Therefore, the search interface plays an important role in studies of information seeking behaviour.

In the user study described in Chapter 5, we left the choice of search interface open to participants as the nature of the study was exploratory and our main objective was to observe the information seeking behaviour in settings as closely related to those in which visually impaired users carry their day-to-day search activities. Also, most of the popular commercial web search interfaces have similar features which implies that our observations would not be affected. However, in the user evaluation described in Chapter 8, participants used the search interface developed as part of this thesis as specified in Chapter 7.

4.4 User Study Procedure

Each of the user study carried out as part of this thesis followed a different overall procedure. For example, in Study 1, there was no need for questionnaires to ask participants to rate interface features whereas in Study 3, given that we were evaluating the proposed search interface, we used questionnaires with semantic differentials to obtain feedback on interface components. However, the three user studies were structured similarly in terms of the activities that were carried out before, during and after users' participation. In the following, we describe the procedure for the user studies.

4.4.1 Pre-Study

After the recruitment process, we sent participants a consent form and a short demographic questionnaire to collect data such as sex, age, search experience and use of assistive technologies etc. These forms were sent in an electronic format for easy access via screen readers and participants were required to type their names to indicate consent.

4.4.2 During-Study

On the day of the study, we called participants on Skype and requested them to activate the screen sharing feature so that the evaluator could observe and record what was on their screen at all times. The verbal conversation was also recorded as part of the screen recording. Users were then requested to start working on their tasks. There were slight variations at this stage between the three user studies. In Study 1 and 2, there were no pre-task and post-task questionnaires whereas in Study 3, we used questionnaires to gather information before and after the session. For Study 3, at the beginning of the first evaluation session, we conducted a training exercise as participants were not familiar with the interface under evaluation. As discussed previously, users were not asked to think aloud, but if the evaluator observed a behaviour that needed immediate follow up, the user would be asked about it straight away.

4.4.3 Post-Study

After the task, for all three studies, we carried out a semi-structured interview to follow up on anything that we noticed during the user observation. This gave us the opportunity to discuss matters in greater details with users who could provide feedback on the task they completed or the search interface they used. For Study 2, the post-study interview allowed participants to further discuss their own design ideas.

4.5 Data Collection Techniques

While the search task and the search interface are important instruments in user studies on search behaviour, it is also essential to be able to capture how participants interact with the search interface when completing the search task. In this thesis, we use different methods of data gathering to fully understand the search behaviour of visually impaired searchers. As previously discussed, think-aloud can be challenging for visually impaired users and thus, we used the following methods of data collection:

4.5.1 Questionnaires

We used questionnaires (Adams and Cox, 2008) to gather data at different points during the user studies, for example, to capture demographic information about participants' search experience and proficiency with assistive technologies as well to gather feedback on interface components during Study 3. The questionnaires contained both closed and open ended questions to be able to capture quantitative and qualitative data that provide insights into the search behaviour of participants (Kelly, 2009). During the interface evaluation, we also used semantic differentials on post-task questionnaires to allow users to rate the usefulness and ease of use of the components on the search interface. Apart from the demographics questionnaire prior to the study, all questionnaires were verbally administered to the participants as this was most convenient for the synchronous remote evaluation setting. In addition, this format was easier and more efficient for the participants to access and complete.

4.5.2 Interviews

Interviews are important tools that allow researchers to gather qualitative information from participants (Adams and Cox, 2008). In the studies conducted in this thesis, we carried out semi-structured interviews post-task and post-study to gather feedback from participants about the search task and the search interface. The open-ended questions in the interview were flexible so that we could probe participants about the different behaviours we observed during their participation (Kelly, 2009). Pre-task interviews in Study 3 also allowed us to find out about participants' existing knowledge of the search domain and their current practices for search task resumption and information re-finding.

4.5.3 Screen Recording

In this thesis, all user studies were carried out remotely using the screen share functionality of Skype. In Study 2, there was no need for screen sharing as the evaluator and the participant interacted exclusively through dialogue. In Study 1 and 3, as we were remotely observing participants, it was essential to record their interaction with the search interface. For this purpose, we used a screen capture software (iShowU HD[2]) to record the participants' screen as well as the verbal communication between the user and the evaluator. Such observation, as a means of collecting data, is time consuming and labour-intensive and is often prone to selective attention and researcher's bias (Kelly, 2009). Therefore, prior to the data analysis, we ensured that we were fully aware of the data that had to be recorded and transcribed. In Study 1, we also used the screen recordings in the absence of logging to derive quantitative data such as number of queries, number of visited links etc.

4.5.4 Logging

As discussed by (Kelly, 2009), logs are typically used to capture the interaction between the user and the system. They record what the system does and how the user reacts to the system's actions. We used logging as a method of data collection for Study 3. We recorded the system-user interaction on the Google Application Engine[3] server which hosted the search interface and after each session with users, we downloaded the logs from the server.

4.6 Data Analysis

For each user study, we transcribed the data from the questionnaires, interviews and screen recordings. The screen recordings, especially in the first exploratory study, were an important source of data which we annotated using a video annotation tool, ELAN[4], to identify emerging patterns. We used an inductive approach similar to the Grounded Theory (Strauss and Corbin, 1998) to identify concepts from the recordings and to devise a coding scheme according to the commonalities across different participants. Grounded Theory advocates for the theory to emerge from the data itself without any prior assumptions or preconceptions. Therefore, it is useful for exploring complex relationships between concepts, such

[2]http://www.shinywhitebox.com/ishowu-hd
[3]https://developers.google.com/appengine/
[4]http://www.lat-mpi.eu/tools/elan

as the relationship between search interfaces, search tasks and searchers and it has been used for data analysis in previous information seeking studies such as (Kuhlthau, 1988; Blandford and Adams, 2005; Makri et al., 2008).

Grounded Theory consists of three stages of coding, namely, open coding, axial coding and selective coding (Strauss and Corbin, 1998). Open coding is the process of generating initial concepts from the data while axial coding is when the data is put together to establish connections between the different concepts and categories. The selective coding process includes the formalisation of the data into theoretical frameworks. However for the studies in this thesis, similar to (Makri et al., 2008), we stopped the data analysis after open and axial coding as we wanted to only explore the behaviour of visually impaired searchers as opposed to developing a new theory.

The transcribed screen recordings provided qualitative data and allowed us to capture the behaviour of participants in the user studies. We complemented the data analysis by using the evaluator's observation notes and the responses from the questionnaires and the semi-structured interviews.

4.6.1 Statistical Testing

In analysing the quantitative data that we gathered from participants, we used both descriptive statistics and inferential statistics. Descriptive statistics are used to summarise a sample by examining the frequency distribution of each variable. They are useful for identifying outliers and anomalies in the data (Kelly, 2009). In all user studies conducted in this thesis, we used descriptive statistics such as mean, range and standard deviation to describe the samples of participants and other quantitative data, for example, query length and number of explored pages.

Inferential statistics are those that allow researchers to make inferences about a population based on the statistics of the sample (Kelly, 2009). In this thesis, we used two types of statistical tests based on inferential statistics, namely, the t-test and the chi-square test. In Study 1, we used a two-tailed unpaired sample t-test to examine the differences between sighted and visually impaired participants whereas in Study 3, we conducted a two-tailed paired sample t-test to compare the information seeking behaviour of visually impaired participants between the two search sessions. In both Study 1 and 3, we used the non-parametric test, chi-square, to analyse count data, for example, the use of specific interface features.

All statistical tests were performed at $p<0.05$ using R statistical package[5].

4.7 Recruitment and Ethical Considerations

We recruited participants for the user studies mainly via online mailing lists such as the list for the British Computer Association of the Blind (BCAB)[6]. Many of the participants in the user studies were not based in the United Kingdom, but given the remote settings for the studies, no difficulties were encountered in conducting the user sessions.

For all the user studies in this thesis, we received approval from the university's research ethics committee (QMREC 2010/60 and QMREC 2012/0698) especially because we were dealing with visually impaired adults. Participants were sent a detailed information sheet about the study so that they were aware of the implications and could make an informed decision about their participation. They were also asked to sign a consent form prior to any involvement. All participants were also informed that they could leave the study without giving any reasons and they were ensured that the data we collected was confidential and would be stored in accordance with the Data Protection Act.

4.8 Chapter Summary

In this chapter, we described the three user studies that were carried as part of this thesis and we discussed the methodology employed for each study. We outlined the design, procedure and instruments for each user study and also discussed the methods used for data collection and analysis. In the following chapter, we describe an exploratory observational study conformed to this methodology (Study 1), to investigate the information seeking behaviour of visually impaired searchers on the Web.

[5]http://www.r-project.org/
[6]http://www.bcab.org.uk/

Chapter 5

The Information Seeking Behaviour of Visually Impaired Users on the Web

5.1 Introduction

Given the challenges imposed by the screen reader, searching can be considered to be a challenging problem for visually impaired users. The type of search task also impacts the search process as it represents the searcher's information needs and drives the information seeking process (Marchionini, 1997, p. 36). Previous research such as (Kellar et al., 2006) shows that people perform a diverse range of search tasks on the Web ranging from simple tasks like finding the capital city of a country to more complex tasks like planning travel or finding medical advice.

Simple search tasks are considered easier as for such tasks, users know which path to follow to satisfy their information needs. Users' mental models for simple tasks are well-defined, for example, they may know which queries to submit to solve the problem at hand. However, search tasks that are perceived by users as complex, affect performance and search effectiveness (Bell and Ruthven, 2004) as users' mental models of the problem situation are ill-defined or incomplete (Marchionini, 1989). This may result from a lack of domain knowledge or a lack of understanding of the task itself. Therefore, complex tasks place high cognitive demands on users (Campbell, 1988) and for visually impaired users, this can make information seeking more intensive given that they already have to split their cognitive effort between the browser, the screen reader and the search interface itself (Theofanos and Redish, 2003).

5.2 Motivation and Research Questions

Despite visually impaired searchers' increasing dependency on the Web for information seeking activities, to the best of our knowledge, no studies on information seeking behaviour have focussed on the visually impaired population. In this chapter, we address this gap in literature by carrying out an exploratory observational study with 15 visually impaired users and 15 sighted users to investigate and compare their information seeking behaviour on the Web. Given the additional cognitive effort required from screen reader users (Chandrashekar et al., 2006), we reasonably assume that the information seeking behaviour of visually impaired searchers is impacted by the speech-based interaction imposed by screen readers. Hence, we investigate the behaviour of visually impaired users at four stages of the information seeking process, namely, Query Formulation, Search Results Exploration, Query Reformulation and Search Results Management. In the following, we describe these stages and formulate the research questions (RQ) for each of them.

Query Formulation. Query formulation is an important and critical stage of the information seeking process (Marchionini and White, 2007) as it has the potential to shape the entire search process. Searchers often find it difficult to successfully translate their information need into a query and employ different strategies to do so. For example, searchers can adopt an orienteering approach (using a series of short queries to reach the information of interest) (O'Day and Jeffries, 1993; Marchionini, 1997, p. 77) or a teleporting approach, described by Teevan et al. (2004) as a more directed behaviour in which a longer, more precise query is submitted (Hearst, 2009, p. 79).

In addition, there have been numerous efforts to address the challenging problem of query formulation; query-level support features such as interactive query suggestions (White and Marchionini, 2006) and search assistants (Anick and Kantamneni, 2008) have been designed and created to assist searchers in formulating their information needs. However, most of these support features have been evaluated with sighted users who interact with search engines differently from visually impaired users. Therefore, we focussed on the following research questions:

RQ1: Which strategies do visually impaired searchers employ when formulating their initial queries?

RQ2: How useful are query-level support features for screen reader users?

Search Results Exploration. Searchers spend most of their time at this stage of the information seeking process (Marchionini and White, 2007) to review retrieved results and to determine whether their queries have been successful. This is an important stage of the process as it plays a significant role in determining the future direction of the search task. The linear processing imposed by screen readers make this stage of the information seeking process challenging and time consuming (Craven and Brophy, 2003) for visually impaired searchers and therefore, we ask the following questions:

RQ3: What are the navigation strategies used by visually impaired searchers on the search results page?

RQ4: How does the sequential access of screen readers affect the number of search results viewed and the number of queries submitted by visually impaired searchers?

RQ5: How does the screen reader affect the number of external pages (beyond the search results list) visited by visually impaired searchers?

Query Reformulation. The process of query reformulation is common during information seeking as searchers' state of knowledge about their search tasks changes. Query reformulations can be a result of a change in the searcher's state of knowledge or in the searcher's mental model of the problem at hand, that is, their information need. Jansen et al. (2005) observed that a large portion of search sessions contain query reformulations. Hearst (2009, p. 80) attributed this behaviour to the ability of search engines to retrieve results in a fraction of a second which makes the strategy of "testing the water" well suited for sighted users. Linear processing of the retrieved results page by screen readers means that access to search results is slower and hence we investigate the following:

RQ6: What effect does the linear access of screen readers have on the query reformulation strategies of visually impaired searchers?

Search Results Management. This stage of the information seeking process is closely related to how searchers collect, analyse (Pirolli and Card, 2005) and use the information (Marchionini and White, 2007) encountered during the search process. For example, a person aiming to book flights online needs to search which airlines travel to their destination, compare the prices and only after doing so, they can use the information they found to complete their intended task. Hearst (2009, p. 80) described this part of information seeking as the broader process of information access and related it to sensemaking (Russell et al., 1993; Pirolli and Card, 2005). Information use, part of sensemaking, is the stage in the information seeking process when searchers understand the results and decide that the information collected is relevant and as complete as necessary to satisfy their information need (Marchionini and White, 2007).

For the study in this chapter, we view search results management as an intermediate step between exploration and information use and sensemaking. As the search sessions with the participants were relatively short, we did not always reach the stage in the information seeking process when they would use the information found. However, as we are studying complex search tasks which may require information gathering from multiple sources, we focus on search results management to investigate the differences in the way visually impaired and sighted searchers manage encountered information that they feel could be useful at a later stage in their information seeking process. We were, therefore interested in the following:

RQ7: How does the lack of persistence of the auditory screen reader interface affect visually impaired searchers' strategies to remembering and managing encountered information?

5.3 User Study

In this section, we describe the exploratory observational study that we carried out to investigate the information seeking behaviour of visually impaired users. Given the lack of previous work in this area, it is hoped that this exploratory study will lead to greater understanding of how visually impaired users carry out search activities on the Web.

5.3.1 Participants

We recruited 15 visually impaired searchers mainly via dedicated mailing lists. Our sample consisted of 13 users with no vision and 2 users with very low level vision. There were also no differences in the data we collected for the participants with different levels of vision as they all used screen readers to access the Web. As shown in Table 5.1, the group of participants that we recruited was diverse in terms of age, search experience and screen reader proficiency. Therefore, we recruited a diverse set of 15 sighted users to take part in this study in order to perform a comparative analysis of the information seeking behaviour. The questionnaire used to collect demographic information from the participants is included in Appendix A.

	Visually Impaired Users	**Sighted Users**
Age	32.6 years [22 - 50]	27.6 years [22 - 54]
Gender	11 male, 4 female	7 male, 8 female
Search Experience	10.3 years	10.9 years
Frequency of Computer Use	Daily	Daily
Use of Online Search Engine	Daily*(12)* Weekly*(3)*	Daily*(15)*
Screen Reader	JAWS *(12)* VoiceOver *(2)* Window-Eyes *(1)*	-
Screen Reader Proficiency	Advanced *(10)* Intermediate *(5)*	-

Table 5.1: Demographics of all participants.

5.3.2 Task

Prior to the experiment, we sent participants an information sheet which contained guidelines for choosing a complex task which they would perform during the observation. Those guidelines were derived from the set of criteria presented in section 2.2.1. Along with those guidelines, we also included examples of complex tasks to further help those who found it difficult to come up with their own search task. We opted for natural tasks (Kelly, 2009) as we wanted to observe participants in settings similar to those in which they carry their day-to-day search activities.

We constructed four categories of example tasks and ensured they were complex by validating them against the criteria presented in section 2.2.1. For example, as shown in Table 5.2, we constructed a travel task which would require the user to make a decision by comparing and analysing information found from different travel websites. The user is also likely to perform multiple searches and for an unvisited country, the task would involve a level of uncertainty. These factors contributed to making the travel task complex and as shown in Table 5.2, we did not fully define the example tasks so that participants use them only as triggers for defining their own information need. For example, every participant who performed a travel task defined it individually, according to where they would like to go, how to get there and what they like to do on holidays etc.

A few days before the observation, we reminded participants that they needed to think of a complex search task to complete and for those who did not use the provided examples, on the day of the observation, we validated their choice of tasks according to the criteria described in section 2.2.1. On some occasions, we did request participants to choose an alternative task as their chosen task did not match our definition of task complexity. In this way, we ensured that search tasks were of comparable complexity across all participants in the study.

Given that the examples were broad and vague, participants who used them still contributed to designing and shaping the task description and thus, we ensured that tasks were interesting for the participants and were as close as possible to real information needs. For visually impaired participants, the examples included one task from four different topics, namely, travel, relocation, audio books and e-books. For sighted users, we replaced the task on audio books with a task about postgraduate education. In Table 5.2, we describe the travel task and the complete list of tasks is provided in Appendix A.

Topic	**Task**
Travel	You will soon be on leave from work and you would like to travel to X. You want to find out the best ways of getting to X and the different places to stay. You are also interested in the places to visit, the different things to do while you are on vacation, the places to eat etc. Use your favourite online search engine to help you plan your vacation to X.

Table 5.2: Example tasks provided to participants.

5.3.3 Experimental Procedure

Each participant chose their own search task and used their own equipment to ensure that we observed them in settings close to those in which they perform their daily search activities. Each session was structured as follows:

- Prior to the observation session, participants were asked to sign a consent form and had to fill a pre-experiment questionnaire. This questionnaire collected demographic information, including data about their search experience and their proficiency with browsers and assistive technologies.

- Participants were then observed while they completed their chosen complex search task and their interaction with the search interface was recorded.

- After the observation, we carried out a semi-structured interview with the participants. This provided an opportunity to follow up issues identified during the observation. We recorded this interview for later analysis.

5.3.4 Data Analysis

The main source of data for analysis was the video recordings of searchers' interaction with the search engine. We transcribed the recording for each participant and analysed the transcriptions to identify emerging patterns as described in section 4.6. The video recordings combined with data from the questionnaires and the semi-structured interviews allowed us to appropriately capture the searching behaviour of the participants in the study. On the quantitative data, we carried out statistical testing at $p<0.05$ with a two-tailed unpaired *t*-test[1] and a chi-square test.

5.4 Results

In this section, we present and compare findings on the search behaviour of the participants at the following stages of the information seeking process, namely, query formulation, search results exploration, query reformulation and search results management. We structure the presentation of the findings according to the research questions (RQ1 to RQ7) identified in section 5.2.

5.4.1 Query Formulation

In this section, we focus on how the participants formulate their queries to express their information needs and we also study the awareness and use of query-level search support mechanisms.

RQ1: Which strategies do visually impaired searchers employ when formulating their initial queries?

[1]Given the differences in the variance between the two groups of participants, we perform unpaired *t*-test for unequal variances using statistical package R. We also checked significant differences with the non-parametric Mann-Whitney test to ensure correct statistical reporting.

We observed that visually impaired users submitted long complex queries representing the complete information need in an attempt to find what they were looking for in one step. Therefore, at the beginning of their search, most visually impaired searchers felt the need to be precise and specific with their search terms. When probed on this strategy, they explained that if they submitted specific queries, it would bring relevant results close to the top of the page, making access easier and quicker. As a result, as shown in Table 5.3, the average query length for the visually impaired searchers was close to 5 keywords. However, despite queries from visually impaired searchers being long and expressive, only 4 of them used advanced query operators such as "double quotes" or "plus" to be more specific in their queries and to restrict the results retrieved by the system.

Among sighted users, we observed an orienteering approach (O'Day and Jeffries, 1993) for query formulation as they issued quick, broad queries to get to the relevant part of the information space. Once the first set of results was retrieved, sighted searchers easily picked up clues and hints to iteratively refine their queries to get to the information they were interested in. This type of behaviour is common among sighted users and has been observed and defined in (O'Day and Jeffries, 1993). Therefore, sighted participants submitted more queries and shorter queries than visually impaired searchers as shown the Table 5.3. The length of queries from sighted users was shorter than sighted users and was close to 4 keywords.

	Visually Impaired Users	**Sighted Users**	**Statistical Testing**
No of Queries	4.47 [1.77] *(1 to 8)*	10.93 [6.54] *(4 to 23)*	$t(28)= -2.41$, $p=0.002$
No of Terms in Queries	4.61 [2.76] *(1 to 18)*	3.86 [0.67] *(1 to 10)*	$t(28)= 1.03$, $p=0.319$

Table 5.3: Mean number and length of queries [SD] *(Minimum to Maximum)*.

In light of this observed importance of the query formulation process, it would be reasonable to believe that visually impaired searchers would find assistance provided by search interfaces helpful and use query-level support mechanisms to support their query formulation process. However, this was not the case as the observations in the next section demonstrate.

RQ2: How useful are query-level support features for screen reader users?

For this research question, we investigate the use and awareness of the query-level support features under study. We describe each of the support mechanisms in the following and explain how they can be accessed with screen readers.

- **Query Suggestions** are alternative queries that appear in a drop down list in real time as users type their query. Screen reader users can access search suggestions by using navigation arrows to move down the list, however they have to be typing at a relatively slow pace to be able to hear this option.
- **Spelling Suggestions** appear at the top of the search results page when keywords have been misspelt and they are accessible by screen readers.
- **Related Searches** are similar to query suggestions but are presented to the user on the results page after the first set of results is retrieved. They are queries that are related to the user's search request and are accessible by screen readers.

Our findings about query-level search support features were surprising as they revealed a lack of awareness and use of these features by visually impaired searchers. Only 1 of the visually impaired participants used any of the search support features while completing their complex search tasks during the observation. The primary search engine used by all participants during the observation was Google whose interface provides all of the above-mentioned query-level search support features. Therefore, we asked screen reader users about their awareness and use of support features in the semi-structured interviews. 40% of visually impaired participants were not aware of at least one of the search support features on the interface and in Table 5.4, we describe the awareness for each of the three support mechanisms.

	Visually Impaired Users	**Sighted Users**
Query Suggestions	66.7% (2)	100.0% (23)
Spelling Suggestions	66.7% (2)	100.0% (12)
Related Searches	60.0% (0)	40.0% (2)

Table 5.4: Awareness of query-level support features (Total times used).

The query suggestion feature was known to two thirds of all visually impaired participants, but as shown in Table 5.4, the feature was used 2 times by only 1 visually impaired searcher during the observation.

During the semi-structured interviews, we probed the group of screen-reader users who were aware of the feature about their reasons for not using it. They agreed that while the suggested queries were accessible with their screen readers, interacting with them was not intuitive and could be difficult, time consuming and cumbersome.

One third of the visually impaired participants ignored the presence of spelling suggestions and most of those who did notice the feature were often confused by it. When using the Google interface and having misspelt a keyword, one of the participants remarked: *"Why does it ask me what I mean if that is exactly what I wrote?"*. One of the reasons for this kind of confusion is where misspelt terms sound the same or very similar to the correct spelling when pronounced by the screen reader. In these cases, visually impaired searchers sometimes fail to perceive the difference in spelling and therefore fail to understand why the system provides them with spelling suggestions. In the study, 47% of visually impaired participants were presented with spelling suggestions at least once (16 times in total), but they were used by only 2 participants.

As far as the Related Searches feature was concerned, 60% of the visually impaired participants were aware of their presence on the search interface. Those who were aware of the feature did know how to use it as the related searches appear as links at the bottom of the page. In general, screen reader users confused those with the links for search results and claimed they would rather *"go back to the part of the interface where there is a description of the results"*.

Sighted searchers had a higher level of awareness for Query Suggestions (100%) and Spelling Suggestions (100%). However, only 40% of participants were aware of Related Searches with participants suggesting that "*It would be great if they had been at the top of the screen*". The differences in awareness for Query Suggestions and Spelling Suggestions were significant with a chi-square test at ($\chi^2(1,30) = 6$, $p = 0.014$). As shown in Table 5.4, sighted participants also used the support features a higher number of times, with the difference in the use of Query Suggestions significant at ($\chi^2(1,30) = 11.63$, $p = 0.007$).

5.4.2 Search Results Exploration

As already discussed previously, the fact that screen readers process web pages sequentially from top to bottom poses numerous challenges, such as information overload and lack of context (Andronico et al., 2006a). This problem is more acute when it comes to searching, as users of screen readers are looking for specific pieces of information. As one of the participants said: *"While searching, I spend most of the time listening to irrelevant information than accessing information that could potentially be of use to me"*. Therefore, in this section, we discuss findings about searchers' browsing strategies when it comes to search results exploration.

RQ3: What are the navigation strategies used by visually impaired searchers on the search results page?

The most popular navigation strategies among the visually impaired searchers were heading to heading navigation (93%) followed by link to link navigation (40%), reading the full content of the page (46%) and searching for keywords (46%). A majority of the visually impaired participants described that they would try multiple strategies to get a better idea about the content and layout of the page. For example, in the absence of headings, a participant who typically navigates using headings will browse the page through the links or will search for specific keywords on the page. Despite improving the effectiveness of navigation, these strategies are still sequential and remain time consuming for the users of screen readers. The visually impaired searchers in the study were aware of this and as a result, we observed only 13% of the screen reader users visiting more than 1 search engine results page.

RQ4: How does the sequential access of screen readers affect the number of search results viewed and the number of queries submitted by visually impaired searchers?

Results exploration is the stage where searchers spend most of their time (Hearst, 2009), making it a critical stage for visually impaired searchers who according to previous research (Craven and Brophy, 2003; Ivory et al., 2004), typically spend between 2 to 5 times longer to browse results than sighted users. Therefore, we studied the number of retrieved pages that all participants viewed when completing their complex tasks and we present the findings in Table 5.5. Before visually impaired users can determine whether a query has been successful, they have to depend on their screen readers to sequentially process the list of results and therefore they only visited a mean number of 4.27 search results .

As far as multiple-tab browsing is concerned, we only observed this behaviour in 2 of the visually impaired participants in the study compared to 10 sighted users who opened multiple tabs or windows either to view more than one results simultaneously or to submit multiple queries. Managing multiple sources of information requires a high level of cognitive effort and users of screen readers have to increasingly

	Visually Impaired Users	Sighted Users	Statistical Testing
No of Search Results	4.27 [2.15] *(1 to 9)*	13.40 [7.39] *(3 to 29)*	$t(28)$=-4.60, p=0.0003
No of External Links	0.40 [0.83] *(0 to 3)*	2.27 [2.60] *(0 to 9)*	$t(28)$=-2.65, p=0.017

Table 5.5: Mean number of visited pages and external links viewed [SD] *(Minimum to Maximum)*.

depend on their memory during their search task. Therefore, it is harder to keep track and remember the contents of multiple pages at the same time.

