Towards Universal Search Design

Laurianne Sitbon, Lauren Fell, David Poxon, Jinglan Zhang, Shlomo Geva
School of Electrical Engineering and Computer Science
Queensland University of Technology
{l.sitbon l l.fell l d.poxon l jinglan.zhang l s.geva}@qut.edu.au

ABSTRACT
For people with cognitive disabilities, technology is more often thought of as a support mechanism, rather than a source of division that may require intervention to equalize access across the cognitive spectrum. This paper presents a first attempt at formalizing the digital gap created by the generalization of search engines. This was achieved through the development of a mapping of cognitive abilities required by users to execute low-level tasks during a standard Web search task. The mapping demonstrates how critical these abilities are to successfully use search engines with an adequate level of independence. It will lead to a set of design guidelines for search engine interfaces that will allow for the engagement of users of all abilities, and also, more importantly, in search algorithms such as query suggestion and measure of relevance (i.e. ranking).

Categories and Subject Descriptors
H.3.3 [Information Storage And Retrieval]: Information Search and Retrieval
H.5.2 [Information Interfaces And Presentation (e.g., HCI)]: User Interfaces

General Terms
Human Factors.

Keywords
Inclusive design, search engines, intellectual disability.

1. INTRODUCTION
When search engines first appeared, they started providing empowerment to users by giving them the ability to make independent rather than prescribed decisions in the websites and documents they wished to access. They provided an interactive information-seeking interface that rapidly took over the curated, categorized listing of existing resources.

Adults with intellectual disability are often limited in their choice of information seeking interfaces because they are all built on the same assumptions about the users’ cognitive abilities and motor skills. In reality, alternative designs could leverage different sets of skills possessed by people with intellectual disability, allowing them to access the full benefit of independent information navigation. For example, supporting the ability to fully articulate information needs with words, to type or pronounce these words correctly, to discriminate useful information from large amounts of displayed information on the same page, or to sequence actions in order to get to this information, would greatly increase access to this technology.

Conversely, satisfying an information need may act as a motivator to encourage users to develop skills they may not otherwise be interested in developing (such as spelling, or typing on a keyboard). It is therefore very important to build on existing skills and allow for configuration of the system rather than thinking in terms of universal minimal design.

Around 3% of the population have some form of intellectual disability [1], and addressing these issues will allow for better access to important services for them - including accessible web-based services such as games, images, and videos. While there has been a lot of research focus on assistive technologies as well as on the presentation and content of web pages to ensure accessibility, including with regards to potential intellectual disability, search engine systems remain largely inaccessible. Our hypothesis is that by better understanding what users with intellectual disability can currently do with search engines, and better understanding their aspirations, we can design a novel flexible search interface that will make the most of their abilities to increase their independence and choices when accessing the web.

This paper presents a review of all of the skills currently required to independently use search engines and how other skills could instead be leveraged to achieve the same outcomes, so as to make them independently accessible to people with disabilities. We first review existing efforts in technology to support adults with an intellectual disability. In section 3 we then highlight the skills at play in current information seeking processes and how users who may not have these particular skills may be at a disadvantage. In section 4 we present guidelines for universal design of search systems such that they suggest both catering for – and allowing for - a wider choice of skills to be used.

2. RELATED TECHNOLOGIES
There has been very little research addressing independent online information seeking for adults with an intellectual disability, with the few that do, such as the Zac Browser [8], limited to web portals that only contain a limited number of references rather than allowing search on the entire web. There has been quite extensive research on how users with intellectual disability manipulate browsers and the cognitive function found most challenged was that of working memory [12]. However, this type of work does not directly address the information seeking process...
as an interaction, especially from the point of view of intentionality.

A number of interfaces to support children in web search have been created, and have involved investigations into how to address a different range of cognitive abilities than those of adults [2], how to assess appropriateness of content for filtering, as well as how to simplify content. One such example is additionally proposing faceted query exploration [3]. These interfaces designed for children do address some of the concerns for adults with intellectual disability when it comes to supporting query formulation and rethinking relevance, however they tend to do this at the graphical user interface level and post-processing rather than as a whole of search design approach.

Users with learning disabilities and visual impairments have largely benefited from the development of search and browsing for mobile devices, and this has encouraged content-owners to increase the accessibility of their contents, and researchers to investigate less cluttered interfaces. Similarly, ambient virtual environments are currently pushing the limits of visual information to allow users to seamlessly search using audio interfaces.

A recent study [7] with elderly users found that spoken commands may be the simplest and the most convenient way to replace a traditional keyboard based control. The study also showed that 85% of users prefer a combination of voice commands and touch screen navigation, and that the longer commands are, the less appealing they become (even when controlled for accuracy rates). However, users are only ready to use voice input if it allows a high recognition accuracy rate.

Audio or reduced visual load interfaces tend to require an even greater level of abstraction by the user, as they often suppose a cognitive mapping of the visual information seeking protocol in an audio format (i.e. keyword based queries, “navigation” between contents headlines, drilling down into contents from various hierarchical levels, etc.).

Expressing a query without language is currently possible for matching media (i.e. We can use images to search for images, or sounds to search for music), but not to search language-based media (using images to search documents). There are, however, several tools that allow people who cannot express themselves with language to communicate semantically with others (see for example Avaz Freespeech (http://avazapp.com/freespeech/), and even translation systems have been built on-top of these tools. Traditionally, users have used these tools to communicate everyday needs and relate stories rather than expressing information needs, but there is potential for them to be used as a basis for ‘querying.’

3. SKILLS FOR INFORMATION SEEKING

There are a number of established taxonomies for cognitive and physical skills, some of them being established for education purposes, and others to investigate issues relating to disabilities. Here, we will focus only on the skills that we have identified as being involved in information seeking with search engines, and organize them in a manner that is relevant to the task rather than according to a specific categorization.

3.1 The information seeking process

We first establish a list of basic sequential steps normally followed by a user to find information in documents. Of course most users do not necessarily follow a strict sequence through all the steps (not necessarily reading everything in sequence), and some information needs