Search results exploration is easier and quicker for sighted searchers as they can benefit from the visual rendering of web pages, that is, they can base their relevance assessments on aspects such as structure of the page, layout and graphics etc. Therefore, the average number of results viewed by sighted participants was significantly higher (13.40) than visually impaired participants (4.27) at ($t(28) = -4.60$, $p = 0.0003$). After submitting their queries, sighted searchers quickly scanned the list of retrieved results to decide whether their search terms have been successful. If they believed the results retrieved were not satisfactory, they changed their search terms to better match their information need. Hence, as shown in Table 5.3, sighted participants submitted significantly more queries (10.93) than visually impaired participants (4.47) at ($t(28)$= -2.41, p=0.002).

RQ5: How does the screen reader affect the number of external pages (beyond the search results list) visited by visually impaired searchers?

While exploring the search results retrieved by the search engine is an important stage of the information seeking process, previous research (Bates, 1989) has shown that searchers do not expect to find all required information in one place. Instead, they expect to find bits of information throughout the search process to meet their information needs. This behaviour is often observed when searchers visit a web page retrieved by search systems and then visit other external links on that page. The decision to do so can reflect the searchers' evolving information need which changes in line with encountered information. For example, a searcher completing a travel task may visit the wikipedia page for the place of interest and then follow the external link for the tourism office or transport facilities. In this study, this behaviour was limited among visually impaired searchers: 4 visually impaired participants visited a total of 6 external links compared to sighted participants (11) who visited external links 34 times as shown in Table 5.5.

5.4.3 Query Reformulation

The query reformulation stage of the search process often represents a change in the state of knowledge of the searcher and Marchionini and White (2007) discussed that the set of documents retrieved for a query often serves as feedback. This means that depending on what was retrieved for a query, the searcher is in a position to judge whether their query has been effective or whether the system has been effective at responding to their query. When searchers are not satisfied with the results, they can choose to reformulate their queries or submit new queries. There are several approaches to query reformulation, for example, searchers can decide to reformulate their queries using terms from their own knowledge or terms that can be found in the set of documents retrieved for the existing query.

RQ6: What effect does the linear access of screen readers have on the query reformulation strategies of visually impaired searchers?

In this section, we investigate participants' strategies for reformulating queries and in Table 5.6, we present data on the mean number of reformulations from visually impaired participants. We define query reformulations as the instances when the searcher refines an existing query by adding or removing terms from it. However, a substantial part of the existing query should be included in the new query for it to count as query reformulation.

	Visually Impaired Users	**Sighted Users**	**Statistical Testing**
No of Reformulations	1.27 [1.16] *(0 to 4)*	3.40 [3.44] *(0 to 13)*	$t(28)=-2.28$, $p= 0.035$

Table 5.6: Mean number of query reformulations [SD] *(Minimum to Maximum).*

The number of query reformulations was significantly lower among visually impaired searchers compared to sighted searchers as shown in Table 5.6. When prompted on this behaviour, visually impaired searchers reported that they trusted the search engines and that if they did not find satisfactory results, they *"would start from scratch with a new query because it is not the system's fault"*. The number of query reformulations was higher among sighted searchers and we observed that most sighted searchers reformulated their queries with search terms that they picked from documents retrieved for their existing queries. Therefore, sighted searchers' query reformulation strategies were more iterative and inline with the orienteering behaviour reported in (O'Day and Jeffries, 1993) where searchers use information in their current state to influence the future directions of their search.

5.4.4 Search Results Management

Given the challenges faced by visually impaired searchers, we investigate how the participants in this study managed the information they found during the search process. We were particularly interested in this stage as we chose to study search behaviour for complex tasks which are known to be challenging and cognitive intensive, requiring searchers to keep track of the information they encounter.

RQ7: How does the lack of persistence of the auditory screen reader interface affect visually impaired searchers' approaches to remembering and managing encountered information?

We observed that 73% of visually impaired participants relied on some form of note taking to keep track of their search results either through word processors such as Notepad or using Braille note taking devices. Notes taken by the screen reader users varied in the level of structure: while some pasted snippets as well as URLs in their notes, others only wanted to keep track of the search terms that led them to specific results. Other common approaches for managing encountered information was through bookmarking (47%) or saving as favourites (47%). All these different strategies had the common goal of serving as memory aids to allow the visually impaired searchers to get back to specific pages which had previously been useful.

During the semi-structured interview, we probed searchers on this practice and found out that given that complex search tasks are likely to be completed in multiple search sessions which are often spread over a period of time, visually impaired searchers need a way of remembering the information they encountered previously and also the stage they were at in their search process. As previously discussed, the search process progresses at a slower pace for the visually impaired searchers and usually takes a much longer time to complete. Therefore, visually impaired participants developed coping strategies to support them in their tasks (Bigham et al., 2007).

Overall, we observed that the search results management stage was less important for sighted users as they know they can always get back to a web page quite easily if they remember anything about how they initially got to that page, for example, the query they used, the URL of the page etc. As a result, note taking was less common (46%) among sighted searchers as most of them reported that they would try to remember the link to the result or they would search for it again. However, 60% of sighted participants reported using bookmarks and 13% said they would save a page as a favourite or print it out.

5.5 Discussion

In this section, we discuss findings from the exploratory observational study focussing particularly on the search behaviour of visually impaired searchers. We structure the discussion according to the four stages of the information seeking process under study namely, query formulation, search results exploration, query reformulation and search results management.

5.5.1 Query Formulation

Query formulation is a critical stage in the search process as users try to express the mental model of their information need using a query. Our observations showed that visually impaired searchers try to express their complete information need in a long precise query and as a result, their queries were more expressive. Therefore, visually impaired searchers displayed a teleporting behaviour (Teevan et al., 2004) which is in contrast to the orienteering behaviour (O'Day and Jeffries, 1993) displayed by sighted searchers who formulated broad queries initially to get to the relevant part of the information space. This difference in behaviour can be readily understood when one takes into account the fact that, as shown by the findings, many aspects of the search process are slower for visually impaired searchers than for sighted searchers. Providing an initial search request which is specific enough that it reduces the number of interactions required from submitting that query to reaching the required results, is one of the most effective strategies a visually impaired searcher can employ to try to reduce the overall search time.

Sighted searchers can afford to display an orienteering behaviour as they can decide within seconds of submitting a query whether it has been successful or not. This is a more difficult and time consuming process for visually impaired searchers. Despite shortcut navigation strategies such as heading to heading or link to link navigation, screen readers still have to linearly process all or a big part of the results list before the visually impaired searchers can decide whether their search is going in the right direction and whether their choice of keywords was correct. These findings show that the beginning of the search process can be challenging for users of speech-based screen readers and that these users should be supported during query formulation especially for longer queries. There are speculations that an orienteering strategy with shorter queries could be less cognitively taxing (Teevan et al., 2004). Therefore, visually impaired searchers could benefit from an awareness of such alternative search strategies to increase the effectiveness of their search activities.

In addition, visually impaired searchers cannot benefit from visual cues on search interfaces that could help their query formulation strategy. For example, dynamic query suggestions which appear in a drop down box in real time as a query is being typed, require screen reader users to navigate away from their focus, listen to the suggestions and navigate back again to the query box. In these cases, such features are considered to have a poor cost-benefit ratio in terms of the time required for access and the likely benefits of such strategies. Therefore, query-level support features were not popular among visually impaired searchers. The lack of awareness and use of support features was unexpected as previous research has shown that searchers are more likely to use support features for difficult or unfamiliar tasks (Fowkes and Beaulieu, 2000; Gooda Sahib et al., 2010). Yet, in this study, all visually impaired participants performed complex search tasks but they still did not use any of the support features because despite being accessible, those support features were not usable in the following ways:

- **Query Suggestions** are only noticeable to users of screen readers when they are typing at a relatively slow pace and to access them, users have to navigate away from the search box. This interferes with the way visually impaired users interact with search systems, making the cost of using query suggestions higher than the potential benefits. Therefore, from a screen reader user's perspective, query suggestions have low utility (Russell et al., 1993) and are most often ignored. Query suggestions was the most-used feature among sighted searchers during our observation. This is because sighted users perceive query suggestions to have high utility as they can interact with the feature without any additional effort.

- **Spelling Suggestions** are accessible by screen readers only if the user is not navigating the search page through headings, because if they are, they will not find the spelling suggestions as they are not at the same heading level as the retrieved results. As searchers are focussed on exploring retrieved results once they have submitted a query, they never reach the part of the interface where spelling suggestions are presented. When using the feature for one of her queries, one participant was still confused as to why suggestions were being presented to her as the screen reader often pronounces misspelt words in the same way they would be pronounced when correctly spelt. This caused confusion and frustration during our observations.

- **Related Searches** was the least-known feature both by visually impaired and sighted searchers, given its position at the bottom of the search interface. If they are not satisfied with the retrieved results, most searchers will not wait until they reach the bottom of the first results page to reformulate their queries. Therefore, searchers rarely encounter the list of related searches. This feature is also not available for all queries and thus is not consistently present on the search interface. This inconsistency is a challenge for screen reader users who 'learn' how to use interfaces, that is, visually impaired users often memorise the layout and structure of the web pages that they frequently visit. For example, for search interfaces, visually impaired searchers are likely to learn whether results will be presented in a table or using headings in order to decide on their navigation strategy.

The lack of awareness and use of search support features highlights the importance for search interface features to be both accessible and usable because if interface components are viewed as having low utility (the potential benefits do not exceed the required efforts), they will remain unpopular with users of speech-based screen readers. Therefore, it is essential to ensure that support features are designed to be accessible with assistive technologies such as screen readers, but they should also be usable and easy to integrate with the mode of interaction.

5.5.2 Search Results Exploration

The results exploration stage is critical for visually impaired searchers as they take two to three times longer than sighted searchers to explore search results (Ivory et al., 2004). Sighted searchers in the study needed a few seconds to quickly get the gist of the retrieved information to decide whether a query had been successful or not. They used the structure, the layout and the style of web pages to decide, within seconds, whether pages were relevant or not as also observed in (Tombros et al., 2005). This was however not readily possible for visually impaired searchers who typically describe graphical user interfaces, firstly by their content and later augment their description with information about the spatial layout (Mynatt, 1997). Hence, visually impaired searchers base their assessment of relevance mainly on the content of the page rather than its structure or layout.

The use of speech-based screen readers necessitates that visually impaired searchers have to invest considerable cognitive efforts to acquire the content of the page as they need to build their mental model of the page from the pieces of information being read to them by the screen reader. This was reflected in the number of search results and external links viewed by visually impaired users in our study. Therefore, there is the need to make this process more effective for screen reader users. This stage of the information seeking process is likely to be the one where the lack of information scents impacts the search behaviour of visually impaired searchers the most as additional information conveyed by visual cues is not accessible. Hence, due to this lack of contextual information, visually impaired searchers displayed a limited exploratory behaviour during the observational study and visited a significantly lower number of external links compared to sighted searchers. This behaviour can be explained by the fact that when visiting web pages from the search results list, visually impaired searchers fail to grasp the benefit that external pages could have on their search process. Therefore, unless there is a clear benefit in visiting an external link, screen reader users are discouraged from doing so as the costs associated with visiting and understanding a new page is high. This calls for further work on information scents for visually impaired searchers; what act as information scents for visually impaired searchers and how they should be designed to be successfully conveyed via a screen reader?

5.5.3 Query Reformulation

Despite completing complex search tasks, the number of query reformulations among visually impaired searchers was low. This supports our observations of a goal-oriented strategy at the initial stages of the information seeking process as visually impaired searchers often think that unsatisfactory retrieved results are not the search system's fault but their own. Instead of fine tuning current queries, visually impaired searchers preferred to submit different ones. One of the reasons for such behaviour is that for users of screen readers, it is more difficult to pick up cues of what might be useful to direct a query in the desired direction. Lack of contextual information and information scent as well as inaccessible search support features also impact the query reformulation process for visually impaired searchers.

This implies that despite the presence of multiple support features on current search engines interfaces, visually impaired searchers do not see the benefits of iteratively reformulating queries and are not fully supported to do so. Therefore, there is the need to increase the awareness of visually impaired searchers on the potential effectiveness of a query reformulation strategy. The process of query reformulation is relatively easier for sighted searchers and in the study, they reformulated their queries significantly more. Currently, search engines retrieve results in a fraction of a second and it is effortless for sighted searchers to get the gist of retrieved results and reformulate in case of unsatisfactory results. In addition, features such as Google Instant[2] which shows search results as queries are being typed, further enhance support for sighted searchers for query reformulation.

5.5.4 Search Results Management

Our observations showed that at this stage of the information seeking process, note taking was the most common strategy employed by visually impaired users to keep track of encountered information. Visually impaired searchers currently rely mostly on external applications such as word processors to take notes during their search process. While this is an effective strategy to relieve the load on working memory and to reduce the time-consuming need to revisit pages, it also requires visually impaired searchers to constantly switch between applications which can be inconvenient and contribute to cognitive load.

The screen reader already requires significant cognitive effort from its users and when managing search results, visually impaired searchers are faced with a high level of cognitive load while comparing and analysing information from multiple sources. Therefore, they develop coping strategies such as bookmarking and note taking to make relevant web pages more persistent and to make them easier to re-access in the future. Note taking was not popular among sighted searchers as they found it relatively easy and effortless to re-find results of interest either by searching for them again or by keeping them open in multiple tabs and windows. This implies that, unlike sighted searchers, visually impaired searchers need to be supported by search systems to manage the information they find during the search process as re-accessing information and re-acquiring the context of the search task are relatively more taxing.

5.6 Implications and Guidelines

The findings reported in this chapter and in previous work (Craven and Brophy, 2003; Buzzi et al., 2004; Leporini et al., 2004; Andronico et al., 2006b; Bigham et al., 2007) have clearly indicated that the needs of visually impaired searchers are not adequately addressed in current search engines and that a number of currently provided support mechanisms are not beneficial to users of speech-based screen readers. It

[2]http://www.google.com/instant/

is clear therefore that the importance of taking an inclusive and user-centered approach to user interface design cannot be underestimated in the development of search interfaces that are both accessible and usable. In this section, we firstly discuss the implications of the findings and provide specific guidelines to consider when developing accessible and usable search interfaces for visually impaired searchers.

5.6.1 Implications for Search Interface Design

Our findings on the awareness and use of query-level support features among visually impaired searchers highlighted an important point about accessibility of interfaces. They suggest that, while it is essential to make interface components technically accessible (Di Blas et al., 2004; Petrie and Kheir, 2007) via assistive technologies, it is equally important to ensure they are usable and do not interfere with the way visually impaired users interact with interfaces. Previous works such as (Andronico et al., 2006b) have proposed accessible search interfaces by adapting what already exists, that is, making components of existing interfaces accessible through assistive technologies. While this is a step forward, we believe it is unlikely to be as effective as an approach which takes into account the specific needs of the user group from the start. As interfaces are usually designed through a user-centred approach, many design decisions are dependent on the cognitive abilities of the target users and factors such as users' approach to processing information, users' use of interface components, users' gaze pattern on the screen etc. are taken into consideration. Therefore, by adapting interfaces that have been designed for sighted users, we assume that the behaviour of visually impaired users for the activity that the interface supports, is the same as sighted users. However, this might not be the case because the way visually impaired users access the interface impacts their perception of both the interface and the activity that it supports and hence, the interface, even if tweaked, remains an interface for sighted users (Leuthold et al., 2008).

Thus, we should take the needs of the target population into consideration to ensure that we are not assuming capabilities that screen reader users do not have (Craven, 2004). For example, the drop down list with query suggestions can be made accessible with screen readers, but how to make suggestions accessible on a cognitive level is important as this is what determines whether searchers will ultimately use this function or not. Query suggestions are useful for sighted searchers because the way they are presented captures the attention of the searchers as they type their queries. This is not currently the case for visually impaired searchers and as a consequence, this group of users ignores a feature that could potentially support them in their search process. Thus, merely making accessible features which have been designed based on visual cues is unlikely to help visually impaired searchers in their tasks, and will increase the cognitive load imposed on such users. This is why design decisions for interface components should be made with considerations for the cognitive effort that they will require from target users.

Our findings on the differences in search behaviour also suggest that we should take into consideration the mode of interaction when designing interfaces, that is, whether users will be interacting with the system visually or using an auditory interface such as the screen reader. This is important because differences were observed between the two groups of searchers in how they explore and manage search results when accessing the search interface in different modes. This is in agreement with previous work (Tombros and Crestani, 2000) which reported how users' perception of relevance for spoken documents were affected by the way the documents were presented to them. Tombros and Crestani (2000) also argued for more sophisticated ways of presenting documents as a result of the low accuracy and low speed of relevance judgements for spoken documents.

5.6.2 Limitations

The type of tasks used in the study relied heavily on the definition of task complexity. Taking into consideration the subjectivity of the concept, despite providing guidelines, participants' understanding of complex tasks might not have been similar to ours. However, to mitigate the impact of this limitation, we validated participants' choice of task at the beginning of each session using the criteria described in section 2.2.1. In addition, we also tried our best to ensure that participants chose tasks that they had not carried out before. We explained the purpose of our work and explicitly required them to choose a complex task that they have not previously completed. However, it was beyond our control if any participant performed a task which they were familiar with. In addition, statistical testing on small samples such as the ones in this study, has its limitations. However, we used the *t*-test and chi-square only to validate the findings on the significant differences that we observed between visually impaired and sighted searchers.

5.6.3 Guidelines for Designing Accessible Search Interfaces

The comparative analysis between visually impaired and sighted searchers for complex search tasks revealed some differences in their search behaviour especially at the query formulation and results exploration stages. Therefore, in this section, we suggest the following guidelines that we believe are important to consider when designing accessible search interfaces for visually impaired searchers:

- **Design interface components that provide the right type of information scent.**

  When designing components for accessible search interfaces, we should ensure that they are compatible with assistive technologies and do not affect the way visually impaired users interact with search interfaces. Interface features, such as query-level support features, should provide the right type of information scent to allow visually impaired searchers to navigate effectively through the information space. The Web is a large unstructured source of information and to encourage an information foraging behaviour as described by Pirolli and Card (1999), the right type of information scent should be provided to screen reader users, taking into consideration their mode of interaction with the search interfaces. However, we also believe that assistive technologies should be enhanced to cope with secondary information that is provided by interfaces, that is, information that is not directly relevant to the user's task but might be useful for the completion of the task.

- **Consider at which stages of the information seeking process the target group of users are most likely to need support.**

  In this way, it will be possible to provide the right type of support at the right stage in the search process, which for the visually impaired participants, are query formulation, search results exploration and management. Depending on the mode of interaction that the target group of searchers use to interact with search systems, information seeking behaviour studies should be carried out to determine when searchers need most support and these studies should be used to inform the design of interfaces.

- **Include auditory previews and overviews for search interfaces.**

  As an information-rich interface, the search interface would benefit from the use auditory previews and overviews. Previews (acting as a surrogate for a single object of interest) and overviews (representing a collection of objects of interest) have been defined and designed to support the dynamic and iterative process of information seeking in digital libraries (Greene et al., 2000). Such representations of objects on the search interface, for example, individual results or a complete results set, would help visually impaired searchers to speed up their search process by allowing them to manage their time more efficiently. Visually impaired searchers could spend more time viewing content that they are interested in and avoid viewing retrieved results that are not relevant to their information need.

- **Display search results to allow more efficient results exploration.**

  Screen readers impose a sequential processing of retrieved results which is time consuming. Grouping techniques such as clustering should be used to put similar results together so that only an overview of the results is provided to the users of screen readers. In this way, searchers can get the gist of the results retrieved and if they find them useful, they can view the more specific results within each group. Therefore, more work and research is needed to explore how new techniques could be applied to results presentation so that searchers are provided with a more efficient exploration strategy.

- **Support searchers in managing their search results so that they can make sense of encountered information.**

  Visually impaired searchers have to rely tremendously on their memory when searching as they do not benefit from persistent information on interfaces. Therefore, system designers should ensure that they provide visually impaired searchers with an integrated solution to keep track of the information they encounter. Also, as there is evidence that the search process of speech-based screen reader users is time consuming and likely to be completed over multiple search sessions, visually impaired searchers should be supported to record their progress with their search task, especially for complex search tasks where they may be uncertain about the search domain or the task itself.

  History mechanisms should be designed to automatically monitor the progress of the search task, for example, through search trails. Search trails show the routes that searchers have travelled within the information space, including details about the origin of the search (queries), the destinations (relevant pages) as well as the information gathered along the way (White and Huang, 2010). While such an interface feature may be able to help visually impaired searchers in managing the search process, it also has the potential to motivate an orienteering behaviour towards searching which, as previously reported, was not observed among visually impaired searchers.

5.7 Chapter Summary

In this chapter, we investigated the information seeking behaviour of visually impaired users for complex search tasks on the Web. We focussed on complex search tasks because they are challenging, cognitive intensive and they affect the performance of all types of users. We described an exploratory observational study that we conducted with 15 visually impaired participants to study search behaviour at the following stages of the information seeking process: query formulation. search results exploration, query reformulation and search results management. We also performed a comparative analysis between visually impaired and sighted searchers and reported significant differences at different stages of the information seeking process including query formulation, search results exploration and search results management. Additionally, we also observed differences in the awareness and use of query-level support features such as query suggestions and spelling support.

The observational study presented in this chapter has provided insights into the information seeking behaviour of visually impaired users on the Web and the comparative analysis between visually impaired and sighted searchers has contributed to our understanding of the impact that the mode of interaction has on information seeking behaviour. Following the in-depth review of web navigation through screen readers in Chapter 3 and the work undertaken in this chapter, we have a better understanding of how visually impaired users perceive search interfaces and the interface components that could support them during the search process, especially for complex tasks.

In the rest of this thesis, we address the difficulties encountered for search results management and query formulation. The study carried out in this chapter provided some indications of the features that could assist visually impaired users at these stages. However, to truly adopt a user-centred approach, we need to engage visually impaired users in the design process. Therefore, in the following chapter, we propose and evaluate an accessible method using a narrative scenario and a dialogue-based interaction to involve visually impaired users in the design process.

Chapter 6

Using Scenarios to Engage Visually Impaired Users in Design

6.1 Introduction

Following the exploratory study in Chapter 5, we identified user requirements for a search interface to support visually impaired searchers during their information seeking activities. However, given that we interact with search interfaces in a significantly different way than screen reader users, it was necessary to verify these requirements with potential users to ensure that we share the same understanding of the challenges experienced during online information seeking.

Therefore, it was essential to engage potential users in the design process and in this chapter, we describe an approach based on a scenario to verify requirements with visually impaired users. We created a textual narrative scenario about the yet-to-be constructed search interface and its features and used it as the basis for a dialogue between the designers and potential users to gather feedback about the proposed design plans and to brainstorm new design ideas. In section 6.3, we explain the rationale for the participatory approach undertaken in the development of the scenario-based technique to engage visually impaired users in the design process. In section 6.4, we describe the scenario-based approach and we report findings from its evaluation with potential users in section 6.5. Finally, in section 6.6, we reflect on the scenario-based approach, discussing its benefits and challenges as well as the practical experiences from using the approach to gather feedback from potential users.

6.2 Motivation

When designing accessible interfaces, it is crucial for the designers to make sure that their understanding of the problem is aligned to the users' experience of their interactions with the interface. When designers interact with systems using different senses, devices and interface widgets compared to the target population, it can be difficult for the designers to exclusively depend on their expertise to correctly imagine the needs of the users and to conceptualise their interactions with the system. Thus, designers have to be particularly sensitive as to how the group of users perceive technology (Newell et al., 2006).

As a result, design paradigms such as "Inclusive Design" (Clarkson, 2003; Imrie and Hall, 2001), "Design for All" (Newell and Gregor, 2000) and "User Sensitive Inclusive Design" (Newell et al., 2010) have been proposed to encourage the design team to include non-standard populations such as older and disabled users in the design process. The aim of these approaches is to give an effective voice to users in the design process, and to enable designers to develop real empathy towards users to ensure they communicate design ideas in an accessible form.

As we were unable to use visual techniques such as storyboards or paper mockups, we propose in this chapter, the use of scenarios for participatory design with visually impaired users. We used a scenario, expressed as a textual narrative, as a basis for dialogue between designers and users in the design of a search interface. There were two levels to our approach to participatory design: firstly, we included a visually impaired user with knowledge of assistive technologies as a full member of the design team and secondly we recruited 4 representative visually impaired users to provide formative feedback during the scenario-driven prototyping sessions. By using scenarios and this multi-level approach to participatory design, we were able to verify user requirements for the information-rich search interface, to engage visually impaired users in the design process to identify limitations with the proposed design plans and to brainstorm new design ideas with users based on their experience and expertise. Therefore, the contributions of this chapter are three-fold:

1. We propose a participatory approach based on a textual narrative scenario, tailored to the abilities of visually impaired users to engage them in the design process We describe the development of the approach explaining the steps involved in the creation of the scenario and we also highlight the contributions of the visually impaired member of the design team during this process.

2. We evaluate the approach with four visually impaired users and describe the type of feedback that we gathered in a participatory design setting through the use of a scenario as a basis for dialogue. We discuss how requirements for the search interface were verified with potential users and how new design ideas were brainstormed after a critique of proposed design plans.

3. We reflect on the proposed approach outlining its benefits, challenges and the practical experiences that we gained from applying it so that the approach can be reused or further developed. As the proposed approach was novel in its use of a textual narrative scenario to engage visually impaired users in the design process, we reflect on its development and evaluation to identify lessons learnt so that any further implementation of this approach can be improved.

6.3 Rationale for the Participatory Design Approach

Many visually impaired users access the Web through speech-based screen readers that render the content of web pages linearly in computer synthesised speech. The linear rendition of text by screen readers plus the fact that they do not represent the spatial layout of web pages, such as columnised format, means that the mental models that visually impaired users form of web pages can significantly differ from those of sighted users (Stockman and Metatla, 2008). Hence, in a participatory design setting, it is essential for visually impaired users and sighted designers to be able to interact at a level where both parties can share the same understanding of the yet to-be-constructed artefact to productively contribute to design plans.

There is a parallel to be drawn here between web navigation and navigation of real world spaces. Given due consideration, it is unlikely that when giving directions to a pedestrian, the way in which one would describe those directions would be the same for a sighted pedestrian as for a blind pedestrian. Instructions to the sighted pedestrian are likely to exploit visual cues, to be given at a granularity level appropriate to someone who can take in their surroundings at a glance. On the other hand, directions to a blind pedestrian, if they are to be useful, should be in terms of landmarks that are detectable by them, and at a level of granularity related to the way in which they interact with their surroundings, whichever mobility aid they might employ, be it a dog or a white cane etc.

Similarly, within human-computer interaction, in order to be useful, the way in which interactions are articulated need to take into account the senses and tools at the disposal of the user, as well as the level of granularity at which they interact with the system. Based on this need to embed an understanding of how end users interact with the system at a deep level and the fact that other members of the development team can not easily share that experience (using a screen reader with a covered screen is not a realistic surrogate for a blind user with thousands of hours of screen reader experience (Petrie and Morley, 1998)), we adopted two levels of participatory design.

Firstly, we included a visually impaired user as a full member of the design team. This individual has been blind since birth and has over 20 years experience of using assistive technologies including speech-based screen readers. He has over 15 years of experience using JAWS, has used Window-Eyes for several years and in the last three years, he has also gained experience using VoiceOver. Additionally, the visually impaired co-designer has extensive online searching experience (nearly 15 years), mainly using Internet Explorer as the main browser. However, he also has some experience with Firefox and Safari. Involving a visually impaired user in the design team provided the development team with immediate feedback in discussions about the development of appropriate interface artefacts, for example, properly labelled controls, the types of interactions supported by screen readers (the use of screen reader commands for web page navigation) and the appropriate vocabulary with which to describe interactions to blind users, for example, keystrokes rather than mouse clicks.

This understanding of how screen reader interaction works led to the development of a scenario and a dialogue about it being pitched at an appropriate level, using the appropriate language, to make sense to a screen reader user. For example, the interface comprised several different components such as a search box, to which the user would frequently want to navigate. In this case, a knowledge of screen reader interaction suggested that the appropriate way for this to be achieved should be through a keyboard shortcut and that an appropriate means of confirming that the action has been executed could be through playing a non-speech sound.

The second level at which participatory design was achieved was through the recruitment of four visually impaired participants who took part in prototyping sessions to provide formative feedback to the design team. In these sessions, the overall scenario was used as the basis of dialogue about how users would interact with the system using a screen reader and the usefulness of proposed interface features.

6.4 Developing a Scenario-Based Approach

In user-centred design approaches, requirements verification is the phase of the design process whereby the user requirements of a system are analysed and validated to ensure that the designers and the users share the same understanding of the problems that were identified during the requirements gathering stage. For participatory design approaches, at this stage, designers communicate very early design ideas to users to get their feedback (Pekkola et al., 2006).

In this thesis, we verified requirements with potential users by using a scenario expressed as a textual narrative which then formed the basis of dialogue between the designers and the users. Basing this dialogue on a narrative scenario evokes a form of role play which works well because the human mind is adept at overloading meaning in narrative structures (Carroll, 2000b) (p. 54). Therefore, they are meant to stimulate the imagination (Jarke et al., 1998) and to provoke new ideas (Bødker, 1999) and are well suited for use in participatory approaches to engage users early in the design process.

The approach described in this chapter is a hybrid one involving a combination of participatory design (Muller, 2007) and the use of a detailed scenario to discuss ideas with target users (Go and Carroll, 2004). We included a visually impaired user throughout the design process, particularly in the development of the scenario-based approach. The participation of a visually impaired user representative was invaluable when developing the scenario and its associated textual narrative as it helped us to conceptualise how potential users will interact with the system given their use of screen readers. It also allowed us to establish the level of detail at which the scenario should be discussed with end users. In Figure 1, we provide a broad overview of the framework we followed to implement the scenario-based approach and in the following we describe each step of the process in detail.

Step 1: Identify set of interface features.

From the initial observations with visually impaired users in Chapter 5, we identified a set of search interface features that we thought could support visually impaired searchers during information seeking on the Web. These interface components were chosen to address the difficulties observed during the exploratory study in Chapter 5 and were influenced by the designers' intuitions and their knowledge of search user interface components. During this process, the visually impaired member of the design team contributed significantly from his knowledge and experience of using both graphical interfaces (via screen readers) and self voicing auditory interfaces. This, to some extent, allowed the sighted designers

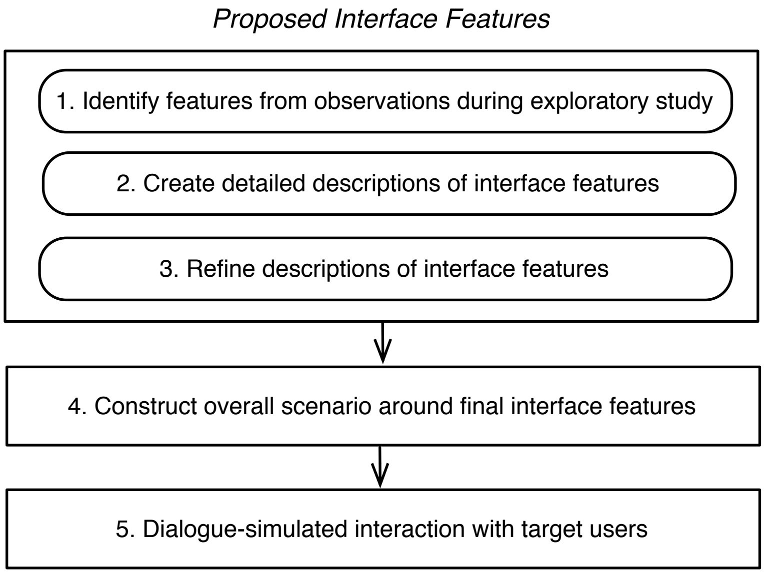

Figure 6.1: Framework for scenario-based approach.

to conceptualise the mental model they had to follow when designing interface components.

Step 2. Create detailed description of features.

To communicate the designers' ideas for the search interface, we created detailed descriptions for all interface features. As we were using a textual narrative scenario, we had to ensure that the designers' ideas were correctly being conveyed to the users and therefore, we focussed significantly on describing each interface component. For example, we provided the following description for an integrated note taking feature that we proposed on the interface:

> *Searchers can create a note and the system asks them where they would like to save this note and to give it a name. The note is divided in two parts: The first part of the note is editable by the searcher, that is, they can type ideas, copy and paste things from web pages etc. The second part cannot be edited and is used to save search results automatically by the system.*

Creating these detailed descriptions of the proposed interface features led to the sighted designers having to vocalise their design ideas for interface features that would typically be rendered visually. In the context of design, this was useful as it forced the designers to re-examine their design proposals taking into considerations the abilities of the users and how they would interact with the proposed feature. Therefore, in this step, the contributions of the visually impaired team member were extremely helpful in discussing the functionality of suggested support features as well as how searchers would interact with them. Through such discussions, the sighted designers could ensure that they were using interaction components that were appropriate, and that they were using the correct vocabulary to describe interface components and were not using terms relevant only to sighted users.

Step 3. Refine description iteratively.

To ensure that the designer's and the users' understanding of the proposed features were the same, we iteratively refined the description of the features through several informal conversations with the visually impaired member of the design team. For example, one idea was that a context menu might be useful to provide access to a set of options that become available when looking at individual search results. The idea of doing this in the form of a context menu was contributed by the visually impaired team member, who highlighted that context menus were familiar interaction artefacts to most screen reader users.

The visually impaired team member further contributed that the way to initiate the interaction with end users about the context menu should be by telling them to use the key combination Shift+F10, rather than right clicking, as the keystroke is the usual way a visually impaired user will initiate the interaction rather than the right mouse click which is familiar to sighted users. Therefore the visually impaired team member provided us both an appropriate interaction artefact, and the most fitting means of describing the interaction to end users. The options to be made available through the context menu were then identified and the best ways of implementing and describing the interactions to end users were then refined through discussions among the design team members. The following was the final description we used for the context menu:

> *You are aware that this new interface has a menu associated with each search result so that you can open, save, email and copy results. You hit the menu key and you find the following options in this particular order (Save Result, Copy, Email, Open). This is rather like the context menu you have in Windows that you bring up using Shift+F10.*

To enhance the textual description of some search support features, we referred to examples from other popular interfaces such as Google Search (results presentation with title, short description and web address) and Windows (context menu) that the users would be familiar with as these familiar points of reference helped the visually impaired users to better envision the proposed search interface.

Step 4. Construct scenario around interface features.

Once we finalised which search support features to include in the scenario, we created an overall scenario, like a story, with a specific setting whereby the user was using a search interface for the first time after hearing about it from a friend. As we were also evaluating a new history mechanism and interface features to support users to resume search tasks and keep track of encountered information (Morris et al., 2008), the scenario also included a stage where the user had to leave the task midway to attend an important appointment.

When constructing the overall story, it was essential to ensure it included all suggested interface features in the correct order and in a reasonable sequence. For example, we could not describe a feature for managing search results before we have asked the users to choose a search task and submit their first query. The overall scenario used for the proposed approach is given in Appendix B.

Step 5. Walk-through the scenario with target users.

After the overall scenario was constructed, we used it as the basis for a formative evaluation with potential users (the procedure for the user evaluation is explained in more detail in section 6.5). The evaluator undertook a walk-through of the overall scenario through a conversation with each of the potential users and at each step of the interaction, the evaluator would describe the interface feature to the user and explain how he could would interact with it. Then, the evaluator would ask the user for feedback on the interface feature followed by discussions on the alternative interaction paths resulting from multiple design ideas.

6.5 User Evaluation of the Scenario-based Approach

We evaluated the proposed approach by conducting a conversation with potential users during which we walked through the overall scenario with potential users of the system. The goals for the evaluation were two-fold. Firstly, we wanted to verify the requirements for a new search interface to assist visually impaired users for complex search tasks and to do this, we initiated the dialogue between the users and the designers to be able to communicate and discuss early design ideas. Secondly, the aim was to evaluate the use of scenarios in a participatory design setting for engaging visually impaired users in the design process. Hence, in section 6.6, we discuss the benefits, challenges and practical experiences of using the proposed approach for user engagement.

6.5.1 Participants

We evaluated the scenario-based approach with four visually impaired users who were recruited through word of mouth and via online email lists. The participants in the evaluation were experienced searchers who rated their proficiency with assistive technologies from intermediate to advanced. In Table 6.1, we provide demographic information about these participants.

Age	37 years
Gender	M*(3)* F*(1)*
Search Experience	12 years
Screen Reader	JAWS *(3)* VoiceOver *(1)*
Frequency of Computer Use	Daily*(3)* Weekly*(1)*
Use of Online Search Engine	Daily*(3)* Weekly*(1)*

Table 6.1: Demographics of all participants.

6.5.2 Procedure

For each evaluation session, we used a standard script of the final scenario that we created (described in Appendix B) to ensure that the users and ourselves shared the same understanding of the requirements for a new search interface. To begin with, the evaluator asked the user to think of a search task to complete. We left the choice of task open to elicit greater participation and user engagement with the scenario. The choice of search task did not affect the use of the script as it was built in such a way that its primary focus was on interaction with individual interface components and thus could be adapted to any search task.

During the session, the evaluator who was the one in charge of the script, started the conversation with the participant by conducting a walk-through of the scenario in line with the script. Therefore, at each step, the evaluator provided the user with complete descriptions of the search interface feature and prompted them for their feedback. The evaluator and the user also discussed how each interaction would work, including alternative interaction paths. We illustrate, in Table 6.2 and in Table 6.3, parts of the dialogue-based interaction between the user and the evaluator. Following the walk-through of the scenario, we conducted a semi-structured interview with participants to further enhance user engagement and to encourage them to speak about their experience. To maximise the capture of user feedback, we audio recorded all of the interactions between the evaluator and users for later analysis.

Evaluator: Your friend has told you about a new search system and you would like to try it out for yourself to see how good it really is. Think of something you would like to search on this new system. Once you have chosen your search task, you type the address of this new page in your web browser and you reach the page with the cursor in the search edit box. **"What do you type as a query?"**
User: *digital rights accessibility*
Evaluator: You type this query and hit enter. If you misspell a word in your query, the system will specify which term you misspelt and allow you to submit a corrected version of your query.

Table 6.2: Excerpt on query specification

6.5.3 Findings

We present, in this section, findings from the user evaluation we conducted. We group the feedback gathered from the participants in the following categories:

- **Verifying requirements**

  The scenario-based approach allowed us to verify the user requirements that were identified during the observational study in Chapter 5. By using the approach described in this chapter, we were able to ensure that the design team and the target users shared the same understanding of the difficulties faced by visually impaired users when using current search interfaces.

  In this respect, we were able to, for example, ascertain that spelling suggestions were a source of difficulties for searchers as the way misspelt words are rendered on current interfaces is not intuitive for screen reader users. One of the users said: *"we hardly notice which term is misspelt. It would be*

Evaluator: There are alternative ways of presenting the search results retrieved:

- ***Standard approach:*** Results are presented in a list with each result described using a title, a short summary and a web address. Each of these items is on a separate single line.
- ***Simplified standard approach:*** Results are presented in a list, but each result is described in one line, with a title and a short summary.
- ***New approach:*** Similar results are grouped together and you are presented with an overview of each group of search results. For example, results that deal with similar topics will be grouped together. If you are doing a travel task, web pages describing things to do at your destination will be grouped together and another group of pages could be about possible places to stay. If you would like to explore one of these groups, you can select the group and it will open in a different window and will contain all search results in that group described with title and a short summary. You can always return to the first window to browse through other result groups.

"What are your thoughts on these results presentation alternatives? Which one would you prefer and why?"

Table 6.3: Excerpt on alternative search results presentation

good if the system clearly said which term is wrongly spelt".

Likewise, we were able to verify user requirements for a new history mechanism. In the scenario, we proposed a search history mechanism that would keep track of the queries submitted and the search results visited by the searcher. Participants in the evaluation commented on the need for such a history feature saying *"I do not like the history in IE, this is more powerful than history. It allows you to call it up and instantly be back to where you were, in the same context"* and *"It is nice to pick up from where we left because sometimes we use keywords which are useful and then forget the right combination"*.

- **Identifying issues with current design ideas**

In addition, we were also able to identify issues with current design ideas that we had proposed. Discussing early design ideas with potential users proved to be beneficial as users were able to provide us their feedback on proposed ideas. In this way, we were able to find problems early in the design process. For example, one of the proposed design ideas for search results presentation included limiting the display of individual results to only one line per result on the search results page. Our reasoning for this idea was that it would reduce the amount of text that screen reader users would have to go through. However, we found that this idea was not welcomed by participants in the evaluation, as they would rather have some context about the search results retrieved by the search engine. They felt that if there was only one line per result, there would not be enough context to decide whether the result was relevant or not among all the results that the search engine had retrieved.

During the interaction with the scenario, the evaluator also had the opportunity to further probe users on factors like keyboard navigation, which plays a central part in the user experience of visually impaired searchers. Keyboard navigation is significantly different from visual navigation and hence, the design team had to ensure that any interface feature they included on the interface was intuitive to access via the keyboard. For example, we proposed to have a context menu so that users could interact with individual search results. Therefore, as the menu would be used through the keyboard, we had to ensure that the menu options were appropriately labelled and correctly ordered in the list.

In describing how they would interact with the interface, participants would often refer to how they would use the screen reader to access the proposed features. About the grouped approach for results presentation, one participant said *"Along the lines of how VoiceOver works, this grouping on the page would be good"* and another questioned how they would navigate back to a previous page *"Would I need to use the screen reader key for this or would there be a special key combination?"*.

- **Users proposing new design ideas**

  Using a scenario-based approach allowed us to engage users in the development process. As participants in the user evaluation interacted with the yet-to-be constructed search interface in the scenario, they came up with ideas of their own to enhance the design of some of the features that were being proposed. For example, in the scenario, we included a note taking feature which could be used by searchers to automatically save results from the search pages or to make notes of their own.

  The initial idea was to allow users to then download or email the note in a text format. However, one of the participants highlighted that the benefits of having an integrated note facility could be enhanced by structuring the note and to include HTML tags to allow users to easily get back to any web pages they considered useful in previous search sessions. About the same note taking feature, another participant took the proposed definition of the feature and added his own design ideas saying *"I can see where you are going with this, it could be in two panes, your browser and your search notes"*. The user was in fact suggesting that there should be two separate areas on the interface, one for regular browser-related activities such as submitting queries and viewing webpages and the second area should be dedicated for note taking and other search management activities. When users suggested such design ideas of their own, we discussed them with the design team including the visually impaired co-designer to ensure that such an approach would be feasible and would enhance the target users' experience.

6.5.4 Discussion

Engaging non-standard populations such as the elderly and disabled users in the design process is challenging as traditional user methodologies are not always effective at capturing the real user requirements. Thus, designers often have to explore different methods or adapt existing ones to ensure that such users can be successfully included in the design process (Lindsay et al., 2012a,b; Newell and Gregor, 2000).

In this chapter, we described an approach which included two levels of participatory design: we included a visually impaired user in the design team and also carried out prototyping sessions with four visually impaired users. The involvement of a visually impaired team member who can combine a good knowledge of assistive technology with an end-user perspective enabled us to create a scenario that was better matched to the vocabulary and interactions familiar to visually impaired users. Therefore, we successfully engaged visually impaired users to solicit their feedback in the design of the search interface.

Search interfaces are highly interactive and to progress in their search task, searchers are required to perform activities such as formulate queries and view search results etc. The scenario-based approach we describe in this chapter allowed us, to some extent, to replicate this interaction through a dialogue between the user and the designer. During the scenario walk-through conversation, users were involved in the scenario and were constantly informed about their evolving interaction, for example, how search results are being handled and the alternative paths available to them. This approach to interaction elicited a high level of participation and engagement from the users in the evaluation, as evidenced by the feedback received. In fact, the use of dialogue is viewed as a model of engagement (Wright and McCarthy, 2010) and a model for effective communication and collaboration (Anderson et al., 2004) (p. 16). Additionally, the proposed approach required users to speak their interaction, for example, tell the evaluator which query they would submit, instead of typing it as they would when interacting with a search interface. We believe this difference in interaction modalities between the prototype and the finished product helped to maintain the pace of the dialogue and the flow of conversation between the user and the evaluator as neither had to consider the specifics of screen reader interaction. This is similar to how sighted users interact with physical paper prototypes (touching or pointing at components to communicate with the evaluator) as opposed to how they would interact with a finished interface. As discussed by (Snyder, 2003, p. 57), such unfinished prototypes improve creativity.

Overall, the findings we gathered from the dialogue-based interaction showed that users had no problems in imagining the interface proposed in the scenario. The narrative was successful in evoking the search experience in users and therefore, they were able to discuss the proposed artefacts for inclusion in the interface in the context of their use within the scenario, and to discuss alternative interaction sequences where they arose. The fact that users were able to go beyond the described interface features to question how they would interact on a relatively low level (screen reader keystroke level) is evidence that they were able to successfully form a mental model of the search interface that was yet-to-be constructed.

In addition, involving visually impaired users at such an early stage allowed the designers to identify limitations with their own design ideas. Participants in the evaluation of the scenario-based approach would often question the practicality of the proposed interface features, requiring detailed explanations of how these interface components would be accessed in a realistically usable way with screen readers. Identifying these limitations at that stage ensured that no further development effort was put into interface features that would not meet the needs of the users, or that would raise difficult usability issues.

The benefit of an inclusive approach, such as the one proposed in this chapter, is that it enables users, especially those with disabilities, to become involved in the process of design and formative evaluation. This involvement in the development process encourages users to speak about their experiences with search interfaces and to contribute to design ideas and hence, the user truly becomes the centre of the design process. User-generated ideas during the scenario walk-through resulted in valuable contributions to the initial design plans. This is so because the participants in the study were experts at navigating the Web through screen readers and thus, they had better insights into how the overall interface and individual components would be perceived by potential users.

6.6 Reflections on the Use of Scenarios to Engage Visually Impaired Users in Design

In this section, we reflect on the development and evaluation of the scenario-based approach. We describe the benefits and challenges of using scenarios for engaging visually impaired users in the design process and discuss the practical experiences of applying the proposed approach with visually impaired users.

6.6.1 Benefits

Scenarios are flexible and adaptable and thus they can be customised according to the needs and abilities of the user group, for example, as a scenario-based drama for the elderly (Marquis-Faulkes et al., 2003). For the approach proposed in this thesis, we created a textual narrative scenario for a dialogue-based interaction with visually impaired users. The value of the scenario was that it allowed visually impaired users to envision the proposed interface and form a mental model of how they would interact with it. This was important to correctly verify user requirements with visually impaired users and also to rapidly communicate design ideas.

In addition, scenarios are adaptable in the level of detail that they convey to the user group, which can assist in enabling them to envision the proposed artefacts. For the proposed approach, given the focus on requirements verification, we provided detailed descriptions for the proposed interface features and less detail about the interaction or the way certain tasks could be completed when using the search interface. For example, when describing a new search history mechanism called the *Search Trail*, we fully described the items such as the queries and visited search results that would be recorded as history, but we did not explicitly tell users how they would navigate the trail at a keystroke level. Instead, during the sessions, the participants themselves wondered and discussed how they would interact with this history mechanism for different types of tasks.

In this way, we achieved the comparable 'unfinished look' of handwritten mock-ups that (Snyder, 2003, p. 57) claimed encourages creativity during low-fidelity paper prototyping. However, depending on the users' needs and the stage of the design process, such an approach could be used for more high-fidelity prototyping to evaluate how users would interact with the proposed artefacts. Discussions with participants regarding how some interface features could be accessed through screen readers showed that the use of scenarios is likely to be effective for such high fidelity prototyping.

In the absence of visual aids to communicate design ideas, sighted designers are likely to describe graphical user interfaces in a way that make references to visual aspects of the interface, such as the layout. For the visually impaired user, these descriptions could be near useless and would not convey a helpful representation of the interface features. For this reason, the involvement of a visually impaired user was crucial to ensure that we used the correct language and context to describe interactions at an appropriate level from the user's perspective. Scenarios, especially when expressed as narratives, have an inherent ability to support participatory design (Jarke et al., 1998; Luck, 2003) and thus complemented the level of participatory design described in this chapter. In such settings, scenarios furthered the communication between the users and the designers to enable successful collaboration (Anderson et al., 2004).

6.6.2 Challenges and Practical Experiences

In the absence of visual aids, the designers in this approach relied on the textual descriptions of the interface features to communicate design ideas to the users. Therefore, the detailed descriptions played a significant role in shaping the mental model that users created of the interface. Using a standard script for the scenario ensured that variations in the way the interface was conceptualised was limited.

Our approach focussed entirely on the functionality of interface components and the way to interact with them. No efforts were directed towards conveying spatial information, which despite not necessarily being of primary importance to visually impaired users, plays a role in how screen reader users perceive an interface, and very importantly, their collaborative use of the interface with sighted peers (Stockman and Metatla, 2008). As an extension to this work, it will be interesting to therefore examine the benefits and drawbacks of incorporating screen reader technology within the prototyping process, rather than the purely conversation-based approach employed in this chapter. It is unclear whether the incorporation of screen reader technology will enhance the realism of the interactions, and/or whether it may detract from the free flow of the dialogue about the interactions and their possible alternatives by overburdening the audio channel (Chandrashekar et al., 2006).

The approach we propose in this chapter was a first attempt at using scenarios to engage visually impaired users in the design process and therefore, we identified a number of important points to consider for any future implementation or extension of this approach. Firstly, we expressed the scenario in a textual medium, with a dialogue-based interaction between the user and the designer. This audio-based approach works well with visually impaired users, but as is common with all audio interfaces, there is a lack of persistence. Therefore, any artefact which is part of the scenario has to be described in significant detail to ensure that users can conceptualise and internally "picture" the proposed design. Visual aids such as paper mock ups convey significant contextual information even in their most early versions and any attempt at replicating these types of approaches for visually impaired users should be constructed using low-level details in the textual descriptions. Detailed descriptions can also be complemented with references to similar existing artefacts to convey as much contextual information as possible. However, this is only possible when re-designing an existing artefact as the designers can then draw from the users' previous experiences using similar artefacts. When designers propose to develop new artefacts that users are not familiar with, they might have to describe components at a finer level of granularity to allow the users to envision the proposed artefact. Thus, they might have to draw from the users' overall interaction experience to find similarities to their design ideas.

From the user evaluation, we observed that to maximise user engagement, scenarios (especially those expressed as a narrative) should be highly interactive to include the user as much as possible. Given that scenarios are stories about people and their activities, it is essential for users to feel part of the scenario to maximise their ability to envision the proposed interface. In the proposed scenario, we regularly prompted users for feedback by asking them to think of a search task, by asking them for their query terms and by allowing them to choose the next step of their interaction etc. When scenarios are textual narratives and interacting with the user is dialogue-based, the designer will be speaking for relatively long periods to describe different parts of the interface. Therefore, to replicate an interactive search experience, users should be active actors in the activities of the scenario to further user engagement.

Involving a visually impaired person on the design team helped in many ways, but it is important to be aware of the dangers of over relying on one person as a representative of a population. For example, the visually impaired co-designer in the process had a lot of experience of using JAWS under Windows with Internet Explorer to perform searches using Google, but only a passing knowledge of other screen readers, browsers and search engine combinations. It is important therefore, to try to ensure *relevant diversity* (Lindsay et al., 2012b), that is, the users involved in the prototyping process, together with members of the design team, should provide as wide as possible coverage of the range of tools and assistive technologies that might be used with the system being designed. It is also important to consider that visually impaired users are not a homogeneous population and therefore it is essential to include users with less experience as they will also be representative of members of the target population.

6.7 Chapter Summary

In this chapter, we proposed a scenario-based approach to engage visually impaired users in the design process. Through participatory design, we developed a scenario that could be communicated to potential users at an appropriate level, using the correct language in order to verify user requirements and gather feedback about proposed design plans. We evaluated the approach with four visually impaired users and found that the dialogue-based interaction between the designers and the users was effective in evoking the search experience in users and thus they could easily envision the yet-to-be constructed search interface. This allowed visually impaired users to critique design plans and suggest new design ideas based on their experience and expertise with assistive technologies.

The proposed approach therefore allowed us to engage visually impaired users early in the design process and through the discussions with potential users, we identified the interface features to include on the search interface to support searchers for complex information seeking on the Web. In the rest of this thesis, we design and evaluate a search interface to assist visually impaired users for complex search tasks, taking into consideration the observations from Chapter 5 and the user-based discussions in this chapter. In the following chapter, we present the design of the proposed search interface and describe the design rationale for interface components.

Chapter 7

Search Interface Design

7.1 Introduction

After our initial exploratory study of the information seeking behaviour of visually impaired users in Chapter 5, from our understanding of the difficulties faced by screen reader users when searching the Web, we established user requirements for a new search interface to support complex search tasks. Then, as described in Chapter 6, we engaged visually impaired users in the design process to ensure that we shared the same understanding of the encountered difficulties to verify the requirements for the search interface. In this chapter, in section 7.2, we describe the concept of design for the proposed search interface. In section 7.3, we specify the iterative approach we employed during the design process and the interface components for the proposed search interface are explained in section 7.4.

7.2 Concept of Design

In Chapter 5 of this thesis, we observed that one of the most challenging stages of the information seeking process for visually impaired users is search results management, especially for complex search tasks such as multi-session tasks. This is so because for tasks that may require more than one search session, searchers are required to keep track of the progress of the search task as well as manage the information they encounter to be able to satisfy their information needs. For visually impaired users, this is particularly challenging as they have to split their cognitive resources between different applications (browser, screen reader, search interface, word processor for note taking) to be able to successfully carry out such tasks as observed in Chapter 5. Therefore, we designed a search interface to support visually impaired users to perform complex searches such as multi-session tasks. The proposed search interface provides users with an integrated solution so that they do not need external applications to assist them in keeping track of their search process and relevant information and hence, reduces the cognitive effort required to carry out such tasks.

Additionally, we addressed usable accessibility as discussed in section 3.7 and we designed components which are usable as well as technically accessible with screen readers. By including potential users in the design process as described in Chapter 6, we gained insights into the mental models that visually impaired users create for search interfaces and thus, we aim to ensure that features on the proposed search interface were designed with considerations for interaction through speech-based screen readers. In this respect, as well as focussing on designing an accessible integrated tool to support visually impaired searchers for note taking and managing the search process, we also re-designed the spelling support mechanism which is common on most web-based search interfaces as explained in section 7.4.2. In the following section, we describe the iterative approach to the design of the proposed search interface.

7.3 Iterative Design Process

We employed an iterative approach (Nielsen, 1993) towards designing the proposed search interface. As described in Chapter 6, we included a visually impaired user in the design process and after finalising the list of features to include on the proposed search interface, we started an iterative development process whereby we repeatedly asked the visually impaired member of the design team to test the features being implemented. As a result of those usability tests, we refined the design of the search interface features as our aim was to ensure that potential users understood each component on the interface, its purpose and how to interact with it so that they can successfully access the features with their screen readers.

Additionally, the sighted team member also tested the interface features by using different screen readers with different browsers and operating systems. However, the visually impaired member of the team was able to provide more insights into how each interface component would be perceived by potential users and through his experience with assistive technologies, he could more easily identify accessibility issues with the proposed search interface.

7.4 Search User Interface Components

In this section, we describe the features of the search interface, focussing on how they can support users during information seeking. We also discuss the reasons for including these components in our design.

7.4.1 TrailNote

In Chapter 5, we observed that visually impaired searchers keep track of the information they encounter using bookmarks and external note taking applications such as Notepad. Therefore, relevant information that would assist searchers to resume a search task or re-find previously encountered information are stored in different places (the notes on the users' device and the bookmarks in the browser). This approach makes it more challenging for visually impaired users to re-access relevant information and to re-acquire the context of a task which was started in another search session. Additionally, both strategies employed by visually impaired users in Chapter 5 have limitations: bookmark lists can quickly become long and unruly (MacKay and Watters, 2008b) and with external notes, users have to continuously switch between different applications which requires additional cognitive effort. Furthermore, previous queries which can also assist searchers in re-acquiring the context of the interrupted search task have to be explicitly recorded by users in their notes as one participant in the exploratory study in Chapter 5 discussed: "*sometimes you know a query was useful but you cannot remember it*".

Therefore, to enhance support for search results management for visually impaired searchers, we designed an integrated feature in the proposed search interface called TrailNote. The aim of designing TrailNote is to provide visually impaired searchers with a simple and easy way to manage the information they encounter during a search session so that re-finding information and resuming search tasks become less cognitively taxing. With TrailNote, all the information needed by searchers to re-acquire the context of a search task is available within the search interface itself, that is, all the submitted queries and visited search results are automatically recorded by the search interface and the notes that searchers might have made during a search session are persistent in a dedicated area on the search interface. Hence, to resume a search task, searchers could use the search trail in TrailNote to resubmit the queries they had previously formulated or to revisit web pages they had previously explored. They could also use the search note in TrailNote to review any relevant information they had recorded in a previous session.

We designed TrailNote as described above so that visually impaired searchers would only be responsible for recording the pieces of information they found relevant on the web pages they visited. Other information such as queries and visited web pages would automatically be recorded by the search interface. This combination of a user-controlled search note and a system-controlled search trail would thus ease the load on working memory for visually impaired users during information seeking on the Web, especially for complex search tasks.

We also designed TrailNote to be technically accessible as well as usable for speech-based screen reader users. We ensured that visually impaired users could access the functionalities of TrailNote by employing different strategies such as the use of shortcut keys, heading navigation, tab navigation etc. In the following, we further describe the two components of TrailNote namely, the search trail and the search note and we also discuss how visually impaired searchers could interact with them.

Search Trail

The search trail automatically records the queries that the user submits to the search system and the search results that are visited during a search session. It is inspired from the history mechanism but is aimed to provide users with an overview of their search sessions. Each submitted query and each visited page are added to the trail in the order in which they occurred. However, unlike the browser history, browser actions such as "Back" and "Forward" do not affect the search trail and thus, searchers are provided with a correct representation of their search session at all times. As a result, the search trail is designed to resemble the functions of 'path breadcrumbs' which is a history mechanism used on websites to represent the sequence of links that a user has clicked on since the beginning of a navigation session (Hearst, 2009, p. 163). Breadcrumbs usually allow users to understand where they are on the page relative to the site (Nielsen, 2007) and in a similar way, the aim of the search trail is to provide searchers with an overview of their current progress in relation to their information need. However, unlike breadcrumbs, that are more static, visually impaired searchers can interact with the trail in the following ways:

1. ***Tag As Useful.*** This feature is similar to bookmarking and allows users to identify pages that are particularly useful or relevant to their search task. When a user navigates through the visited pages in the search trail, the interface alerts the user through a non-speech sound if a page was previously tagged as useful. We included this feature on the search interface to be somewhat

equivalent to bookmarking. However, it allows users to keep an 'uncontaminated' list of useful pages that are related to a specific search task, that is, the list of tagged pages for one search task would not contain bookmarked pages from another activity that the user might have carried out on the Web. Thus, the user could easily re-access information encountered for a specific search task. In addition, unlike bookmarking, with the search trail, searchers have access to more contextual information about the pages they tagged as useful, for example, which pages they visited before or after the useful page and for which query a page was tagged as useful etc.

2. ***Add to Trail.*** For each search result displayed, there is an associated context menu with an option to "Add to Trail". This feature was designed so that users could add individual results to their trail without visiting the page itself. Results snippets sometimes give searchers an indication that a web page will be useful even if they have not yet viewed it (the snippet shows that the page contains a specific piece of relevant information or the URL of the page is of a well-trusted or particularly authoritative source) and therefore, this feature allows users to add this page to their trail for future reference.

Figure 7.1: The search trail.

Search Note

The search note, also referred to as the sketch pad as shown in Figure 7.2, is a dedicated area on the search interface to allow users to make notes. It is similar to a word processor document such as Notepad, but searchers can interact with it in the following ways:

1. ***Save to Note.*** Users can directly save individual search results to the search note. The context menu has a "Save in Note" option from which users can save search results without visiting the page. If the user wants to save a page while viewing it, there is the option of doing so on the web page itself. When pages are saved in the note, they are saved in HTML format with the title, URL and description recorded as they appear on the lists of search results. We designed this feature following observations in Chapter 5 whereby searchers saved search results in word processing documents by copying items from the lists of search results from the search interface. Thus, we provided an equivalent function which can be achieved by a single key press to improve efficiency.

2. ***Edit/Copy/Paste.*** Apart from directly saving items in the search note, users can also interact with the note as they usually interact with a word processor. For example, they can type their own notes, categorise search results and copy text from web pages etc. As observed in Chapter 5, note taking is very popular with visually impaired users as they try to keep track of goal-relevant information so that it is easier to re-access. However, apart from items copied directly from web pages, it was also observed that visually impaired searchers used the note to record information of their own, for example, structuring the note, breaking down the task into sub-tasks etc. Therefore, through the search note, we support that behaviour by allowing users to control the contents of the search note on the search interface.

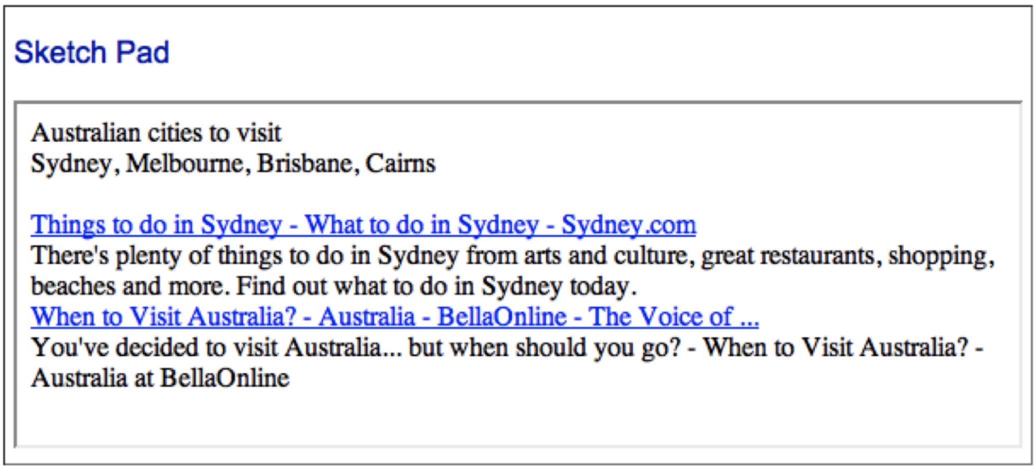

Figure 7.2: The search note.

Users also have the option to download the TrailNote locally to their computers or to email it to themselves or others. In both cases, the TrailNote is in HTML format with the search trail structured as a list of linked headings. This is to allow users to get back to visited web pages directly from their saved search trail or search note.

7.4.2 Spelling Suggestions

In Chapter 5, we observed that spelling suggestions were challenging for visually impaired searchers for the following reasons: firstly, visually impaired users cannot benefit from the real time query suggestions that appear as the user types a query and therefore they only find out about misspelt terms when the query has been submitted. Secondly, the way spelling suggestions are presented on current search interfaces often caused confusion among searchers because screen readers often pronounced the misspelt terms in a way that is not very different to how the correctly spelt terms would be read out. For example, as shown in Figure 7.3, for a misspelt query "***acustic cues***" when the search interface displays "*Did you mean **acoustic cues***", some users are confused as to why this prompt is being displayed as the screen reader reads out both the misspelt query and the suggested query in the same way.

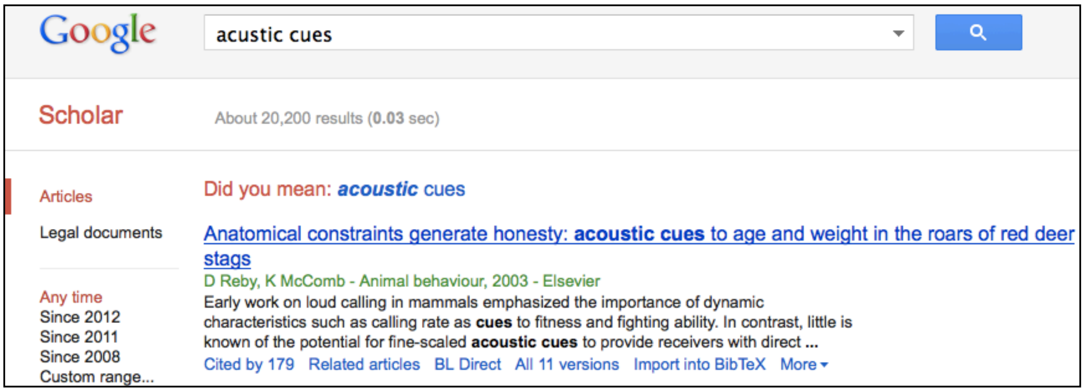

Figure 7.3: Spelling suggestion on Google Scholar.

Irrespective of these difficulties encountered, visually impaired users can benefit from spelling support because they face additional challenges in learning a language especially if they rely on speech-based output (Couper, 1996). In fact, it has been observed in (Arter and Mason, 1994) that visually impaired children have spelling difficulties as they cannot recognise and remember the visual pattern of letters in order for them to retain and learn the spelling when using audio output and thus blind users tend to make more spelling mistakes than sighted users when using speech-based screen readers as a reading medium

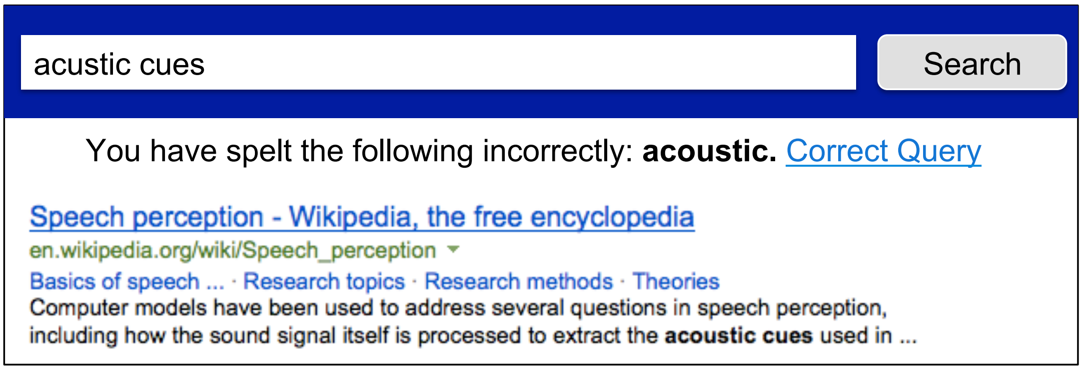

Figure 7.4: Spelling suggestion on the proposed search interface.

(Papadopoulos et al., 2009).

Therefore, to address the observed difficulties and to provide spelling support to visually impaired users, we designed a spelling support mechanism based on non-speech sounds to alert visually impaired searchers about incorrectly spelt keywords. We used earcons (Blattner et al., 1989), which are abstract sounds bearing no semantic relationship with the function they represent, to convey to visually impaired users that a query has been incorrectly spelt.

1. While the user is typing a query, we used a short double beep-like earcon to inform them in real time if they misspell a keyword. Such beep-like earcons are commonly used for auditory feedback and as a non-speech sound, it does not interfere with output from the speech-based screen reader. We designed these real time alerts to make accessible the kind of instant spelling support that sighted users benefit from on search interfaces in the form of dynamic query suggestions that appear as they type their queries. However, at this point we did not provide suggestions for the misspelt term as we believe it would interrupt the visually impaired user's interaction with the search interface. This is because unless the spelling support at this stage is audio-based, it will require the user to navigate away from the search box to find out about the spelling suggestions. At this stage, even audio-based feedback can pose difficulties as it can mask or interrupt useful output from the screen reader especially if it is played at the same pitch.

   Similarly to what was observed in Chapter 5, the costs of this action outweigh the potential benefits that users can derive from it. Therefore, we did not provide query suggestions at this stage. At this point, the user has the option to cursor backward character by character to check the spelling of the keyword and to correct the query from their own knowledge.

2. If the user does not correct the term as the query is being typed and submit the misspelt query, they hear a similar double beep-like alert immediately after they submit the query. To prevent the kind of confusion that we observed in Chapter 5, we specified to the user the terms that were incorrectly spelt. For example, if the user submits a query for "***acustic cues***", the proposed spelling support mechanism notifies them by displaying "*You have spelt the following incorrectly* ***acoustic*** " and provides the user with the option to correct the query as shown in Figure 7.4. However, like current search interfaces, the user's query is automatically corrected in order to retrieve search results for the correct query.

7.4.3 Non-speech Sounds

We used two types of non-speech sounds in designing the proposed search interface namely, auditory icons (Gaver, 1986) and earcons (Blattner et al., 1989). Auditory icons are informative sounds that are easy to learn and remember as they have a semantic link to the object they represent. On our proposed search interface, an auditory icon (a typing sound) was used to indicate to users when they navigate to the search note area on the interface.

We used earcons on our interface to indicate the presence of misspelt terms in a query (as described in section 7.4.2) and also for confirmation purposes after users have performed specific actions such as tagging a page as useful or saving a page to the search note. Earcons were also used to indicate which pages in the search trail have been tagged as useful when users navigate through the queries and visited results in the search trail.

By using these non-speech sounds, we aimed to convey useful information to visually impaired users without overloading their memory or requiring much cognitive resources Brewster (1997). The earcons used in the design of the proposed interface were simple in structure, that is, they were not being used to distinguish between different options or properties. Instead, we used earcons to enhance the users' awareness of the outcome of their actions and to indicate the presence of tags on visited web pages. Additionally, we used auditory icons, for example, a typing sound to the search note, to improve users' awareness of where they were on the search interface and thus, we avoided the confusion that is common among screen reader users in respect to their location on the interface (Lazar et al., 2007).

7.4.4 Context Menu

To make it easier for users to interact with search results displayed on the interface, we designed a context menu to be associated with each search result. Therefore, users can perform actions such as saving the search result in the note or emailing the search result to oneself or someone more easily. We also assigned earcons to the context menu so that searchers are aware of when it opens or closes to enhance their interaction. The context menu can be accessed using the shortcut key combination Ctrl+Shift+F10 and the options available in the menu are the following:

- Open
  This menu option provides users with an alternative way of opening the web page represented by the search result on the search interface. Users can achieve the same outcome by pressing the Enter key on the title of the search result.

- Save Result
  Using this menu option, searchers can directly save individual search results to their search note. We provide this feature to allow users to save pages of interest even if they have not visited the web page. For example, by reading the search results snippets on the search interface, a user might decide that the page is relevant to their information need and therefore decides to save it for future reference.

- Add to Trail
  Visited search results are automatically added to the search trail and therefore, we provide this menu option to allow searchers to add a search result to the search trail without having visited the web page. Similar to 'Save Result', we give users the option of keeping track of pages they have not visited given that they might be able to decide that popular websites or websites that they are familiar with would be useful in the future.

- Email
  Through this menu option, searchers can email specific search results to themselves or to others directly from the search interface. The aim of this option is to allow users to email search results without much effort, for example, this equivalent action on current search interfaces would require users to select the search result (title, description and URL) and copy it before opening their email

client and pasting the information and then send it to a particular recipient. On our search interface, users have the option of doing the same by just typing in the email address of the recipient and pressing the ‘Send Button’.

7.4.5 Keyboard Shortcuts

As visually impaired users typically interact with interfaces through the keyboard, we assigned keyboard shortcuts to those features on the search interface which we anticipated would be frequently used by searchers. Therefore, we provide the following keyboard shortcuts:

- Search box (Ctrl+Shift+U)
  We provided a keyboard shortcut for the search query box so that users can easily navigate to the search box irrespective of their position on the screen. This makes it easier for users to locate themselves on the interface to submit a new query or to edit an existing one.

- Related Searches (Ctrl+Shift+I)
  To keep the search interface clutter free, we did not display related searches to the user’s query at all times on the interface. Therefore, we assigned a keyboard shortcut to this function so that the user can easily bring up the list of related searches in case they want to consult the list before reformulating one of their queries.

- Search Note (Ctrl+Shift+O)
  This shortcut key is associated with the search note in order for users to be able to directly navigate to the note area if they want to edit the notes they have made on the interface. The aim of this shortcut is to simplify access to the search note which iss at the bottom of the screen without having to sequentially go through all of the preceding elements on the interface.

- Search Trail (Ctrl+Shift+P)
  We anticipated that for multi-session search tasks, users will need to repeatedly consult the search trail to have an overview of the queries they submitted and the search results they visited in previous search sessions. Therefore, we assigned a keyboard shortcut to this feature to allow users to directly navigate to that part of the search interface.

We did not use representative letters for the functions of the keyboard shortcuts, for example, the letter 'T' for the search trail as there were several clashes with native browser shortcuts on several browsers. Therefore, we used the top four consecutive letters on the keyboard to make it easier for users to remember which shortcuts would be used across the search interface.

7.5 Technical Details

We implemented the search interface using the Google Web Toolkit[1] (GWT) which is a development toolkit used to build and optimise complex web-based applications without the developer having to be an expert in web and browser technologies such as JavaScript. Instead, GWT enables productive development by allowing developers to code web-based applications using Java which is later compiled into optimised JavaScript by the GWT compiler. This allowed us to create reusable components for our search interface. However, this also meant that the resulting search interface is most compatible with the Chrome[2] browser. However, in order to facilitate recruitment of participants for the evaluation process, we also ensured that the search interface works well with Mozilla Firefox[3].

Spelling suggestions, related searches and search results relevant to submitted queries are retrieved in real time using the Bing API[4] and we used the sound library, Freesound[5], for the auditory icons and earcons on our interface. Ahead of the user evaluation, the final version of the search interface was hosted on the Google Applications Engine[6] so that it could be accessed remotely by participants.

7.6 Chapter Summary

In this chapter, we explained the concept of design for the proposed search interface outlining the process through which the interface features were iteratively developed. We also described each interface components and detailed how potential users would interact with them. Lastly, we highlighted some technical details relevant to the development of the search interface including the technologies and libraries used. In the following chapter, we describe how the proposed search interface was evaluated and the feedback

[1] https://developers.google.com/web-toolkit/
[2] www.google.com/chrome/
[3] http://www.mozilla.org/en-US/firefox/new/
[4] http://www.bing.com/developers/
[5] http://www.freesound.org
[6] https://developers.google.com/appengine/

we gathered from potential users.

Chapter 8

Search Interface Evaluation

8.1 Introduction

In this chapter, we describe the evaluation of the proposed search interface to support the information seeking behaviour of visually impaired users for complex search tasks. We conducted a user study with 12 visually impaired participants to evaluate the proposed search interface components for usability and accessibility from the user's perspective. The evaluation process was structured so that each participant in the study was involved in two sessions which were separated by several days. Therefore, this evaluation also allowed us to gain insights into the search behaviour and strategies employed by visually impaired users when resuming search tasks and re-finding information.

However, in this chapter, we only focus on how visually impaired users interacted with the proposed search interface components. We also use findings from the exploratory study in Chapter 5 to provide insights into the way visually impaired participants use similar features on the proposed interface and other popular web-based search interfaces and to explore the differences in the information seeking behaviour of visually impaired users. The behaviour of visually impaired users when completing multi-session search tasks is reported in Chapter 9.

8.2 Motivation and Research Questions

Prior to designing the search interface proposed in Chapter 7, we conducted an exploratory observational study in Chapter 5 to investigate the information seeking behaviour of visually impaired users and the difficulties they encounter when using current search interfaces for web searching activities. Additionally, we also engaged potential users in the design process as described in Chapter 6 to verify requirements for the search interface and to brainstorm design ideas. Therefore, the requirements for the proposed user interface were gathered by employing user-centred approaches.

As a result, the aims of the user evaluation presented in this chapter are to study how users interact with the proposed interface components. We also investigate the differences in the way visually impaired participants use similar features on the proposed search interface and popular web-based search interfaces and we provide insights into the information seeking behaviour of visually impaired users when completing a complex multi-session search task using the proposed search interface. Hence, in this chapter, we address the following research questions:

RQ1: How do visually impaired users interact with proposed interface components such as TrailNote and the spelling support mechanism etc.?

The search interface proposed in this thesis include many features, however, two of the main novel features are TrailNote and a spelling support mechanism based on non-speech sounds. TrailNote is an essential part of the user interface as it was designed to support the information seeking behaviour of visually impaired users for complex search tasks, especially during the search results management stage of the information seeking process. As for the spelling support mechanism, it was designed to address usability issues encountered when using popular web-based search interfaces as described in Chapter 5 and Chapter 7. In fact, all components on the proposed search interface have been designed to be easy and intuitive to access with screen readers to ensure usable accessibility and thus, for this research question, we observe how visually impaired participants interact with the interface features.

RQ2: What are the differences in the use of similar features on the proposed search interface and popular web-based search interfaces?

Following the exploratory study in Chapter 5, we designed the proposed interface in this thesis to better support visually impaired searchers during information seeking. For this purpose, we included additional interface components (TrailNote) and we re-designed other interface features to ensure usable accessibility (spelling support mechanism). Therefore, there are some similarities between the search interface proposed in this thesis and popular web-based search interfaces. Hence, for this research question, we investigate how participants interact with those similar features and we use the findings from the study in Chapter 5 to investigate the differences in the use of similar features on the proposed interface and other search interfaces used during the study in Chapter 5.

RQ3: What is the impact of the proposed search interface on the information seeking behaviour of visually impaired users?

In Chapter 5, we described the information seeking behaviour of visually impaired searchers when using popular web-based search interfaces. We observed the search behaviour at specific stages of the information seeking process and found that search results management was a particularly challenging stage for visually impaired users. As a result, we designed the proposed search interface, as described in Chapter 7, to support visually impaired users for complex information seeking. For this research question, we use the findings in Chapter 5 to provide insights into the behaviour of visually impaired users when using the proposed interface at the following stages of the information seeking process, namely, query formulation, search results exploration and search results management. However, given the focus of the proposed interface to support searchers in managing the search process and encountered information, we expect the most significant impact of the proposed interface to be at the search results management stage.

For both RQ2 and RQ3, we use the findings from Chapter 5 to study how the behaviour of visually impaired participants was impacted both for the use of similar interface features and for information seeking. However, there are some differences between the methodology of the study described in Chapter 5 and the one presented in this chapter (more details on the limitations of this comparison are given in section 8.5.1 of this chapter). Nevertheless, taking into consideration the limitations, the aim in this chapter is not to perform a strict comparison between the interfaces referred to in Chapter 5 serving as baseline for the proposed interface. Instead, we focus on the differences in the way visually impaired participants use similar features such as spelling support, note taking and bookmarking for search tasks of comparable complexity, on different search interfaces. Likewise, for RQ3, we use the findings in Chapter 5 only to provide insights into the information seeking behaviour of visually impaired participants when using the proposed interface.

8.3 Evaluation Methods

In this section, we present the user evaluation of the search interface described in Chapter 7. The user evaluation was conducted over two sessions (referred to as Session I and Session II in the rest of this thesis) and in the following, we describe the participants, the tasks and the experimental procedure for the evaluation process.

8.3.1 Participants

We recruited 12 visually impaired users for this evaluation, mainly via dedicated online mailing lists. Ten of the participants had no vision and two participants had very low level vision. However, there were no differences in the data we collected for the participants with different levels of vision as they all depended on speech-based screen readers for all interactions with computers. Nine of the visually impaired participants used JAWS as their screen reader and three participants used VoiceOver. Seven participants rated their screen reader proficiency as advanced and the remaining five considered themselves to be intermediate users. For browsing proficiency, seven participants rated themselves as advanced and five were intermediate users. The high level of proficiency of the self ratings is reasonable given the frequency of computer use by visually impaired users and the fact that all their interactions with computers involve the screen reader. In Table 8.3.1, we provide additional demographic information on the participants in the user evaluation.

Age	35.4 years [24-69]
Gender	11 male, 1 female
Search Experience	9.27 years
Frequency of Computer Use	Daily
Use of Online Search Engine	Daily *(10)* Weekly *(2)*

Table 8.1: Demographics of all participants.

8.3.2 Task

We constructed a complex multi-session search task for the evaluation as per the criteria defined in section 2.2.1. As we planned on doing a multi-session evaluation, we constructed a task that is likely to span multiple sessions in real life circumstances. Therefore, for the first session, we created a simulated work task (Borlund, 2003) that was broad and then in the second session, we modified the search task to refine the information need. We anticipated that in the second session, participants would have more knowledge about the search domain as well as an evolved information need.

At the beginning of Session I, after we assigned the task to participants, they were required to fill a questionnaire about the task and 92% of participants reported carrying out similar tasks frequently during their day to day search activities. As for prior domain knowledge, 92% had an intermediate level of knowledge about the task (I know where the country is but not much about its cities) and 83% of the participants understood the requirements of the task very well while only 58% were very confident about the assigned search task. We anticipated that in Session II, participants would have more knowledge about the search domain as well as an evolved information need. The tasks we constructed for the two sessions are given in Table 8.3.2.

Session I	You have always wanted to visit Australia after hearing great things about the country. You might have some days off soon and you are thinking of travelling to Australia. Find out more about the country, the cities you can visit and things to do there.
Session II	You have now confirmed your travel plans and know you will be staying in Australia for 7 days. Using the information you encountered in the previous session and new information, make a rough schedule of how you would like to spend your days there.

Table 8.2: Search tasks provided to participants

8.3.3 Experimental Procedure

We conducted a remote evaluation with 12 visually impaired users over Skype using the screen sharing feature. When participants shared their screen, the evaluator could observe and record participants' interaction with the search interface. The user evaluation was conducted over two sessions, each lasting for one hour. In this section, we discuss the structure of each session for the user evaluation.

Session I

1. Prior to this session, participants were asked to sign a consent form and to fill a demographic questionnaire. We used the consent form to inform participants about the data that would be collected during the evaluation sessions and the questionnaire was used to collect information on participants' search experience and use of assistive technologies.

2. During the session, participants were first told about the interface and its different components and how to access them. They were also asked to perform a quick search on the interface so that the experimenter could demonstrate all the features on the interface. The training process lasted on average for 14.50 minutes with a standard deviation of 9.84 minutes.

3. After the training task, participants were told about the search task that they will have to perform. Prior to beginning the task, participants were asked a few questions to determine their level of knowledge for the task and how well they understood what they had to do during the session.

4. Participants were then observed while they completed the assigned search task. Their interaction with the search interface was recorded both with screen recording software (iShowU HD[1]) and by system logging. At the beginning of the task, participants were reminded that in the second session, their task would be related to what they had done in the first session.

5. After half an hour, participants were stopped in their task and asked to save their search session. Participants were then asked to fill a short questionnaire about the usefulness and ease of use of the interface features. Following this, a semi-structured interview was carried out to gather users' feedback on their overall experience when using the proposed interface.

Session II

1. In this session of the user evaluation, we started by loading the participants' previously saved search session. Because of the security requirements of the hosting server, we could not allow users to load their saved sessions themselves. Thus, prior to the second evaluation session, we

[1]http://www.shinywhitebox.com/ishowu-hd

ensured that the interface would be correctly configured with the user's previously saved session. When the participant opened the search interface, the last query that they had submitted would be in the search box and their search trail and search note would be loaded.

2. Participants were told about the task that they had to perform in the second session but before they started the task, the experimenter asked them about their current strategies for resuming searches and for re-finding previously encountered information.

3. Participants were then observed for 30 minutes while they performed their task and their interaction with the search interface was again recorded and logged.

4. After the task, participants completed a short questionnaire about the interface and we carried out a semi-structured interview to get insight into their experience of resuming the task and re-finding information from a previous search session.

8.3.4 Data Analysis

The data from the questionnaires and interviews were transcribed and the screen recordings were annotated using a video annotation tool, ELAN[2], to identify emerging patterns. We also used the system logs that we downloaded from the Google Application Engine server to complement the data analysis. As described in section 4.6, we used Grounded Theory (Strauss and Corbin, 1998) to identify concepts from the recordings and to devise a coding scheme according to the commonalities across different participants. The transcribed screen recordings provided qualitative data and allowed us to capture the behaviour of participants in the user study, while the search logs were used to derive quantitative data on the use of features on the search interface. We complemented the data analysis by using the experimenter's observation notes (based on user interactions via shared screens during the evaluation) and the responses from the questionnaires (attached in Appendix C) and the semi-structured interviews.

8.4 Findings

In this section, we present findings from the user evaluation. We first report on participants' interaction with the components on the proposed interface in section 8.4.1. We also present in section 8.4.2, the

[2]http://www.lat-mpi.eu/tools/elan

different ways in which visually impaired participants used similar features on the proposed search interface and the ones used in the study described in Chapter 5. In section 8.4.3, we discuss the information seeking behaviour of visually impaired participants when using the proposed interface.

8.4.1 Participants' Interaction with Search Interface Features

In this section, we report on how the participants interacted with interface features across the two sessions of the evaluation. Participants reported that their experiences of interacting with the search interface was pleasant and that they liked the extra features that were included and the way they were designed. One user explained why they liked the additional features because "*they do not clutter the interface and do not make life difficult*". Other participants described the interface as "*a good interface, nice ideas, simple and accessible*", "*the interface has potential, I like the fact that I can get to results directly without any clutter*" and "*easy to navigate*". Participants found the search interface accessible and easy to use and commented that over time, as they get used to the features and "*spend some time finding out how the screen reader will react to the interface*", their interaction and user experience would improve.

However, some users also proposed that there should be a feature to allow them to get back to the search home page directly from any search results that they visit. Also, it was suggested that the interface should be compatible with Internet Explorer. In the following we discuss participants' feedback for individual interface features.

TrailNote

In this section, we present data on how participants interacted with TrailNote during the user evaluation. There were many different ways of interacting with the search trail and the search note. For the search trail, participants could navigate the trail, tag pages as useful and also add pages they have not visited to the trail. For the search note, participants could save search results directly in the note and make their own notes through editing or copying information from visited web pages. Overall, users could also download or email their TrailNote for a search session.

The feature of TrailNote that was most frequently used was 'Tag as Useful' which was used by 11 out of 12 participants tagging 19% of all visited pages as useful. 'Save in Note' was used by five participants saving 17% of visited pages in the note on the search interface. The feature to download and email TrailNote was less popular and was used by two and four participants respectively. Overall, users commented on the usefulness of TrailNote to continue search tasks and to re-find relevant information as one participant explained "*It helps to have the TrailNote especially if you have many pages*". In the following, we describe user's feedback for the search trail and the search note.

Search Trail: The majority of participants found the search trail useful and easy to use because "*they could know what they searched for*". The queries and visited pages in the search trail were recorded as links (as shown in Figure 7.1) so that if the user selects one of them, the system would redirect to that particular stage of the process. For example, in Figure 7.1, if the user selected 'Query 1: visiting australia', the search interface would replace its current query with the query 'visiting australia' and display the corresponding search results.

There was another benefit of the items of the search trail being displayed as links, especially because visually impaired searchers could use the link list feature of their screen reader to access the search trail. The link list feature of the screen reader allows its users to move up and down a web page by navigating to the next or previous link on the page and therefore, users found it quick and easy to access the items on the search trail. In addition, participants in the study liked the chronological display of the trail as it allowed them to gain an overview of the actions they carried out, in the order in which they were performed. Related to this, users thought it was good to know which of the visited web pages were tagged as useful as it allowed them to "*have a more accessible way of having a search history*". However, some users also said they would like to be able to edit the search trail so that they only keep links that they know are useful as "*not all pages you visit are useful*". At the end of Session II, participants were asked about the usefulness and ease of use of the search trail. As shown in Figure 8.1 no participants rated the search trail as 'Not Useful' while 75% and 25% of participants rated the search trail as useful and very useful respectively. The search trail was also viewed as very easy to use by 58% of the participants in the user evaluation as shown in Figure 8.2.

Search Note: This feature was used by 66% of the participants in the study either by saving search results or making their own notes. Overall, users liked having an integrated option to take notes so they do not have to constantly switch between different applications, that is, the browser and the word processor. Many participants in the study commented that such a note taking feature would be most useful for complex tasks ("*The note is really useful especially if you are doing* *some research*") as for such tasks, there would be a definite need to gather information and keep track of the pages that have been explored.

The search note on the proposed interface was limited in some ways as it allowed users to take notes only using plain text. However, as some users commented, it might be more useful if the note could be enhanced with features typical in other word processors such as the ability to structure using heading levels etc. Also, some participants in the study enquired if they could create more than one note for a search which was not possible with the version of the interface under evaluation. There were also some concerns about whether notes will persist on the interface as users move from the main search interface to specific web pages. Therefore, we had to reassure participants that the search note would be available at any point in their interaction with the search interface as we had developed a contained solution, recording all states of the search process.

In Session I, participants in the study used the note mostly through the 'Save in Note' feature, that is, saving search results directly into the search note. It was in Session II of the evaluation that visually impaired participants used the search note to record information from web pages of interest and structure the contents according to the identified subtasks, for example, things to do and places to stay etc. Similarly to the search trail, we asked participants to rate the usefulness and ease of use of the search note at the end of Session II. The data presented in Figure 8.1 and 8.2 only sums to 11 participants as one of the users in the study did not rate the search note as he had not used the feature and felt that he could not fairly rate how useful or easy it was to use during the search session. Regardless, the search note was viewed as very useful and very easy to use by 42% of the participants.

Spelling Support Mechanism

This feature was very well received among users, with participants suggesting "*the spelling is the most useful feature in the application*" and "*the spellings are good especially for someone with no vision*". During the two sessions, 58% of the participants used the spelling suggestions at least once for 14% of all submitted queries. Like other search interfaces such as Google, the search interface that we developed automatically corrected the query but still informed the user that there had been a misspelt query. We observed that with the design of the spelling suggestion feature described in Chapter 7, the real time alert using non-speech sounds ensured that participants were aware that a term was not correctly spelt and even if they did not take any explicit action to correct it, it did not cause any confusion or frustration as they understood that a term was misspelt and the reason why the interface was presenting them with the option of correcting their query. Furthermore, they could also understand which terms in their queries had been incorrectly spelt.

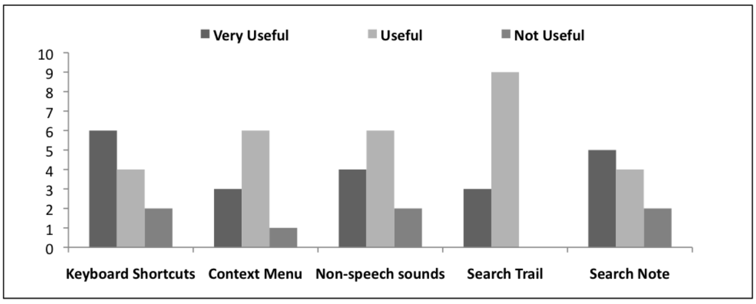

Figure 8.1: Usefulness of use of interface features.

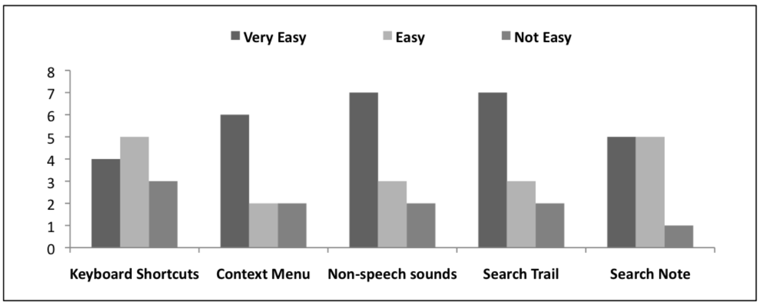

Figure 8.2: Ease of use of interface features.

Keyboard Shortcuts

The keyboard shortcuts that we used on the interface did not relate in an obvious way to the features they represented, for example, the letter U for the search query box. This design decision came out of the need to ensure that the keyboard shortcuts would not clash with default browser shortcuts and screen reader keys. Therefore, participants thought that the keyboard shortcuts were not descriptive and that they should be easier to remember. Nevertheless, the shortcut for the search box was used 34 times whereas the shortcuts for the search trail (Ctrl+Shift+P) and the search note (Ctrl+Shift+O) were less popular and used 15 times and 5 times respectively, as shown in Table 8.3.

We believe this was because for the search box, apart from the screen reader default form access option, there was no other way to access the search box and therefore, users quickly learnt and used the shortcut. As for the search trail and search note, they were also easily accessible by heading navigation which is available within most screen readers and is very popular among visually impaired users (WebAIM Survey, 2012). Hence, participants found it easier to access these features using a method that they were very familiar with. Yet, as shown in Figure 8.1 and 8.2, participants in the post-task questionnaire rated the keyboard shortcuts as very useful (33%) and useful (50%) while 33% and 42% of participants thought the shortcuts were very easy and easy to use respectively. In later versions of the proposed interface the choice of keyboard shortcuts could be made more mnemonic through the use of a modifier key specific to the search application.

Keyboard Shortcuts	**Session I**	**Session II**
Search Box (Ctrl+Shift+U)	25	9
Related Searches (Ctrl+Shift+I)	11	3
Search Trail (Ctrl+Shift+P)	3	12
Search Note (Ctrl+Shift+O)	3	2

Table 8.3: Number of times keyboard shortcuts were used.

Non-speech Sounds

The non-speech sounds were included on the search interface mainly to confirm users' actions. They did not interfere with participants' use of their screen reader and as shown in Figure 8.1 and 8.2, most participants found the non speech alerts useful and easy to use once they were aware of the meaning of the sounds. Only 17% of the participants viewed the non-speech sounds as not useful and difficult to use.

Context Menu

Six of the participants found the context menu useful as it allowed them to interact with individual search results in various ways, for example, they could email or save results directly in the note. Other users found the context menu less useful as "*it is a bit limited because before you use a page, you cannot know whether you will find it useful*". However, despite the differences in opinions about the usefulness of the context menu, most users (50%) found it very easy to access. The total number of participants for the context menu ratings in Figure 8.1 and 8.2 only add up to 10 as two users could not access the context menu as it clashed with a default option in the Mac operating system. This difficulty can also be addressed through the use of a modifier key that is specific to the search application.

8.4.2 Comparing the Use of Similar Features on the Proposed Interface and Popular Web-based Search Interfaces

In this section, we compare how participants used similar features on the proposed interface (Study 2i) and other popular web-based search interfaces which were utilised in the study described in Chapter 5 (Study 1). We observed the differences in visually impaired participants' interactions with the spelling support feature and we also focussed on their use of note taking and bookmarking (discussed in *Strategies for Managing Search Results* of this section).

Spelling Support Mechanism

We compare in this section, how participants interacted with the spelling suggestion feature on the proposed interface and other web-based search interfaces which were used in Study 1. When using the search interface proposed in this thesis, searchers were alerted about incorrectly spelt keywords in two ways: firstly, they would be notified via an earcon in real time as they were typing the query and thus they had the option of navigating backwards character by character to correct the term using their own knowledge. Secondly, searchers would be notified through the same earcon if the misspelling persists when they had submitted their query, that is, they did not take explicit action to correct the query while typing. On web-based search interfaces such as Google (most popular search interface in Study 1), searchers are usually notified about misspellings after the query is submitted. Therefore, for the purpose of this comparison between Study 1 and Study 2i, we only consider the use of spelling suggestions on the proposed interface when it was provided post-query.

In Study 1, spelling suggestions were provided to 47% of the participants while in Study 2i, 66% of participants were provided with spelling suggestions post-query. However, the feature was used by more participants in Study 2i, that is, 50% of all participants who were provided with spelling support used the feature to correct their queries. Comparatively, only 29% of participants who had misspelt a query in Study 1 used the feature. We had previously reported in Chapter 5 that when using popular web-based search interfaces, screen reader users were often confused as to why they were being prompted to correct their queries as they were not aware that any keyword had been incorrectly spelt. Additionally, when presented with the correct spelling, visually impaired failed to identify which term(s) had been incorrectly spelt as the screen reader often pronounces incorrectly spelt words in the same way as the correctly spelt ones would be pronounced.

We did not observe this confusion among the participants in the evaluation of the proposed interface as the way we designed the spelling support feature on the proposed interface (described in section 7.4.2) implied that visually impaired searchers were notified in real time when a keyword was misspelt and the option to correct the query was accessible so that users of speech-based screen readers could clearly identify which terms had been incorrectly spelt.

Strategies for Managing Search Results

In Study 1, participants used web-based search interfaces such as Google for their information seeking tasks and therefore, to manage encountered information, they relied on word processors such as Notepad and browser tools such as bookmarking as described in Chapter 5. As for the participants in Study 2i, TrailNote was available on the proposed interface to support them in managing search results through a search trail and a search note. TrailNote allowed participants to tag visited pages as useful and also to directly save search results in the search note. Thus, there were equivalent features in both studies for note taking and bookmarking and in this section, we investigate how they were used by participants.

In Study 1, only 6% of the participants saved search results in their note whereas in Study 2i, 33% of participants used the ‘Save in Note’ feature of the TrailNote to save search results directly into the search note. Saving search results in Study 1 required significant cognitive efforts from participants, that is, if a searcher wanted to save a search result, they would have to copy it from the search result list on the search interface and then navigate away from the browser to their word processor document and paste the copied search result. The same action could be performed in a much easier way, simply by using the context menu or by the ‘click of a button’ when exploring the web page itself in Study 2i.

We also observed that the content of notes varied in both studies. In Study 1, participants used word processor documents to record different types of information such as search results, information of interest copied from web pages as well as query terms. However, in Study 2i, participants mostly saved pages directly to their search notes. They did not record query terms and at the end of the first session, there was a limited amount of information that had been copied from web pages in the search notes.

On the proposed interface, the equivalent function to bookmarking was ‘Tag As Useful’ and it was used by 42% of the participants in Study 2i, tagging 29% of all visited pages as useful. When users tagged a page as useful, they would be notified through an earcon when they navigate the search trail. Thus, compared to bookmarking, ‘Tag As Useful’ was easier to carry out and more effective as after the search session, searchers could access an 'uncontaminated' history of the pages they visited and also know which of those pages they particularly found useful. There was a limited use of bookmarking in Study 1 as only 3% of the participants bookmarked 4% of all visited pages. It is possible that this difference in the use of bookmarking is related to the fact that in Study 1, there was no following search session as explained in section 8.5.1.

8.4.3 Comparing the Information Seeking Behaviour of Visually Impaired Users on the Proposed Interface and Popular Web-based Search Interfaces

In this section, we present findings about the information seeking behaviour of visually impaired searchers when using the proposed interface. As described previously, we use findings from Study 1 to examine the differences in the information seeking behaviour of visually impaired users when using the proposed search interface. As the search tasks performed in both studies were of comparable complexity, we provide insights into the information seeking behaviour from two perspectives: firstly, we compare the behaviour for all participants in Study 1 and Study 2i and secondly, we focus on a group of 5 visually impaired participants who took part in both studies. In the rest of this section, we refer to these two perspectives as the 'overall comparison' and 'group comparison' respectively.

	Study 1	**Study 2i**
Average No. of Queries	4.47 [1.77]	2.92 [1.83]
Average No. of Terms in Queries	4.61 [2.76]	4.17 [2.73]
Average No. of Visited Search Results	4.27 [2.15]	3.42 [1.98]
No. of Saved Search Results	8 (1 user)	8 (4 users)
No. of Bookmarked Pages	3 (2 users)	12 (5 users)

Table 8.4: Overall comparison between Study 1 and Study 2i. (Mean [SD])

Query Formulation

Query formulation is an important stage of the information seeking process and often reflects searchers' understanding of their information needs. When using the proposed search interface, visually impaired participants submitted fewer and shorter queries both for the overall and the group comparison as shown in Table 8.4 and Table 8.5. We also observed that queries in Study 2i were broader than those in Study

	Study 1	Study 2i
Average No. of Queries	5.00 [1.22]	3.60 [2.51]
Average No. of Terms in Queries	6.44 [4.92]	4.28 [3.08]
Average No. of Visited Search Results	4.80 [1.48]	3.80 [2.59]
No. of Saved Search Results	0	6 (3 users)
No. of Bookmarked Pages	2 (1 user)	8 (2 users)

Table 8.5: Comparison between common participants in Study 1 and Study 2i. (Mean [SD])

1. These differences could be caused by the fact that in Study 1, participants chose their own tasks which means they had a better mental model of the what was required to satisfy their information needs. In Study 2i however, participants were assigned a task at the beginning of the session and the task description was relatively vague which could have been responsible for the broad queries submitted by visually impaired users.

Search Results Exploration

Compared to Study 1, we observed that participants in Study 2i visited a lower number of search results as shown in Table 8.4 and Table 8.5. In fact, participants in Study 1 viewed on average 4.27 search results compared to 3.42 in Study 2i for the overall comparison. For the group comparison, the average number of visited results in Study 2i (3.80) was also lower than in Study 1 (4.80). On the proposed interface, web pages were displayed in a slightly different way from current interfaces as we developed an interface to keep track of all users' actions during the search process. Searchers had some difficulty in getting used to this new presentation format and therefore, they took more time to explore search results. This could have led to the number of visited search results being lower for both the overall and the group comparison. Additionally, given the broad nature of the search task in Study 2i, participants displayed a more exploratory behaviour than in Study 1. For example, in Study 2i, participants would consider different aspects of the topic including those not directly related to planning travel whereas in Study 1, participants were more focussed on satisfying their particular information needs.

Search Results Management

This stage of the information seeking process is when searchers gather, analyse, and use the information encountered during the search process. As TrailNote was one of the most important features on the proposed interface, we expected the information seeking behaviour to be mostly impacted at this stage. As shown in Table 8.4 and Table 8.5, more participants saved and tagged a higher number of web pages in Study 2i than in Study 1 for both the overall and the group comparison. The differences in the way participants interacted with similar features to manage search results in both studies have been discussed at length in section 8.4.2, however saving and tagging pages were easier to perform in Study 2i when using the proposed interface.

The differences in the behaviour for search results management could have been caused by two factors: firstly, saving and tagging visited pages were cognitively less taxing in Study 2i when using the proposed search interface and secondly, in Study 2i, participants were aware that there would be a second evaluation session which would be related to the first one. However, as explain in section 8.5.1, participants did not know what the task would be and therefore it is unlikely that they saved and tagged pages in anticipation of the task in the second session.

8.5 Discussion

In this section, we discuss the findings from the user evaluation. We structure the discussion according the research questions identified in section 8.2 focussing on the way participants interacted with the proposed search interface and the impact that the search interface had on their information seeking behaviour.

RQ1: How do visually impaired users interact with proposed interface features such as TrailNote and the spelling support mechanism?

Prior to designing the search interface described in Chapter 7, we carried out an exploratory observational study to investigate the information seeking behaviour of visually impaired users and to establish user requirements for the search interface. Therefore, as a result of this user-centred approach, the features on the proposed search interface were mostly well received by participants. We designed the interface to take into consideration the observations from Chapter 5 in order to support visually impaired searchers for complex information seeking and to address the previously observed difficulties. As a result, we designed a spelling support feature with non-speech sounds to alert users in real time when a keyword has been misspelt. By notifying users in real time and by specifying which terms had been misspelt, we were able to avoid the confusion that we observed with other web-based search engines as described in section 7.4.2. This, we believe, highlights the importance of considering the abilities of the target users in the design process and also how essential user-centred approaches are, as such observations would not be apparent to the sighted designer without user involvement. Such small considerations contribute to improving the search experience of visually impaired users when the focus of design shifts to designing for their abilities, rather than adapting designs to their disabilities (McElligott and van Leeuwen, 2004).

Our main focus on this search interface was to be able to support visually impaired searchers for complex search tasks, such as those requiring more than one search session. TrailNote was motivated to allow users to keep all the important information necessary for search task resumption (previous queries, useful pages etc.) within the search interface to facilitate the sensemaking process which is integral to complex information seeking. We found that users liked the search trail as it allowed them to have an overview of their previous session. The list of queries and visited links from Session I, presented in a chronological order, allowed participants to quickly recap their progress on the task at hand. The visually impaired searchers in the user evaluation also found it easy to navigate the search trail as it was accessible with the screen reader and it also could be accessed using the popular link navigation feature found in the most popular screen readers such as JAWS, Window-Eyes and VoiceOver.

The search trail also helped to address the navigation difficulties faced by speech-based screen reader users as described in section 3.5. In this respect, the automatic recording of submitted queries and visited web pages in the search trail improved the persistence of information on the search interface and provided searchers with more contextual information about their interactions with the search interface, for example, the order in which specific pages were explored and for which query a page was visited. The search trail also helped to reduce the information overload of visually impaired searchers as they did not have to remember every aspect of their interaction during the search process.

During the user evaluation, interaction with the search note was similar to how users would interact with an external word processor for note taking purposes. Some users found it useful to be able to save search results directly into the search note, especially in a format that they could easily re-access the web page at a later stage. The main advantage of having an integrated search note is that users do not have to continuously switch between different applications. However, they still had to use the shortcut key or manually navigate to the search note. The search note feature on the proposed search interface had basic functionalities and could be enhanced in the future to include additional features to allow visually impaired users to structure and further organise the content of their search notes. In summary, it appears that users liked the fact that the search trail is organised automatically in a chronological order by the search interface, as that is an ordering that facilitates overview of their search history. Yet, they also valued the flexibility of being able to restructure the contents of the note themselves.

RQ2: What are the differences in the use of similar features on the proposed search interface and popular web-based search interfaces?

For this research question, we examined how visually impaired participants used similar feature on the proposed interface and popular web-based search interfaces. The findings showed that it was easier for participants to use the spelling support mechanism on the proposed interface. We believe this is so because participants could effortlessly interact with the feature using speech-based screen readers and they were given appropriate feedback when they misspelt a keyword. Our use of non-speech sounds in the form of an earcon meant that participants were immediately aware of an incorrectly spelt term in the query and thus, there were no confusion or frustration as was observed with popular web-based interfaces in Chapter 5.

When using web-based interfaces such as Google, there was a limited uptake of the spelling support mechanism among visually impaired participants as they were often unsure as to why they were being prompted with suggestions for an alternative query when via the screen readers, they perceived both the submitted and the suggested query exactly the same. This is because the screen reader would output both the correct word and the incorrectly spelt one in the same way. To the sighted user, the difference would immediately be recognised but as orthographic information is lost when the screen reader converts text into speech (Stein et al., 2011), visually impaired users cannot immediately perceive the difference between the query they typed and the one the interface suggests.

Therefore, we believe that the way we re-designed the spelling support feature on the proposed interface (described in more detail in section 7.4.2) could also assist visually impaired users to learn the correct spelling of keywords as they know exactly which term has been misspelt. As a result, they can navigate the word character by character to determine the correct spelling. This requires less cognitive efforts from the screen reader user than having to navigate an entire query character by character and being unsure which term has been misspelt.

During online search, correct spelling can be a dilemma for all types of users especially if they are unfamiliar with the search domain. However, for sighted users, finding the right spelling can be relatively easy as most search interfaces provide dynamic query suggestions while a user is typing a query. Thus, a sighted user can find the correct spelling for the term from the list of suggested queries and thus also learn about the correct spelling. For visually impaired users, this is not as straightforward for several reasons: firstly, dynamic query suggestions are not usable for visually impaired users despite being accessible with screen readers as users have to move their focus from the search box to the drop down list and linearly navigate down the list of query suggestions. As discussed in Chapter 5, the effort required for this outweigh the potential benefits and thus, this query formulation support mechanism was not popular among visually impaired users. However, even if visually impaired users do navigate down the list of suggested queries, it is relatively difficult for them to immediately perceive the correct spelling of terms unless they cursor individual terms character by character. Furthermore, if visually impaired users submit an incorrect query, popular search interfaces prompt them about what they meant (shown in Figure 7.3) and similarly, without significant cognitive efforts, they cannot identify the correct spelling and learn it.

In fact, spelling is challenging for visually impaired users because of the way they learn languages especially when using voice output. Visually impaired users cannot perceive the visual pattern of words and therefore cannot recognise and remember the pattern in order to learn and retain the spelling (Arter and Mason, 1994). It has also been shown that blind users make many spelling mistakes, significantly more than sighted users (Papadopoulos et al., 2009). Thus, there is the motivation to support visually impaired searchers not only in correcting their queries on search interfaces, but also to learn the correct spelling of terms. The interface proposed in this thesis takes a few initial steps in that direction and despite being out of the scope of this thesis, it would be interesting to further explore how sound could be used to successfully assist visually impaired people to identify and learn correct spelling when using computer-based interfaces with speech-based user interfaces.

For this research question, we also compared the use of tools for managing search results and the findings showed that in Study 1, participants relied on external word processors and browser tools to manage the information they encountered. In Study 2i, participants used TrailNote to manage the search process and information of interest and a higher percentage of participants took explicit actions to save or tag web pages. This is likely to be because when using the proposed interface, saving and tagging web pages were comparatively easy to perform by a click of a button and thus was cognitively less taxing.

Furthermore, participants' search notes were different in both studies. When compared to notes made by participants in Study 1, the search notes in Study 2i were less diverse, that is, they mainly contained search results directly saved from the search interface whereas in Study 1, participants' notes contained saved results, copied information from web pages as well as query terms. One of the reasons for this could be that despite the proposed interface being unfamiliar for the visually impaired participants, they were aware of the features prior to starting their search sessions as they took part in a training session. Therefore, they knew that through the search trail, they could re-visit any page and that queries they submitted to the interface would be automatically recorded. Consequently, they were less diligent about recording all aspects of the search process.

In this way, TrailNote was effective in relieving some of the burden placed on the users for complex tasks such as those requiring multiple sessions (Kotov et al., 2011). Given that participants were aware that all their queries and visited results would be recorded in the search trail, they did not have to take to constantly take measures to ensure that information of interest would become more persistent in order to facilitate re-access at any time in the future. The way visually impaired participants used the search trail and the search note will be further discussed in Chapter 9 where we discuss the behaviour of visually impaired users for multi-session search tasks.

RQ3: What is the impact of the search interface on the information seeking behaviour of visually impaired searchers?

To study the information seeking behaviour of participants when using the proposed interface, we examined the findings from Chapter 5 from two perspectives including an overall comparison and a comparison between the common participants between Study 1 and Study 2i. As described in Section 8.5.1, given the differences in the methodology of both studies, we could not make a strict comparison to conclude exactly how the proposed interface impacted the information seeking behaviour of visually impaired users. Instead, we provided insights into the differences in behaviour and explore the reasons for which these differences might have occurred.

The proposed interface was new and rather unfamiliar to searchers. Despite a training session prior to their participation, participants needed more time to fully understand the new proposed features on the interface. In contrast, participants in Study 1 had significant experience with using their current search interface and therefore could progress faster with the task. In addition, as discussed in Chapter 5, screen reader users often memorise the layout of web pages that they visit on a regular basis and thus, they know exactly which navigation strategies work best on the page, for example, if the page has headings level or has a table, users will use the most appropriate keys to browse the page. Therefore, with a new interface, users need time to explore the layout and page structure and possibly multiple uses to fully form a correct mental model of the page and correctly understand the best navigation strategies.

Queries submitted by participants on the proposed search interface were shorter in comparison to Study 1. A possible reason for this could be the difference in the search tasks between the two studies. In Study 1, participants had to choose their own tasks and were told to do so several days prior to their participation. Therefore, they might have had time to think more about the task and the aspects of the task they would explore during their participation. As a result, during their participation, they submitted longer queries that represent a more defined information need even though the search task itself was complex. However, for Study 2i, we assigned the search task to the participants on the day, at the start of Session I after the training session. In this case, participants did not have time to consolidate their information need, to think of the perspectives from which they would conduct their search and thus, queries were more spontaneous and exploratory.

For search results exploration, participants in Study 2i visited fewer search results and as discussed in Section 8.4.3, this was mainly due to the fact the users had to get used to the way web pages were being displayed on the proposed interface and thus, they took more time to access the content of the web page. In addition, less familiarity with the domain of the search task means that users also spent more time reviewing the content of web pages to find out about different aspects related to Australia.

As expected, with the inclusion of TrailNote on the proposed interface, most differences in information seeking behaviour were observed at the search results management stage. We had explicitly designed TrailNote to support visually impaired searchers at this stage and therefore, we observed that more users saved search results and tagged pages as useful. Our findings in Chapter 5 showed that visually impaired users often evaluate the efforts required by an action with the potential benefits to decide whether to perform that action. It is likely that in the case of the proposed interface, visually impaired participants viewed the potential benefits of saved or tagged pages considerably higher than the costs required for these actions in terms of time and efforts. Therefore, even if participants were not to use those saved or tagged pages in the future, they still invested the efforts to keep track of those pages.

Note taking was also easier for participants in Study 2i as the integrated note taking feature meant that users did not have to navigate away from the search interface and the browser in order to make notes related to their search task. Hence, users did not have to continuously switch between applications which usually contribute to the load on working memory as each time users change to an application like the browser, they have to remind themselves of the current state of that application, for example, whether they were still on the search interface or a specific web page was being displayed.

Therefore, using the findings from Chapter 5 to provide insights into the behaviour of visually impaired participants when using the proposed interface has illustrated how the additional features and the differences in task might have impacted the search behaviour of participants. However, the differences observed both in the use of similar features and in the information seeking behaviour are not surprising, given that the proposed interface as developed to address the challenges observed during the observational study in Chapter 5.

8.5.1 Limitations

One of the most important limitations of the evaluation presented in this chapter is the fact that participants were not familiar with the interface. The proposed search interface was different from the ones participants frequently use for their search activities in that it included some additional features. Therefore, visually impaired users had to learn the interface layout and also how to access different features. This process can be quite difficult for screen reader users because they cannot perceive an interface as easily and quickly as a sighted user would. As a result, this could have affected the way visually impaired participants used the proposed interface, for example, they might have taken a longer time to carry out certain actions. The evaluation sessions also lasted for about 30 minutes each which was limited and thus, participants may not have had enough time to find information during each session given that they were unfamiliar with the search interface. However, we tried to limit the unfamiliarity with the proposed interface by conducting a training session prior to users' participation. Additionally, at any time during the evaluation sessions, participants were also allowed to ask the evaluator to remind them of how to access an interface feature, for example, the shortcut key to use.

Furthermore, there are some limitations in using the findings from the study described in Chapter 5 to examine the observations from the study presented in this chapter as there were the following differences in the methodology of both studies. Firstly, the tasks for the two studies were different as in Study

1, we left the choice of task open to participants and in Study 2, participants were assigned a task in both sessions of the evaluation. This could have resulted in users having different mental models of the tasks as the assigned tasks are likely to have been more structured than the ones that participants chose themselves. However, in Study 1, as described in section 5.3.2 we validated participants' choice of tasks against a set of criteria to ensure that they were complex search tasks and in Study 2, we deliberately chose complex multi-session tasks for the evaluation process. Thus, despite the differences in the way search tasks were chosen, in both studies, the search tasks completed by participants were of comparable complexity and should not have significantly affected the interaction with the search interface.

There were also differences in the structure of the evaluation as for Study 1, users took part in only one session and in Study 2, the evaluation process included two sessions. Therefore, in the study presented in this article, given that participants were aware that there would be a second evaluation session, this could have caused them to have a different behaviour towards the tasks. However, participants only knew that the task in the second session would be related and not exactly what the task would be, which limit the impact that this had on the comparative analysis.

Overall, these limitations imply that for the differences we observed between the two studies, there might have been other contributing factors. However, as discussed in section 8.2, the aim for the comparison is not to compare the information seeking behaviour, but only to observe the ways in which participants use similar interface components on different interfaces. Therefore, we focus on aspects such as how did the contents of the notes change or how did users perceive the spelling support mechanism.

8.6 Chapter Summary

In this chapter, we described the user evaluation of the search interface proposed in Chapter 7. We examined how visually impaired users interacted with the proposed interface features which were designed to be both accessible and usable. We also compared how visually impaired participants used similar features on the proposed interface and popular web-based search interfaces used in the study described in Chapter 5. We discussed the differences in the use of the spelling support mechanism, note taking and bookmarking. We also provided insights into the information seeking behaviour of visually impaired participants when using the proposed search interface. Thus, we could understand the impact that the proposed interface had both on the information seeking behaviour of visually impaired users and the way they interacted similar interface components.

Therefore, this chapter's main contribution focus on visually impaired users' interaction with search interface features that were designed through user-centred approaches, that is, those components that were designed after observing users' behaviour during information seeking on the Web. Therefore, we showed how user requirements that were gathered in the real context of use, informed the design of interface components which were effective in supporting visually impaired users during information seeking. The structure of the evaluation also allowed us to gain insights about the information seeking behaviour of visually impaired users for multi-session search tasks which we present in Chapter 9.

Chapter 9

The Behaviour of Visually Impaired Users for Multi-session Search Tasks

9.1 Introduction

A multi-session search task is not usually a routine task: it is one which requires more than one web session to complete and has a specific goal and a defined point when the task is completed (MacKay and Watters, 2008a). For example, in planning a vacation to Australia, a user is likely to search for different aspects of the trip (flights, hotels and things to do) and there is a goal (go on vacation) and a defined completion date (when the trip is over or the idea abandoned). Shneiderman [cited by (Hearst, 2009, p. 82)] describes these as "1-week to 1-month" searches in contrast to "1-minute" searches. Therefore, such multi-session tasks can be complex and cause large memory and cognitive demands for which searchers must be supported.

For visually impaired searchers, such complex tasks can be cognitively more taxing as due to the lack of persistence of screen readers, they are faced with a higher load on working memory in order to keep track of various aspects of the complex search tasks. To the best of our knowledge, there is no reported research into the behaviour of visually impaired users for multi-session search tasks. Therefore, in this chapter, we provide some insights into how visually impaired users resume search tasks and re-find previously encountered information.

9.2 Motivation

For search tasks that take place across multiple sessions, users are required to resume the task after a period of time (hours, days or weeks) either because of interruptions or because they have a redefined information need. Morris et al. (2008) surveyed information workers about their strategies for resuming search tasks and found that users could adopt an active approach (note taking, bookmarking) or a passive approach with strategies such as depending on memory, leaving the browser open or depending on the autocomplete feature of the browser.

When completing complex search tasks online, people are likely to encounter more information than they are able to analyse in the time available to them (Bruce et al., 2004). Therefore, searchers need ways to ensure that the web pages that they identify as potentially useful can be made persistent and be returned to at a later stage. Previous research (Sellen et al., 2002; Kellar et al., 2007) have shown that search tasks on the Web are often repeated and that "it can be almost impossible to remember the exact query that was used when a specific piece of information was found" (Aula et al., 2005). Capra and Perez-Quinones (2005) differentiated between finding and re-finding information. They describe finding as an uncertain process where users may be unsure about whether the information is available at all while re-finding is a more certain and focussed process as the user already knows that the information is there and they need to find a way to get back to it. Therefore, to re-find information, searchers may need to remember queries or web pages along the path that led to the information in the first place (Maglio and Barrett, 1997). They may depend on contextual cues on the search interface or related websites.

For complex search tasks such as those requiring multiple sessions, the main challenge is to help users to maintain the current state of their search between search sessions. When searchers return to a task, they need to remember the state in which they had left the task (the queries they had submitted and whether they were effective), the web pages that they had visited and whether any of the visited pages was particularly relevant etc. For any searcher, this is likely to be a challenging process unless they have taken active measures to preserve the state in which they left the task using tools such as those discussed in section 9.3. An overview of the activities undertaken in previous sessions is important to searchers as it helps them to make sense of the task's progress and the information they have gathered so far.

In the search interface proposed in this thesis, we designed TrailNote to support searchers for multi-session tasks and as described in Chapter 8, we conducted a user evaluation with 12 participants to investigate the behaviour of visually impaired users for multi-session search tasks. The evaluation was structured in two sessions (Session I and Session II) to simulate a search task that would typically span multiple web sessions. We therefore study the strategies employed by visually impaired participants for resuming search tasks, for reviewing previously encountered information and to satisfy an evolved information need. In this respect, we address the following research questions in this chapter:

RQ1: What is the habitual behaviour among visually impaired participants for resuming search tasks?

At the beginning of the second session of the evaluation, we interviewed participants about the strategies that they currently employ to keep track of encountered information whether using external applications or browser tools. Thus, for this research question, we report on the current habits of visually impaired users when faced with multi-session tasks.

RQ2: What is the observed behaviour among participants for resuming search tasks in Session II of the evaluation?

After users were assigned their search tasks at the beginning of Session II, we observed their behaviour towards resuming the search task. Given that the task was related to the one visually impaired participants had performed in Session I, we were interested in the starting point for Session II, that is, how participants would start the session and the strategies they would use throughout to satisfy this evolved information need. Furthermore, as the proposed interface included TrailNote, a feature designed to support visually impaired searchers for complex search tasks, we also focussed on how participants used the knowledge they had previously acquired and the role that the search trail and search note played in assisting them to resume the search task. Therefore, we seek to further address the following questions:

RQ2.1: How did participants resume the search task?
For this research question, we study the starting point for Session II as we wanted to find out how visually impaired participants would resume the search task, for example, which aspects of the previous search session would be important to start the task in Session II.

RQ2.2: What were the search strategies employed by participants during the task in Session II?
In Session II of the evaluation process, participants had improved domain knowledge about the

task, for example, they might already know which city they want to visit and how to get there or at which time of the year they want to plan their travel. Therefore, we focussed on studying their search strategies, to observe whether they review any previously encountered information or rely solely on new information tailored to their more defined information need.

RQ2.3: How did participants use TrailNote in Session II?

TrailNote was designed to assist visually impaired searchers in managing the search process and the information encountered during complex search tasks. Therefore, our aim for this research question is to investigate the different ways in which participants used the information contained in the search trail and the search note to complete the assigned task.

RQ3: What were the differences in the information seeking behaviour of visually impaired users between the two sessions of the evaluation?

There are clear differences between the two sessions of the evaluation: in the second session, participants were more familiar with the search interface and also had increased knowledge about the domain of the search task. Thus, we investigate the differences in their information seeking behaviour and more specifically, we study how their approaches to query formulation, search results exploration and search results management were impacted across the two sessions.

9.3 Existing Tools for Managing the Search Process

There is a diverse set of reported strategies (Jones et al., 2001; Morris et al., 2008) used by searchers to manage the search process and the information gathered across different search sessions including printing/saving pages, sending email, remembering URLs, history mechanisms, bookmarking etc. MacKay and Watters (2012) identified two categories of tools for supporting multi-session search tasks on the Web, namely, tools that facilitate revisitation of web pages and those that facilitate management of information across different search sessions. Most browsers support revisitation by providing features such as Back/Forward, autocomplete, history list, bookmarking and tab restoration (Jhaveri, 2004). Back/Forward are only available for revisiting pages during the search session and autocomplete is useful if users remember at least a part of the URL of the page they would like to re-access.

History lists and bookmarks are browser tools that allow users to revisit pages even after they have ended their search sessions. However, many users tend not to use history lists (Aula et al., 2005; Weinreich et al., 2008) because they are not easy to use as the organisation of previously visited pages can become confusing and users can become disoriented (MacKay and Watters, 2012). As for bookmarks, they can be difficult to manage as the list of bookmarked pages becomes long and unruly (MacKay and Watters, 2008b). Despite its limitations, bookmarking remains popular among web users. MacKay and Watters (2008b) reported that bookmarks were the most common approaches for revisiting pages after both a diary and a field study of multi-session search tasks. Similarly, in the "Keep Found Things Found" (KFTF) project, Bruce et al. (2004) reported that 89.72% of participants frequently used bookmarks following a survey of 214 people.

Tab restoration can also be useful for searchers especially if they use multiple tabs to view different pages during their search activities. This strategy is common among sighted users as discussed in Chapter 5. However, Weinreich et al. (2008) argued that opening a link target in a new tab or window means that users have to remember what actions were performed in which window to be able to re-access certain information and this places further cognitive burden on the user. As reported in Chapter 5, this is why the use of multiple tab and windows within a browser is not common among visually impaired users.

Given the limitations of these browser tools, previous research have proposed other tools to support users in managing information across different search sessions: TopicShop (Amento et al., 2000) was designed to provide users with integrated support in organising websites through annotations and grouping. Similarly, Session Highlights (Jhaveri and Räihä, 2005) provided a workspace where users could drag URLs of the web pages they find useful to create a collection which was organised as thumbnails in a chronological order. To support users in managing information they encounter while viewing web pages, Hunter Gatherer (schraefel et al., 2002) and Web Clippings (Brown and Sellen, 2001) were proposed to allow users to highlight and save specific components of a web page.

MacKay et al. (2005) also proposed the use of landmarks to support users not only to revisit the previously visited page, but also to find the position of relevant information on the page. One or more landmarks could be added to a page in a similar fashion as bookmarks, but when users select a landmark from their list, the page would open with the scroll position in the exact location where the text was marked. For visually impaired users, similar functions have been recently included within screen readers and are referred to as Web Spots in VoiceOver and PlaceMarkers in JAWS and Window-Eyes. As a web page is opened by VoiceOver, the visual design of the page is evaluated and Web Spots are automatically placed to mark key information. However, Web spots can also be added by the user as is the case with PlaceMarkers which are exclusively under the users' control.

Additionally, Bharat (2000) and Morris et al. (2008) proposed more search-centric tools, namely SearchPad and SearchBar to assist users during their search activities on the Web. SearchPad (Bharat, 2000) was developed as a search engine extension to help users to be more effective during their searches by explicitly maintaining the context of the search task. The tool which was deployed as a helper window was search specific to allow searchers to keep track of the queries and search results that they visited. Searchers could interact with the SearchPad by deleting visited leads, renaming and merging queries. However, the SearchPad was only a short-term solution to complement the use of the browser's history as it was not available after the searcher had completed the search task or closed the search session.

More recently, Morris et al. (2008) proposed the concept of a SearchBar, a rich history mechanism that integrates query histories, browser histories and users' notes. The feature, available as a plugin to Internet Explorer, catered for both users who were active and passive in managing their search process. In this respect, users could create custom-named topics and notes (active strategy) or they could do nothing and the system proactively captures all the queries they submit and the pages they visit (passive strategy). The tool was evaluated with 16 participants in two sessions of 90 minutes each which were scheduled one week apart. Participants were planning a travel itinerary with frequent interruptions and therefore found SearchBar effective for re-finding information in the second session, thereby saving users from doing redundant work, for example, searching for things that had already found before.

To the best of our knowledge, no such tools have been developed for visually impaired users. Complex information seeking can be challenging for visually impaired users as they face high demands for cognitive effort by the different components of interaction with search interfaces, including screen readers. Therefore, in this chapter, we investigate the behaviour of visually impaired users for multi-session tasks. We also evaluate how TrailNote supported searchers in resuming their searches and re-access previously encountered information. Our proposed tool is most similar to SearchBar (Morris et al., 2008) as it includes a history of queries and visited pages and also allows visually impaired users to take notes during the search process.

9.4 Methods

As described in section 8.3, we conducted a user evaluation of the proposed search interface with 12 visually impaired participants. The user evaluation was structured so that each participant took part in two sessions (Session I and Session II) separated by several days (on average 9 days). In Session I, users were assigned a broad task and were allowed 30 minutes to search on the topic. At the end of the session, they were asked to save their search session using the 'Save Session' which was available on the proposed search interface. In Session II of the evaluation, as shown in Table 8.3.2, we assigned a search task which was more specific to the users to reflect an evolved and more defined information need. Participants were then allowed to search on the topic for 30 minutes. The tasks were constructed to simulate multi-session search tasks that happen in real life circumstances. The full description of the user evaluation can be found in section 8.3 including the approach for data analysis. In this chapter, we performed statistical testing on all quantitative data using the R statistical package and all statistical tests were performed at $p<0.05$. We used a two-tailed paired *t*-test for comparing averages such as query length across the two search sessions and a chi-square (χ^2) test for statistical testing on count data such as the use of particular interface components.

9.5 Findings

Before Session II, we interviewed participants about their current practices for resuming search tasks and we discuss these in section 9.5.1. In section 9.5.2, we present the behaviour that we observed among the visually impaired users in our study when resuming search tasks in Session II. Multi-session tasks can have an impact on search behaviour as across search sessions, users' knowledge of the search domain and their understanding of the information need are likely to change as a result of search activities in previous sessions (Vakkari, 2005; Kuhlthau, 2004; Robertson, 2001). Therefore, in section 9.5.3, we compare the information seeking behaviour of visually impaired searchers across the two sessions of the evaluation at the following stages of the information seeking process, namely, query formulation, search results exploration and search results management.

9.5.1 Habitual Behaviour for Resuming Search Tasks

By asking users about their current practices, our aim was to find out how users currently keep track of task progress and also the information encountered for tasks that could not be completed in one sitting, for whatever reason. 58% of users reported that they took notes during the search process. However, the type of information that went into the note differed among users and also according to the task at hand. For example, some users said that they would copy the URL of the page in a text file while others would copy and paste chunks of text from a web page in order to record information relevant to their goal.

Bookmarking (Save as Favourite in some browsers) was popular with 50% of the users, agreeing with (MacKay and Watters, 2008b) who showed that despite its limitations, bookmarking remained a popular method of monitoring the information encountered on the Web. Some of the users in the study were aware of the difficulties that can be caused by long bookmark lists. One of the users said "*I usually add pages to favourites, but I know this is not a good method as I have to regularly clean up the list*".

One quarter of the users in our study also depended on their memory to keep track of their search process. Among this group of users, some said "*I tend to remember a lot of things as well*" while others would only attempt to "*vaguely remember what I did before*". Other strategies mentioned by the visually impaired users were: browser history, print document using a Braille printer, send email to self, save in calendar and creating desktop shortcuts for relevant pages.

9.5.2 Observed Behaviour for Resuming Search Tasks

During Session II of the evaluation, we loaded the search interface from where the user had stopped the task in the first session. We reminded participants that all previous information was still persistent on the interface and that the query box contained the last query they had submitted. In this section, we present our observations categorised according to the research questions outlined in section 9.2.

RQ2.1: How did participants resume the search task?

For this research question, our aim was to investigate the strategies employed by visually impaired users when resuming the search task in Session II of the evaluation process. We were interested in observing the behaviour of participants when assigned a search task in Session II, which represented a more defined information need as opposed to the one assigned in Session I.

42% of the participants resumed the search task by re-visiting a search result from the search trail which contained a list of submitted queries and visited search results from Session I. Among those participants, the starting point for two users were visited results which they had tagged as useful in Session I.

Another strategy for search task resumption, used by 42% of participants, was to start Session II by formulating a new query which reflects the information need in the newly assigned search task. Therefore, we observed specific queries such as "cheap travel packages to Australia in July" and "tourist activities in Sydney" after participants have used the task description to refine their information need by deciding on the time period to travel and on the city to visit respectively.

When the search interface was loaded in Session II, the last query submitted by the participant in Session I was in the query box and the interface would display search results for the specified query. We observed that the remaining 16% of participants resumed the task literally from where they left off in the previous session by visiting search results that were currently displayed on the interface. This was possible because the proposed search interface would be loaded with the user's last query in the search box in Session II and thus, this strategy would not be possible if the interface did not have this feature.

RQ 2.2: What were the search strategies employed by participants during the task in Session II?

Search strategies are plans for the whole search and in this case, the search session. During Session II, we observed the following strategies among visually impaired participants:

1. *Find New Information*

   For this strategy, searchers were focussed on finding new information relevant to their evolved information need, that they were looking for and exploring information they had not seen in previous sessions. It includes the following actions: submitting new queries, exploring new search results and browsing new pages from previously encountered websites.

2. *Review Existing Information*

   This strategy involves searchers reviewing information from the previous session in light of their information need. Therefore, it includes the following actions: re-visiting pages that were explored in Session I, navigating the search trail to gain an overview of the submitted queries and visited results and examining the content of the search note.

During Session II, we observed that 58% of the visually impaired participants employed a combination of 'finding new information' and 'reviewing existing information'. As a result, the activities of submitting new queries and exploring new web pages were interleaved with getting an overview of what was achieved in Session I or re-visiting a previously encountered web page. There was no particular order in which these activities were carried out; some users would start with getting an overview of their previous session using TrailNote (as described for RQ 2.1) while others would start by finding new information for the re-defined search task and then later reminding themselves of what they did in the previous session. We also observed that users who employed both strategies were mostly those, who at the beginning of the search task in Session II, would have already decided or have an idea of the city in Australia that they would like to visit. Therefore, this group of participants focussed in the assigned task to find specific information to satisfy their evolved information need in Session II.

In comparison, 42% of participants only used the 'find new information' strategy for the whole of Session II, that is, they did not review any previously encountered information, they did not use the search trail or the search note. Therefore, this group of participants treated the task in Session II as a completely new task with a new information need and throughout the search session, they searched for new information without trying to remember or navigate through the information they encountered previously. However, the type of queries that they submitted were longer and more specific as discussed in section 9.5.3 at the query formulation stage. Among these users, we observed that in Session II, they still displayed an exploratory behaviour about the assigned search task. For example, they would still be exploring facts about Australia such as the cities without any focus on what they would like to do in the seven days they would spend there as specified by the task description for Session II.

Additionally, we observed that 25% of participants did not submit any new queries in Session II of the evaluation. However, apart from reviewing information encountered in the previous session, they also found new information by visiting new search results from existing queries in the search trail or by exploring new web pages from websites they had previously visited (For example, sub pages from the main Wikipedia page on Australia).

RQ 2.3: How did participants use TrailNote in Session II?

On the search interface designed in this thesis, one of the most important components was TrailNote which was aimed at supporting visually impaired users for complex search tasks such as those that require multiple sessions to complete. As described in Chapter 7, we designed TrailNote to assist users in managing the search process and encountered information across search sessions. Therefore, in this section, we observe how users interacted with TrailNote in Session II especially as there was the need to remember, re-find and use information encountered previously.

Overall, TrailNote was used by 10 participants in Session II either through the search trail or the search note. This was expected as it was during Session II that participants had more need of TrailNote to have an overview of their activities for the search task in the previous session. However, we observed that the search trail and the search note was used for different purposes as described in the following.

83% of participants used the search trail in Session II mainly by re-visiting web pages encountered in Session I and by re-submitting queries that were previously formulated. In fact, 42% of participants re-visited a page from the search trail, 16% re-submitted a query and 25% visited the search trail without explicitly using any of its features. Overall, participants also used the search trail to gain an overview of what they have achieved in Session I as the queries and visited results were listed in a chronological order. There is evidence that the search trail allowed participants to form a mental model of what they had completed in Session I as we observed participants' comments such as "*last time, we looked at flights, currency, things to do etc.*" to recap on what they did previously. We also found that the search trail helped to trigger participants' memory about the first search session as participants claimed "*I did so much last time*" or "*I was not very successful last time*" when navigating the queries and visited results in the trail on the interface.

The search note was used by 42% of participants in Session II for various purposes. Most participants made their own notes by copying information from web pages of interest, for example, hotels details and places of interest in a city etc. During note taking, we observed that participants also structured the search note by dividing the main search task into sub tasks. Consequently, the search note would include headings such as *'from Brisbane to Cairns'* and *'Three day trip from Sydney'*. Among participants who used the search note in Session II, we also observed that during the task, they would often go through the note to get an overview of its contents and this often resulted in them further organising the note, to add headings or to delete information they no longer deemed as relevant.

9.5.3 Differences in Information Seeking Behaviour

In this section, we compare the information seeking behaviour of visually impaired users in the two sessions of the evaluation. We wanted to investigate how participants resumed their task and how, in light of their re-defined information need, their information seeking behaviour changed. In Session II, users had some knowledge about the topic of the task, so they knew that the search domain would be about Australia. In addition, they had more experience using the search interface. We particularly focussed on three stages of the information seeking process, namely query formulation, search results exploration and search results management, as they are likely to be the stages of the information seeking process that undergo most changes as a result of a change in the search task at hand.

It is hoped that an understanding of how information seeking behaviour changes across search sessions can further help designers to design interface components that support visually impaired users for complex multi-session tasks. In addition, further insights into the behaviour of users when resuming search tasks and re-finding information can enhance our understanding of how users make sense of the progress of their task across different sessions.

Query Formulation: We observed a change in the type of queries formulated by participants in the two sessions. In the first session, participants submitted broad queries such as "*visiting Australia*" and "*visiting Australian cities*" as the task description was rather vague and open to interpretation. In the second session, following a more specific search task description, we observed that participants' queries were more specific, for example, "*events Australia in July*" and "*flights July Australia*". Such queries reflected the change that we incorporated in the simulated work task description for Session II.

Furthermore, the more focussed queries in the Session II were of an average length of close to six keywords, higher than the queries in Session I whose length was close to four keywords as shown in Table 9.1. The differences in the mean length of queries between the two sessions were not statistically significant ($t(11) = 0.21$, $p = 0.841$), but they reflected the improved knowledge that participants had acquired about the search domain in the first session of the evaluation and the fact that users had a more specific information need. This behaviour is similar to what has been observed in a longitudinal study conducted by (Vakkari et al., 2003) whereby the search tactics and terms used by students writing a research proposal changed as their domain knowledge and experience increased.

	Session I	Session II	Statistical Testing
No. of queries	2.92 [1.83] (1 to 6)	2.5 [2.84] (0 to 10)	$t(11)$=0.47, p=0.646
No. of terms in queries	4.17 [2.73] (1 to 13)	5.63 [2.06] (2 to 10)	$t(11)$=0.21, p=0.841

Table 9.1: Mean number and length of queries [SD] (Range).

Search Results Exploration: In the first session of the evaluation, participants were looking for general information about travelling to Australia and therefore their searches were mostly broad. As a result, they reviewed a mean of 6.92 web pages (including search results and external links) in Session I, higher than the 5.25 pages visited in Session II at ($t(11)$=2.19, p=0.051).

Participants displayed a more exploratory behaviour in Session I, visiting a mean of 3.50 external links (web pages from URLs on a page they visit from the search results list on the search interface) compared to 2.33 in Session II as shown in Table 9.2. As the information need was open to interpretation, participants often explored different aspects of travelling to Australia. Hence, while some users were looking for information on cities in Australia or its history, others were looking at more practical issues about travelling to Australia, for example, searching for flights, checking the currency rates etc. In Session II, as the simulated work task mentioned a trip of seven days, users became more focussed and could not afford to be distracted by pages which were not directly related to the specific task.

	Session I	Session II	Statistical Testing
No. of search results	3.42 [1.98] (1 to 7)	2.92 [2.11] (1 to 7)	$t(11)$=1.00, p=0.339
No. of external links	3.50 [2.91] (0 to 8)	2.33 [1.61] (0 to 5)	$t(11)$=1.33, p=0.211

Table 9.2: Mean number of search results and external links viewed [Standard Deviation] (Range).

Search Results Management: Managing search results is important mostly for complex search tasks such as those that require multiple sessions to complete. This is so because for such tasks, which can span days or weeks, searchers have the need to keep track of the information they encounter during one session to be able to effectively manage the search process and to avoid having to search for things they have already searched for previously. Hence, in Session I, 29% of all visited pages was tagged as useful and 19% was saved in the search note compared to 8% of tagged pages and 14% of saved pages in Session II. The differences in the use of these features of the TrailNote were not significant with a chi-square test at $p<0.05$.

We also compared participants' use of the search trail in both sessions of the evaluation. As expected, participants used the search trail mostly in Session II to gain an overview of what they had done in Session I. Therefore, 83% of participants used the search trail in Session II compared to 42% in Session I. The difference in the use of the search trail was significant with a chi-square test at $p<0.05$ ($\chi^2= 4.44$, $p = 0.035$). As for the search note, it was used in Session I mostly when searchers directly saved web pages whereas in Session II, 42% of the participants used the search note by copying relevant information from web pages and by structuring its contents. This is because in Session II, participants needed the search note to build an itinerary and thus there was more need for a document to keep all the information encountered along the search process.

9.6 Discussion

In this section, we discuss the findings from the user evaluation. We focus on the behaviour of visually impaired users for resuming search tasks and we discuss the strategies observed during our evaluation when using the proposed interface. Additionally, we also discuss the comparative analysis of the behaviour of visually impaired participants across the two sessions of the evaluation.

9.6.1 Habitual Behaviour for Resuming Search Tasks

Prior to users resuming their search tasks in Session II, we interviewed them about their current strategies for keeping track of the search process as well as the methods they use to record information of interest for search tasks that are completed over a period of time. We reported a diverse range of strategies ranging from note taking and bookmarking to printing using a Braille printer and creating desktop shortcuts. It is clear therefore that visually impaired users attempt to explicitly record the information they encounter and this behaviour is readily understood when the lack of persistence of screen readers and the time and efforts that visually impaired users require to re-access any relevant information are considered.

In addition, we found that bookmarking and note taking were among the most popular strategies, confirming our findings in Chapter 5. As previously discussed, these tools are effective at supporting visually impaired users but they are inefficient and often require additional cognitive efforts from screen reader users as information important for task resumption (previous queries, visited web pages and bookmarked pages) is scattered or even non existent unless the user was active and had taken explicit measures to keep track of encountered information (Morris et al., 2008).

At the time when visually impaired users, like anyone else, are starting a search task, they might not know whether this task will span more than one session and thus, they might not take any deliberate actions to keep track of their search process. In those cases, relying on the strategies mentioned as part of the habitual behaviour of visually impaired users would have limited value in assisting the searchers to resume the task and to re-find any relevant information. In those cases, searchers would have to repeat the steps that were previously undertaken to satisfy their information needs.

9.6.2 Observed Behaviour for Resuming Search Tasks

In Session I, participants were not aware of the task they would be assigned in Session II even if they knew that it would be a related task. Therefore, when faced with a task for which they had a level of domain knowledge, we observed the strategies they employed to resume the task and to find information that was tailored to an evolved information need. We categorised the discussion according to the research questions identified in section 9.2.

RQ 2.1: How did participants resume the search task?

As described in section 9.5.3, we observed different starting points among the participants. 42% started Session II through the search trail and as the search trail was organised in chronological order of the queries and visited results, participants who resumed the task through the search trail had to navigate at least part of the trail before re-starting the search task. For example, if the starting point for one user was a visited page on the trail (web page X), they would have had to navigate the search trail linearly until they reached the trail entry for web page X which implies that they have had to navigate through all entries above page X in the search trail. Thus, this would have allowed them to gain an overview of what was performed previously which is likely to impact their search behaviour for the rest of the session. In fact, we observed that after re-visiting a web page from the trail, participants would further refine their information need and submit specific queries that were informed by the re-visited page. For example, one user started the session by re-visiting a page about australian cities and using that information, they decided to travel from Brisbane to Cairns and thus, their efforts in the remaining time were focussed on finding out about how to travel to Brisbane and places to stay etc.

However, we also observed that 42% of users also started the session with new queries that were formulated to reflect the new information need and thus the queries were very specific and goal oriented. Among these participants, some navigated through the search trail but did not take any explicit actions, for example, re-visit a visited page from the trail or re-submit a previous query. Therefore, the search trail could have had an impact on their behaviour but it could not be explicitly measured. 16% of the participants started Session II by visiting search results for the query that was currently in the search box (in Session II, the search interface was loaded at the point where the participant stopped in Session I and the last submitted query would be in the search box). We believe that for these users, this strategy was used because at the end of Session I, they were still exploring information about Australia and therefore could not make a decision about where to go for seven days as was suggested by the task in Session II. Thus, as there were search results already displayed when the interface was loaded, they literally picked up from where they left off, to further explore and gain more domain knowledge.

RQ 2.2: What were the search strategies employed by participants during the task in Session II?

During Session II, we observed that a majority of participants used a combination of 'finding new information' and 'reviewing existing information' to address their evolved information need. Therefore, these participants used the information they had gathered in the first session and also searched for aspects of the task they had not previously considered and which were new to the second session, for example, requirements for travelling for seven days.

Our findings show that in the context of the assigned task, both search strategies are important for visually impaired searchers when performing multi-session tasks. Even among sighted users, previous research (Obendorf et al., 2007; Weinreich et al., 2008) have reported that reviewing previously encountered information is a common web activity. However, current search interfaces only support finding information, while reviewing previously encountered information has to be done through the users' own efforts. In fact, web search interfaces are stateless (Kotov et al., 2011) and hence, the cognitive efforts required to keep track of multi-session search tasks has to come from the user. This highlights the need for better support on search interfaces especially for visually impaired searchers who are regularly faced with a high load on working memory as they have to split their cognitive resources between different applications such as the browser, the screen reader etc. (Theofanos and Redish, 2003).

However, in our evaluation, there were only two sessions for the multi-session task. In real life situations, such complex tasks are likely to span more than two sessions. Therefore, we cannot generalise our findings for all sessions that might occur in such tasks. Yet, it is reasonable to assume that at the beginning of a multi-session task, users might employ more of the first tactic, 'Find New Information', which then leads to a combination of finding new information and reviewing existing information to finally end in users engaging more in reviewing activities. As shown by the diversity in our observations, the order in which actions are described above is just one potential order in which actions can be performed. Searchers are likely to find the best order to suit their task requirements or personal preferences. Nevertheless, search interfaces should aim to support searchers for multi-session tasks by catering for these different sub activities.

RQ 2.3: How did participants use TrailNote in Session II?

TrailNote was a popular feature among participants in Session II as 83% used the search trail and the search note for various purposes. The search trail allowed participants to gain an overview of their activities in Session I and therefore participants could re-visit web pages and re-submit previous queries. The chronological display of the search trail made it possible for participants to reconstruct the previous search session in their minds as they could re-access and remind themselves of queries, visited pages and useful search results by using only one interface component. In fact, this was one of the main objectives for designing a feature like TrailNote in order to ensure that pieces of information which could be important for resuming a search task would be structured and stored together so that visually impaired users are supported for sense making.

There is evidence from the user evaluation that the search trail particularly assisted the participants in making sense of the search process and the information they had previously explored. For example, we observed that after navigating through the trail, participants would decide which aspects of the task was still incomplete or they would remember the actions they undertook in the previous session. Therefore, on the proposed search interface, the search trail acted like a cue to help trigger participants' memory as shown by the findings discussed in section 9.5.2. This highlights the importance of such cues in improving user experience as screen reader users often cannot benefit from cues on interfaces because they are not accessible or they are not persistent in an auditory interface. It is thus essential to further investigate the different ways in which visually impaired users can be supported to gain an overview of their previous search sessions without themselves having to explicitly take measures to do so.

The search note served different purposes in Session II as participants relied on note taking mostly to record information of interest. As a result, we observed that the 42% of participants who used the search note would copy information from web pages and then structure the note using different headings to identify the sub tasks. This is a common strategy among visually impaired users and was also observed in Chapter 5. Therefore, to further support visually impaired searchers in note taking, the search note could be enhanced in the future with a simple outlining mechanism to aid structuring while ensuring it remains a feature that is quick and easy to use.

9.6.3 Differences in Information Seeking Behaviour

We also observed the differences in information seeking behaviour of the participants in the two sessions of the evaluation. The most important change noticed was a change in strategy for query formulation. As the search task became more specific in Session II, we observed that searchers' queries also became longer and more focussed. In Session I, queries were broad and reflected the vague nature of the assigned task. This shows that as users gained knowledge about the search domain and their information need evolved, their strategies for query formulation also changed as suggested by many previous works (Bates, 1989; Vakkari et al., 2003).

In Session II of the evaluation, users submitted a lower number of queries and viewed a lower number of search results as they spent more time in reviewing activities. In Session I, in response to a broad information need, users could more easily decide whether a page was relevant or not and there were no reviewing activities as participants were still at the exploring stages of the search task, that is, they were beginning to find information about the search domain. For example, a page containing information on australian cities could immediately be classified as useful. In Session II, however, given the more specific information need, searchers were more attentive in judging the content of the page and were less distracted by pages which were not directly relevant to travelling to Australia. This could also explain why a lower number of pages were visited, saved or tagged as useful in Session II.

Most information seeking theories work under the assumption of a single session task, identifying stages that searchers go through to satisfy their information need. As we observed during our study, visually impaired users spend time reviewing information, recalling progress from the previous search session to gain an overview of what had been achieved in the previous session and to deciding what is left to complete in the forthcoming session. This stage of the process is not accounted for in information seeking models of search tasks that are completed in single sessions. This stage is likely to be applicable also for sighted searchers who could also benefit from an overview of what they achieved in previous sessions of a search task as previous research (MacKay and Watters, 2008b) has identified that when performing multi-session tasks, sighted users have to make sense and manage the information they gather to keep track of the current status of the task. Hence, search interfaces should be designed to support searchers in managing and reviewing information for complex tasks in addition to supporting finding new information. An integrated approach such as the one we propose could also mean that search interfaces and systems could be tailored to the individual. The system could leverage the additional information available, for example, pages saved or tagged as useful to personalise the user's search experience.

9.6.4 Limitations

In this study, we tried to simulate a multi-session search task. However, our evaluation included only two consecutive search sessions which does not necessarily reflect the real circumstances in which such tasks occur. Nevertheless, our aim was to observe behaviour for resuming search tasks and we believe this was not compromised by the experimental settings as we were able to study the differences in search behaviour following an evolved information need and improved search domain knowledge.

Another limitation of our study is that between the two search sessions, participants could have searched on the topic in their own time, therefore gaining more domain knowledge in the process. However, we have no evidence that this happened and because participants were unaware of the task until the start of the second session, it is unlikely that, in the event it did happen, that it affected the data we collected.

9.7 Chapter Conclusion

In this chapter, we provide insights into the information seeking behaviour of visually impaired users for multi-session tasks. As the evaluation we carried out was structured in two sessions, we were able to observe the strategies employed by visually impaired users to resume their search tasks. We also discussed how TrailNote, a feature on the proposed interface, assisted participants in resuming search tasks and reviewing previously encountered information.

Furthermore, we compared the information seeking behaviour of visually impaired users between Session I and Session II and found that across the two sessions, there were differences in the strategies employed at different stages of the information seeking process. For example, as participants' domain knowledge about the task increased in Session II, their strategies towards query formulation also changed and reflected the knowledge they had acquired in Session I. Therefore, the findings in this chapter allowed us to further our understanding of the information seeking behaviour of visually impaired users for complex search tasks so that effective support mechanisms can be designed to assist visually impaired users. In the following chapter, we summarise the work presented in this thesis. We outline the contributions that each component makes to research and we discuss possibilities for future work.

Chapter 10

Discussion and Conclusions

In this chapter, we provide an overview of the thesis and outline the contributions that each component makes to specific research areas. We also discuss the limitations of this thesis and present possible avenues for future work.

10.1 Overview of the Thesis

In this thesis, we present work on designing search interfaces for visually impaired searchers through a user-centred approach. In doing so, we address aspects from several research areas including information science, participatory design, accessibility and interface design. In this section, we summarise the different components of work carried out as part of this thesis and outline the implications that each component has in light of previous research.

The user group under study in this thesis was visually impaired users who depend on speech-based screen readers to interact with computers and to access the Web. We focussed on speech-based screen reader users as voice output is the most popular form of output among the visually impaired population (Lazar et al., 2007). Other contributing factors such as the high cost of Braille displays and low Braille literacy (Lazar et al., 2007) have made speech-based output prevalent among visually impaired users. In Chapter 3, we conducted an in-depth review of how visually impaired users navigate the Web using speech-based screen readers. We outlined the strategies employed by visually impaired users for navigating and browsing web pages and we discussed the difficulties encountered while doing so. In addition, we examined the different solutions that have been proposed by previous works to enhance web navigation for speech-based screen reader users.

In Chapter 3, we also highlighted the importance of usable accessibility, identifying examples of design components which despite being compliant with accessibility guidelines, could not be used by visually impaired users with efficiency, effectiveness and satisfaction. We thus discussed how accessibility guidelines and technical accessibility are not sufficient to ensure a positive user experience and that user-defined usability criteria should be an integral part of accessibility guidelines. Through this review, we identified that while visually impaired users' interaction with search interfaces in terms of browsing and navigation is relatively well researched, there was a gap in literature on the information seeking behaviour of visually impaired users on the Web.

Therefore, in Chapter 5, we investigated the information seeking behaviour of visually impaired users on the Web by conducting an exploratory observational study with 15 visually impaired participants. We focussed on complex search tasks as they are challenging, cognitively intensive (Campbell, 1988) and require a high level of engagement from users (Fowkes and Beaulieu, 2000). Through the exploratory user study, we examined the behaviour of visually impaired users at the following stages of the information seeking process: query formulation, search results exploration, query reformulation and search results management. In addition, to further understand the impact of the interaction method on information seeking behaviour, in Chapter 5, we carried out an equivalent observational study with 15 sighted users and we conducted a comparative analysis of the information seeking behaviour of the two groups of participants. During this comparative analysis, we observed significant differences in the information seeking behaviour of visually impaired and sighted users, for example, different strategies for formulating queries and managing relevant search results. We also documented the difficulties encountered by visually impaired users when interacting with search interfaces through speech-based screen readers, for example, we observed that query-level support mechanisms such as dynamic query suggestions and spelling suggestions posed usability challenges despite being technically accessible.

Following the exploratory observational study, given the challenges faced by visually impaired users for search results management, we decided to focus on supporting visually impaired users for complex information seeking. We aimed to design an integrated tool on the search interface to support visually impaired users to manage the search process and to keep track of the information encountered during search sessions. Complex search tasks such as multi-session tasks are challenging for all types of users, but for visually impaired users, the challenge can be greater, as the screen reader increases the required cognitive effort (Chandrashekar et al., 2006) and thus the load on working memory can be significant.

Through the exploratory observational study and the comparative analysis in Chapter 5, we gathered user requirements for a search interface for visually impaired users to support complex information seeking. However, given the consideration for users' abilities in this thesis, we needed to engage potential users in the design process to ensure that the designers and the users shared the same understanding of the difficulties observed during the exploratory study. In addition, as the designers and the users interact with search interfaces in different ways, there are significant differences in the way they perceive search interfaces and the Web at large. The potential users are also the experts in interacting via speech-based screen readers. Therefore, from a design perspective, it was clear that the proposed search interface would benefit from the inclusion of potential users in the early stages of the design process.

However, given that existing user-centred methodologies to involve potential users in the design process contain barriers to participation for visually impaired users, we proposed an accessible approach to engage visually impaired users in the early stages of design in Chapter 6. The approach is based on the use of a narrative scenario as a basis for a dialogue between the designers and the users in order to verify user requirements for the proposed search interface, to identify limitations with suggested design plans and to brainstorm new ideas for design. In Chapter 6, we described how the scenario-based approach was developed and its evaluation with four visually impaired users. We discussed the type of feedback we gathered from the user evaluation of the approach with visually impaired users and the impact it had on the design plans. We also reflected on the proposed approach, outlining the benefits, challenges and practical experiences from the use of a narrative scenario and a dialogue-based interaction for user engagement in the design process.

After gathering and verifying user requirements with potential users, we designed and implemented a search interface with novel features to support complex information seeking. The interface components described in Chapter 7 were motivated both by the exploratory observational study in Chapter 5 and the user engagement sessions we carried out using the scenario-based approach in Chapter 6. Therefore, to support visually impaired users for complex information seeking, we developed TrailNote, a tool integrated on the search interface to assist searchers in managing the search process. TrailNote consists of a search trail and a search note to support users to re-acquire the context of their searches and to keep track of encountered information, especially for multi-session search tasks..

Additionally, while designing the proposed interface, we addressed the difficulties experienced by visually impaired users when using spelling support mechanisms on web-based search interfaces as observed in Chapter 5. Spelling support mechanisms can in fact benefit visually impaired users as previous research (Arter and Mason, 1994; Papadopoulos et al., 2009) has shown that spelling can be challenging for users with visual impairments if they are using speech-based output, given that they cannot perceive the pattern of letters to recognise and remember the pattern to learn and retain the spelling. However, findings from the exploratory study in Chapter 5 showed that spelling support mechanisms were challenging for visually impaired users to interact with via speech-based screen readers. Thus, on the proposed search interface, we re-designed this feature using non-speech sounds in order that visually impaired users can fully benefit from it. We also included other features in the design, such as a context menu and keyboard shortcuts to enhance users' interactions with the proposed search interface.

We evaluated the proposed interface with 12 visually impaired users and observed how searchers interacted with the interface components. The findings reported in Chapter 8 showed that TrailNote was effective in supporting visually impaired participants in keeping track of encountered information during the search process. We also compared the findings from the user evaluation with the findings from the exploratory study described in Chapter 5 to investigate how participants used similar features (spelling support mechanism, note taking and bookmarking) on the proposed interface and other web-based search interfaces. In this respect, findings from the user evaluation showed that interaction with the re-designed spelling support mechanism on the proposed interface was easier, more accessible and more usable for visually impaired searchers. We also used findings from the exploratory study to provide insights into the differences in the information seeking behaviour of visually impaired users when using the proposed interface compared to other web-based interfaces. As expected, the most significant differences were observed at the search results management stage.

The user evaluation of the proposed search interface was structured so that each participant took part in two evaluation sessions which were separated by several days. We set up the evaluation in this way in order to simulate a multi-session search task. Multi-session searches are not routine tasks and take place over multiple search sessions (MacKay and Watters, 2008a) and therefore are complex and challenging as in subsequent search sessions, searchers have to re-acquire the context of the search task (Rose and Raju, 2007) as well as keep track and make sense of information encountered across different search sessions. In Chapter 9, we investigated the information seeking behaviour of visually impaired users for multi-session search tasks. We explored the strategies used by searchers to resume the search task, to review previously encountered information and to find new information to satisfy their evolved information need. In addition, we also examined how TrailNote supported visually impaired searchers during their task in the second evaluation session. We also compared the information seeking behaviour of participants across the two evaluation sessions and studied how the information seeking process was impacted as the searchers' knowledge of the search domain improved.

The findings reported in Chapter 9 showed that the search trail supported users in the second session of the evaluation to obtain an overview of the activities they performed in the first session. This overview was important as it helped users to recap on the previous session and it also allowed users to re-acquire the status and progress of the search task. The search note was effective as users did not have to constantly switch between different applications to record information during the search process. Participants could thus use the integrated tool to structure the information they encountered as different sub-tasks which helped them in making sense of the requirements of the task at hand. Participants in the user evaluation also used a combination of strategies to review existing information and to find new information when their information needs became more specific in the second session. We also observed differences in information seeking behaviour across the two search sessions, for example, in response to a more defined task, participants' queries became longer and more specific.

Investigating the behaviour of visually impaired users for multi-session tasks contributed to understanding the information seeking behaviour of visually impaired users for complex search tasks on the Web. Therefore, this enhanced understanding can inform the design of search interface components in the future to further support visually impaired users during complex information seeking.

10.2 Contributions

The work in this thesis contributes to different research areas including information science, participatory design, accessibility and search interface design.. In this section, we describe the contributions that each component of this thesis makes to research.

1. **A detailed overview of web navigation through speech-based screen readers.**

   The review presented in Chapter 3 contributes to work on accessibility for visually impaired users as it provides an in-depth overview of how visually impaired people access the Web using speech-based screen readers. The most recent work reviewing web accessibility by (Harper and Yesilada, 2008) consists of a comprehensive set of chapters addressing different types of impairments as well as assistive technologies that aim to make the Web accessible for users with disabilities. Therefore, it has a broad focus with discussions on evaluation methodologies, application areas etc. In comparison, the review conducted in this thesis has a narrower focus and only addresses visually impaired users accessing the Web through speech-based screen readers. Thus, this review provides a detailed overview of how visually impaired users perceive the Web including the strategies employed and the challenges experienced during web navigation as well as the state of the art solutions that have been proposed by previous research to enhance navigation for speech-based screen reader users. Any reader of this review also benefits from the discussion on usable accessibility which is essential when designing for users with disabilities to ensure that compliance with accessibility guidelines does not become the exclusive focal point of accessible design endeavours.

2. **Investigating the information seeking behaviour of visually impaired users on the Web.**

   Previous works such as (Leporini et al., 2004; Andronico et al., 2006b) have focussed on how visually impaired users access search interfaces from an interaction perspective (in terms of browsing and navigation strategies) and therefore have resulted in suggestions for more accessible designs, for example, how to modify popular web-based search interfaces such as Google to simplify interaction for visually impaired users (Andronico et al., 2006b; Yang et al., 2012). The work carried out in Chapter 5 of this thesis investigated the information seeking behaviour of visually impaired users from an information seeking perspective, that is, in terms of searchers' behaviour at specific stages of the information seeking process. To the best of our knowledge, no previous work has focussed on the behaviour of visually impaired users during information seeking on the Web. The findings from the exploratory study contribute to existing research in the field of information science, similarly to how other studies of information seeking of specific groups have, for example, of academic lawyers (Makri et al., 2008), architects (Makri and Warwick, 2010) and people with low literacy (Kodagoda and Wong, 2008). Therefore, this exploratory study has allowed us to understand how users' abilities affect their requirements and expectations of search interfaces, particularly the importance of specific stages of the information seeking process. This understanding is valuable for the design of search interfaces and other search tools in order to be able to effectively support visually impaired searchers in their information seeking activities on the Web.

Additionally, the comparative analysis between visually impaired and sighted users has highlighted the impact of the mode of interaction on the information seeking behaviour, on the way the Web is perceived and the user's experience of search interfaces. Thus, the findings from comparing these two groups of users are useful to design interface components that are not only technically accessible but also usable for users of speech-based screen readers.

3. **An accessible method to engage visually impaired users in the early stages of design.**

   There is little reported research on the methodologies to involve visually impaired users in the design process and many (Patomäki et al., 2004; Saarinen et al., 2006; Magnusson and Brewster, 2008; Miao et al., 2009) have focussed on including users in the design of tactile artefacts. Given the barriers posed by existing user-centred techniques, the scenario-based approach proposed in Chapter 6 makes a significant contribution to research on participatory design. Scenarios are popular within the field of human-computer interaction and dialogue has been successfully used in participatory design (Luck, 2003). However, in the context of participatory design with visually impaired users, the use of a narrative scenario and a dialogue-based interaction is a novel way of engaging users in the design process. By using existing methods and practices, we demonstrated that in developing methodologies for non-standard populations, we can draw on well-established techniques from within the field of user-centred design. Thus, by having considerations for the abilities of the user group and by adapting existing methods and practices, we can develop accessible methodologies to engage non-standard populations in order that the design process can benefit from their experience and expertise.

   The scenario-based approach therefore proposed a novel way of involving visually impaired users in the design process and by using a dialogue-based interaction, we highlighted the role that dialogue can play in the absence of visual aids to communicate design ideas to users to allow them to envision an artefact that is yet-to-be constructed. This approach was a first attempt at participatory design with visually impaired users, using a narrative scenario and a dialogue in the design of a search interface. Therefore, we also reported reflections from the use of the approach and these can benefit any endeavours that extend the proposed approach in the future as well as those aiming to develop new participatory design methodologies for visually impaired users.

4. **Novel features to support visually impaired searchers during information seeking.**

The novel features on the proposed search interface include TrailNote and the re-designed spelling support mechanism and they both illustrated how considerations for the users' behaviour and abilities can result in a positive user experience. TrailNote was designed to support visually impaired users at a stage of the information seeking process that they found challenging and therefore was effective in assisting searchers to keep track of encountered information. The spelling support mechanism was re-designed using non-speech sounds to address previously observed difficulties caused by interaction with speech-based screen readers. The use of non-speech sounds meant that important information could be conveyed to visually impaired users in real time without interfering with output from the screen reader. This has implications for the design of accessible search interfaces as it shows that non-speech sounds successfully convey contextual information to visually impaired users especially on information-rich interfaces such as search interfaces.

5. **Investigating the behaviour of visually impaired users for multi-session search tasks.**

   Several previous works such as (Vakkari et al., 2003; MacKay and Watters, 2008b) have studied the information seeking behaviour of sighted users over a period of time, reporting the differences in behaviour throughout the process as well as proposing tools to support sighted users to keep track of information across search sessions (Morris et al., 2008). To the best of our knowledge, no such studies have been conducted with visually impaired users and thus, the findings from the user evaluation that we carried out provided insights into the behaviour of visually impaired users for search tasks that span multiple sessions.

   Given the lack of persistence of screen readers, multi-session search tasks can be challenging for visually impaired users. The observations made across the two sessions of the user evaluation illustrated the challenges that visually impaired people face during complex information seeking. These observations enhance our understanding of the information seeking behaviour of visually impaired searchers for complex search tasks and they can be used to inform the design of interface components and other tools to support visually impaired users in their information seeking activities on the Web.

10.3 Limitations

One of the most important challenges faced in conducting the user studies in this thesis was the recruitment of representative members of the visually impaired population locally as is common when working with disabled users (Petrie et al., 2006). Therefore, we used online mailing lists dedicated to discussions among visually impaired users and the users we recruited were often from other parts of the world than the United Kingdom. This is why all the user studies in this thesis have been carried out remotely. However, the results we gathered from our user studies were not impacted by the multiple nationalities of the participants as they were all English speakers and used the state of the art in terms of assistive technologies such as screen readers.

Conducting remote user studies ensured that visually impaired users were using familiar equipment configured to their personal preferences. However, as we were conducting synchronous remote evaluations, we had to capture users' interactions with the search interface and thus, we had to request that participants activate the screen share function of Skype. This, in some cases, proved to be challenging as participants used different versions of Skype on different operating systems. We had to provide explicit and very detailed explanations on how to activate that feature. In extreme cases, visually impaired participants got sighted help from a friend or family member to ensure that they were correctly sharing their screens with the evaluator. While we could easily observe and record participants' interactions with the search interface, we could not observe anything that was beyond the screen-based interaction and this may have impacted the amount and richness of the qualitative data that we collected (Petrie et al., 2006).

Furthermore, another limitation of this thesis is that we did not conduct a comparative study for the evaluation of the search interface presented in Chapter 8. It is likely that if we had performed a user study with a multi-session search task and participants were using another search interface (one that does not have the additional features we proposed), we would have been able to more reliably compare the information seeking behaviour of participants. Nevertheless, we did not conduct a comparative study for the reasons described in the following.

The search interface proposed in this thesis was designed as a result of the difficulties observed in the study described in Chapter 5. Therefore, a comparative study with participants using the same search interfaces as those used in Chapter 5 is likely to reveal similar difficulties that we had previously observed and that had led to the development of the proposed interface in the first place. Thus, from this perspective, the potential benefits of a comparative study do not justify the efforts it would require in terms of time and recruitment of visually impaired participants as a comparative study would not have contributed significantly to us uncovering previously unidentified issues.

We believe that a comparative study conducted in the same settings as the user evaluation described in Chapter 8 would not represent a fair comparison between the proposed search interface and other search interfaces. This is because of interface familiarity, that is, visually impaired users who access interfaces through screen readers tend to learn the layout and structure of any interface that they regularly access. For example, if they use Google for their day to day search activities, they would memorise the way search results are displayed so that they know which screen reader navigation strategy (heading navigation or link navigation etc.) is most effective. As a result, screen reader users tend to take longer than sighted users to familiarise themselves with new interfaces as they have to spend some time getting used to the layout of the interface to form a correct mental model and also to determine which navigation strategy would work best (Kurniawan et al., 2003; Borodin et al., 2010). Additionally, an interface is not persistent for visually impaired users as it is for sighted users given that the screen reader only outputs specific parts of the interface at one time. This implies that visually impaired users have to remember the different components they access on the interface and this is likely to contribute to a longer learning curve. Therefore, a fairer comparison between the proposed search interface and other popular web-based search interfaces should be in the form of a longitudinal study whereby participants would have the opportunity to become familiar with the proposed interface before the evaluation process. We were unable to conduct such a longitudinal study due to time constraints.

However, in the absence of such a comparative study to act as a baseline, we used the data gathered in the exploratory study in Chapter 5 to provide insights into the way the proposed search interface might have impacted the information seeking behaviour of visually impaired users. Yet, given the differences in the methodology of the exploratory study and the user evaluation, we are unable to conduct a strict comparison and provide quantitative evidence for the differences in the information seeking behaviour in terms of the stages of the information seeking process. Instead, we are able to identify what the differences are and theorise how they could have been caused by the design of the interface.

Even if we were not able to perform a strict comparison between the findings from the study in Chapter 5 and the study in Chapter 8, we were still able to successfully compare how visually impaired participants in both studies used specific interface components such as the spelling support mechanism, note taking and bookmarking and we could also observe the way the information seeking behaviour was affected especially for search results management. This is so because the search tasks in both studies were of comparable complexity and the abilities of participants were equivalent in terms of search experience, use of online search engines and proficiency with assistive technologies and browsers etc.

10.4 Conclusions

This thesis is a comprehensive account of how visually impaired users were engaged in the design of a search interface through a user-centred approach. Visually impaired users interpret search user interfaces in a significantly different way because of the way they interact with the Web through speech-based screen readers. Our study of the information seeking behaviour of visually impaired searchers showed that there are significant differences in the behaviour of visually impaired users compared to sighted users at specific stages of the information seeking process. Thus, it is essential to ensure that when developing interfaces, developers do not make assumptions neither on the search behaviour of visually impaired nor on their abilities to interact with search interface components.

Technical accessibility (adapting what has been designed for sighted users in order to make it accessible with assistive technology) is an important first step, but it is not sufficient to ensure that interface components are usable for visually impaired users. Therefore, developers should take into consideration the abilities and needs of visually impaired users and should focus on designs that visually impaired users can perceive and successfully interpret to support them in their search tasks. This can have a significant impact on user experience as evidenced by the design of the sound-based spelling support mechanism on the search interface proposed in this thesis in Chapter 7.

Additionally, the work presented in Chapter 6 of this thesis has particularly highlighted the need for techniques to successfully engage visually impaired users in the design process. When designers and potential users interact with the product to-be-designed in different ways, there is the need to ensure that they share the same understanding of the needs of the user and the requirements of the product. In this thesis, we proposed one approach based on a narrative scenario and a dialogue-led interaction, but there is a wealth of existing techniques in HCI literature that can be adapted in order to engage visually impaired users in design. By engaging different types of users in the design process, designers can understand the needs of different users and thus can design to accommodate a wider spectrum of usage. This can lead to innovative design ideas that benefit all users as demonstrated by the design of TrailNote (interface component to manage the search process and encountered information) described in Chapter 7 of this thesis. Despite being designed mainly to support visually impaired searchers for complex tasks, discussions with sighted searchers have shown that they could also benefit from this feature.

The findings in this thesis can also impact the design of other types of interfaces for visually impaired users. For example, our observations and suggestions for the design of a sound-based spelling mechanism can be employed on any other interface that requires text input from visually impaired users. Similarly, our findings about the information seeking behaviour of visually impaired searchers can inform the design of information systems that include any stage of the searching process, for example, formulating search queries using keywords or viewing results retrieved by a system.

10.5 Future Work

In this section, we discuss the possible avenues for future work for the work undertaken in this thesis.

10.5.1 Information Seeking Behaviour and Search Interface Design

In the first part of this thesis, we studied the information seeking behaviour of visually impaired users which led us to understand how the way visually impaired users interact with search interfaces impact their search behaviour on the Web. In this case, the assistive technology, that is, the speech-based screen readers, changed the way visually impaired users perceived search interfaces compared to sighted users and thus, their strategies for information seeking were also different at several stages of the information seeking process. This understanding of the information seeking behaviour of visually impaired users informed the design of a search interface with novel features to support them for complex information seeking activities. In this respect, we focussed mostly on supporting search results management and on addressing accessibility challenges encountered when using the spelling support mechanism.

However, our study of the information seeking behaviour highlighted other stages of the information seeking process where visually impaired users would benefit from additional support, for example, during search results exploration and query formulation. Therefore, future work will focus on designing interface support mechanisms to assist visually impaired searchers during these stages. Additionally, our study of the information seeking behaviour revealed how factors such as interaction methods can influence the information seeking process for visually impaired users and how this can impact the way users perceive search interfaces and the mental models they create of searching on the Web. Therefore, future work could focus on other non-standard populations such as the elderly, users with low-literacy or language barriers to investigate what is their perception of web-based information seeking. Also, as previously discussed, a longitudinal study can be carried to evaluate the proposed interface in order to have further insights into the search behaviour of visually impaired searchers, especially for multi-session search tasks.

Furthermore, there is scope for usable accessibility to be further explored. A collection of concrete examples where technically accessible interface components fail to be usable for interaction through assistive technologies will improve awareness among designers about the importance of usability which in turn can assist in the development of tools for users with disabilities.

10.5.2 Engaging Non-standard Populations in the Design Process

When designers do not interact with interfaces using the same senses as the target user group, it is often difficult for them to correctly imagine how the users perceive the interface. Hence, the designers' understanding of the requirements of the interface might not match that of potential users. Therefore, it is essential to include target users in the design process to ensure that artefacts are designed to suit the abilities of the users, especially if the users are part of non-standard populations such as those with disabilities or the elderly. User-centred methodologies are not always accessible to non-standard populations and thus need to be adapted to engage users in the design process, to understand their concerns about design plans and to ensure that their ideas are taken into consideration. In this thesis, we proposed an approach based on scenarios for visually impaired users to verify requirements for a search interface and as a result, we expressed our scenario as a textual narrative to match the abilities of our user group. We used our approach mainly to obtain feedback from visually impaired searchers about the features to include on the interface irrespective of how these features would be laid out on the overall interface or how the user would interact with these features with a speech-based screen reader. Hence, as future work, we will investigate whether including screen reader technology as part of the scenario that was used as the basis of dialogue between the designers and the users, will enhance the realism of the yet to-be-constructed interface and improve the user's ability to form a mental model of the proposed artefact.

A second avenue for future work is to investigate how other techniques such as Wizard of Oz (Dow et al., 2005) could be adapted to engage visually impaired users in design. A comparison of the types of feedback that can be gathered using different methods would allow designers to pick the right methods for user engagement depending on their needs. Different techniques for user engagement do not have to be competing, but could instead complement each other to ensure that the designers are able to cover a diverse range of issues with the user group. Furthermore, an investigation of methods for user engagement that can be used with non-standard populations such as the elderly or users with disabilities would result in increased possibilities of including such users in the design process. Such methods would be useful for inclusive design projects, especially as many countries move towards digital economies.

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Appendix A

Materials for the Exploratory Observational Study

This appendix contains materials from the exploratory observational study described in Chapter 5 to investigate the information seeking behaviour of visually impaired users for complex tasks on the Web. It includes an example of the consent form used, the example tasks for both sighted and visually impaired participants, the pre-study demographic questions and the questions used in the semi-structured interview carried out after each observation.

A.1 Consent Form

Queen Mary
University of London

Consent form

Please complete this form after you have read the Information Sheet and/or listened to an explanation about the research.

Title of Study: *Complex Information Seeking for Visually Impaired Users*

Queen Mary Research Ethics Committee Ref: ***QMREC2010/60***

- Thank you for considering taking part in this research. The person organizing the research must explain the project to you before you agree to take part.
- If you have any questions arising from the Information Sheet or explanation already given to you, please ask the researcher before you decide whether to join in. You will be given a copy of this Consent Form to keep and refer to at any time.
- *I understand that if I decide at any other time during the research that I no longer wish to participate in this project, I can notify the researchers involved and be withdrawn from it immediately.*
- *I consent to the processing of my personal information for the purposes of this research study. I understand that such information will be treated as strictly confidential and handled in accordance with the provisions of the Data Protection Act 1998.*

Participant's Statement:

I [Please insert your name] agree that the research project named above has been explained to me to my satisfaction and I agree to take part in the study. I have read both the notes written above and the Information Sheet about the project, and understand what the research study involves.

Signed (Please print your name to give your consent)

Date

Investigator's Statement:

I ***Nuzhah Gooda Sahib*** confirm that I have carefully explained the nature, demands and any foreseeable risks (where applicable) of the proposed research to the volunteer

Figure A.1: Consent form for exploratory study.

A.2 Example Tasks for Visually Impaired Participants

Example 1: Travel

You will soon be on leave from work and you would like to travel to X. You want to find out the best ways of getting to X and the different places to stay. You are also interested in the places to visit, the different things to do while you are on vacation, the places to eat etc. Use your favourite online search engine to help you plan your vacation to X.

Example 2: Moving to a new country/city

You have recently seen an advertisement for a job in country/city X and you think the job description matches what you are looking for. However, as you would have to move with your family to X, you decide to find out a little more about desirable areas to live in, its lifestyle, its cost of living, its taxation, its political system, its education system etc. Using your favourite search engine, gather this information before you apply for the job.

Example 3: Sources of audio books

Your friend has recently mentioned that he finds audio books really enjoyable and you decide to carry out some research on sources on audio books to find out which ones would better suit your requirements. Using your favourite search engine, find out about sources of audio books and decide on the ones that you think you are more likely to use.

Example 4: E-books

Your friends have been talking a lot about e-books recently and you realise you do not know much about them. You decide to find out more about e-books online using an online search engine. You are particularly interested in ways to read e-book, the formats in which they are published and the

Figure A.2: Example tasks for visually impaired users.

A.3 Example Tasks for Sighted Participants

Example 1: Travel

You will soon be on leave from work and you would like to travel to X. You want to find out the best ways of getting to X and the different places to stay. You are also interested in the places to visit, the different things to do while you are on vacation, the places to eat etc. Use your favourite online search engine to help you plan your vacation to X.

Example 2: Moving to a new country/city

You have recently seen an advertisement for a job in country/city X and you think the job description matches what you are looking for. However, as you would have to move with your family to X, you decide to find out a little more about desirable areas to live in, its lifestyle, its cost of living, its taxation, its political system, its education system etc. Using your favourite search engine, gather this information before you apply for the job.

Example 3: University

You have recently decided to go back to university to study for a postgraduate degree in your field. However, you are not sure where to go for the degree as you are also considering going abroad. Using your favourite search engine, find out more information about the different options available to you.

Example 4: E-books

Your friends have been talking a lot about e-books recently and the new devices coming on the market to allow electronic reading of books. As you do not know much about e-books, you decide to find out more about e-books online using your favourite search engine. You are particularly interested in ways to read e-book, the formats in which they are published and the devices/software you would need to use them. Gather the information on e-books and decide which one you would prefer.

Figure A.3: Example tasks for sighted users.

A.4 Pre-study Demographic Questionnaire

Please type your answer after the question.

1. Age
2. Gender
3. Country
4. Which high school/college/university diplomas/degrees have you been awarded? Please also mention the field in which you achieved these qualification.

   High School
   College Diploma
   Undergraduate
   Masters
   PhD
   Other (Please Specify)

5. What level of sight do you have?

   Blind
   Partially Sighted

6. What kind of assistive technology do you use?

   Screen Readers
   Screen Magnifiers
   Optical character recognition
   Braille Output
   Other (Please Specify):

7. How did you learn to use the assistive technology that you use?

   Professional Training
   No formal training

8. Please rate your proficiency with the assistive technology that you use

   Beginner
   Intermediate
   Advanced

9. Please rate your proficiency with browsing the Internet

   Beginner
   Intermediate
   Advanced

10. Which browser do you use?

Internet Explorer
Firefox
Safari
WebbIE
Other (Please specify)

11. Which search engine do you use on a regular basis?

Google
Yahoo
Bing
Other (Please specify)

12. How easy is it for you to use search engines?

Easy
Intermediate
Difficult
Usually depends on the task

13. Overall, how many years have you been doing on-line searching?

14. How frequently do you use a computer to perform any kind of task as part of your professional activities?

Never
Less Frequently
A few times a month
A few times a week
One or more times a day

15. How frequently do you search for information on-line (for example, use web search engines)?

Never
Less Frequently
A few times a month
A few times a week
One or more times a day

16. How much time do you spend on a computer on average in a given day?

Less than 2 hours
Between 2 and 5 hours
Between 5 and 8 hours
More than 8 hours

A.5 Post-task Interview

Challenges

What kind of information tasks do you usually carry out on the Web?

What are the main challenges you think you face when using web-based

Is anything in particular a source of frustration?

Do you have recommendations/suggestions about how it could be improved?

Search Results Page

When carrying out a search on a web-based search engine, how many results/results pages on average do you view?

What is your strategy when examining results list?

When do you stop examining results?

Assessing Relevance

How do you decide whether a page is relevant or not?

What part of the snippets help you decide whether to follow a result or not?

Support

How do you keep track of the bits of information you find?

Suggestions, reformulation help, are those helpful?

Appendix B

Materials for the Evaluation of the Scenario-based Approach

This appendix contains material from the user evaluation of the scenario-based approach described in Chapter 6. It includes the pre-study demographic questionnaire and the narrative scenario which was used as a basis for the dialogue interaction between the designers and the users. This appendix also lists the questions that were used in the semi-structured interview which followed each participant's prototyping session.

B.1 Pre-study Demographic Questionnaire

Please type your answer after the question.

1. Age
2. Gender
3. Country
4. Which high school/college/university diplomas/degrees have you been awarded? Please also mention the field in which you achieved these qualification.

   High School
   College Diploma
   Undergraduate
   Masters
   PhD
   Other (Please Specify)

5. What level of sight do you have?

   Blind
   Partially Sighted

6. What kind of assistive technology do you use?

   Screen Readers
   Screen Magnifiers
   Optical character recognition
   Braille Output
   Other (Please Specify):

7. How did you learn to use the assistive technology that you use?

   Professional Training
   No formal training

8. Please rate your proficiency with the assistive technology that you use

   Beginner
   Intermediate
   Advanced

9. Please rate your proficiency with browsing the Internet

   Beginner
   Intermediate
   Advanced

10. Which browser do you use?

Internet Explorer
Firefox
Safari
WebbIE
Other (Please specify)

11. Which search engine do you use on a regular basis?

Google
Yahoo
Bing
Other (Please specify)

12. How easy is it for you to use search engines?

Easy
Intermediate
Difficult
Usually depends on the task

13. Overall, how many years have you been doing on-line searching?

14. How frequently do you use a computer to perform any kind of task as part of your professional activities?

Never
Less Frequently
A few times a month
A few times a week
One or more times a day

15. How frequently do you search for information on-line (for example, use web search engines)?

Never
Less Frequently
A few times a month
A few times a week
One or more times a day

16. How much time do you spend on a computer on average in a given day?

Less than 2 hours
Between 2 and 5 hours
Between 5 and 8 hours
More than 8 hours

B.2 Narrative Scenario for Interaction between User and Evaluator

Setting the scenario

Your friend has told you about this new search system and you would like to try it out for yourself to see how good it really is. You think of something you would like to search on this new system.

Choice of Task

To better test this new system, you decide to choose a search task that is fairly complex, that is, one that would require you to find information from different sources to complete. For example, you can try to plan a trip abroad; you can research a new concept that is related to your professional work etc.

Once you have chosen your search task, you type the address of this new page in your web browser and you reach the page with the cursor in the search edit box.

"What do you type as query?"

You type this query and hit enter.

If you misspell a word in your query, the system will specify which term you misspelt and allow you to submit a corrected version of your query.

The system retrieves a list of results to match your request and you are presented with a page with 2 headings Related Search and Search Results.

Related Searches provide you with queries that are similar to yours and that you might want to consider as alternatives. The suggested queries are hyperlinks so that if you select one of them, the system will replace your query with the selected query and display a new set of results.

Search Results provides a list of results related to your request.

There are alternative ways of presenting the results:

- Standard approach: Results are presented in a list with each results described using a title, a short summary and a web address. Each of these items is on a separate single line.
- Simplified standard approach: Results are presented in a list, but each results in described one line, with title and short summary.
- New approach: Similar results are grouped together and you are presented with an overview of each of the group of search results. For example, results that deal with similar topics will be grouped together. If you doing a travel task, web pages describing things to do at your destination will be grouped together.

If you would like to explore one these group, you can select the group and it will open in a different window and will contain all search results in that group described with title and short summary. You can always return to the first window to browse through other result groups.

"What are your thoughts on these results presentation alternatives? Which one would you prefer and why?"

For the rest of the scenario, lets assume you were using the standard approach of results presentation.

You start navigating down the list of results and find a page that seems interesting. You click on the page to view it. You navigate through the page and find some parts of it that are interesting and you would like to make a note of it.

Your friend mentioned that the new search system had a note taking facility whereby you could use a key (which) to directly create a note.

You hit (Ctrl+N) to open the note. The system asks you where you would like to save this note and to give it a name. Your note is divided in two parts. The first part of the notes is editable by you, that is, you can type ideas, copy and paste things from web pages etc. The second part can be edited and is used to save results automatically by the system. (Cases when the system will do this will become clear very shortly.) However, you can browse both parts of the notes.

You copy and paste what you wanted from that page.

You use the back button to go back to the list of results to navigate to the next results in the list. You find that a title sounds like it is interesting and you would like to save this result to your note. You are aware that this new interface has a menu associated with it so that you can open, save and copy results.

You hit the menu key and you find the following options in this particular order (Save Result, Copy, Email, Open). This is rather like the context menu you have in Windows that you bring up with a right mouse click or Shift+F10.

Save Result: This feature allows you to save a particular result to your note. If you select this option, the title, description and the URL of this result will be save in your note, in the part that you cannot edit.

Copy: By selecting this option, you are copying the title of the result and its web address to the system clipboard.

Email: This option will allow you to email a search result to yourself or to a friend.

"What do you think about these menu options and the order?"

You have not found what you are looking for, but you realise that you have to attend a meeting. You would like to get back to this search later on and would like to pick up from where you left off.

The new interface also has a history feature where all the steps you have taken during your search session is recorded and you have the option of saving it, if you want to remember what you have looked at. In this case, the following would have been recorded: your query, the title and address of the first page you visited. The search session is saved in a format that allows you to later browse through the session to remember your queries and the links you visited.

You can save your session at any time by hitting a key. You will be prompted for a name for the session (by default will be your first query and date) and the location where it should be saved.

The search session is saved in a format that allows you to open it to get back to where you left off your search task.

You can also browse a text version of the search session to remind yourself of the queries you submitted and the web pages you visited. You now close off your browser and attend your meeting.

"What are your thoughts about this history mechanism? Are you likely to use it? If so, when?"

Two days later, you have some free time and you would like to resume your search. You open your saved session and the note to continue from where you left off.

B.3 Post-study Interview

- Do you ever do similar search tasks that require multiple search sessions?
- Do you ever do multiple searches for different things and so would you find it useful to be able to save several sessions like this?
- Does this approach help you to get back to your search, if you know what you have previously searched for, the queries you submitted?
- Can you think of other features in such a system that would be useful, i.e. what are your preferences for the format of displayed results?
- Do you have any other thoughts about options it would be good to have in the menu?
- Do you think some form of overview of the results would be useful when they first appear? If so, what form might that overview take?

Appendix C

Materials for the Search Interface Evaluation

This appendix contains materials from the user evaluation of the proposed search interface described in Chapter 7. It includes the pre-study demographic questionnaire and lists the pre-task and post-task questionnaires that were completed by participants in both sessions of the user evaluation.

C.1 Pre-study Demographic Questionnaire

<u>About You</u>

Age

Gender

Country

What level of sight do you have? (Blind / Partially Sighted)

<u>About Computer Use</u>

How frequently do you use a computer to perform any kind of task ?

Never
Less Frequently
A few times a month
A few times a week
One or more times a day

How much time do you spend on a computer on average in a given day?

Less than 2 hours
Between 2 and 5 hours
Between 5 and 8 hours
More than 8 hours

<u>About Assistive Technology</u>

What kind of assistive technology do you use?

- Screen Readers
- Screen Magnifiers
- Optical character recognition
- Braille Output
- Other (Please Specify):

How did you learn to use the assistive technology that you use?

- Professional Training
- No formal training

Please rate your proficiency with the assistive technology that you use

- Beginner
- Intermediate
- Advanced

About Internet Browsing

Please rate your proficiency with browsing the Internet

Beginner
Intermediate
Advanced

Which browser do you use?

Internet Explorer
Firefox
Safari
Chrome
WebbIE
Other (Please specify)

About Online Searching

Which search engine do you use on a regular basis?

Google
Yahoo
Bing
Other (Please specify)

How easy is it for you to use search engines?

Easy
Intermediate
Difficult
Usually depends on the task

Overall, how many years have you been doing on-line searching?

How frequently do you search for information on-line (for example, use web search engines)?

Never
Less Frequently
A few times a month
A few times a week
One or more times a day

C.2 Session I - Pre-task Questionnaire

Questions

What is your level of knowledge about country X?

I know about its cities and things to do
I know where it is but not much about its cities
I do not know anything

How often do you use online search engines to find such information?

Often
Rarely
Never

How well do you understand the requirements of this task?

Very well
Not so well
Not at all

How confident are you about what you need to do to complete this task?

Very confidant
Somewhat confidant
Not confidant

C.3 Session I - Post-task Questionnaire

Rating the Interface Features

How useful did you find the following features on this interface?

Context Menu

Very Useful	*Useful*	*Not Useful*

Non Speech Sounds

Very Useful	*Useful*	*Not Useful*

Interface Shortcuts

Very Useful	*Useful*	*Not Useful*

Related Searches

Very Useful	*Useful*	*Not Useful*

How easy was it to use the following interface features?

Context Menu

Very Easy *Easy* *Not Easy*

Non Speech Sounds

Very Easy *Easy* *Not Easy*

Interface Shortcuts

Very Easy *Easy* *Not Easy*

Related Searches

Very Easy *Easy* *Not Easy*

Overall, how did you find the interaction with the interface?

Are there any features that you particularly liked or disliked? Why?

Are you satisfied with your performance on this task in the given amount of time?

C.4 Session II - Pre-task Interview

Task

You have now confirmed your travel plans and know you will be staying in Australia for 7 days. Using the information you encountered in the previous session and new information, make a rough schedule of how you would like to spend your days there.

Questions

When searching online, how do you currently keep track of information that you might need at a later stage?

C.5 Session II - Post-task Questionnaire

How useful did you find the following features?

Trail

Very Useful *Useful* *Not Useful*

Note

Very Useful *Useful* *Not Useful*

How easy did you find it to use the following features?

Trail

Very Easy *Easy* *Not Easy*

Note

Very Easy *Easy* *Not Easy*

How was your experience re-finding information using this interface?

Did you think the TrailNote feature supported you in re-finding information you encountered in the first session?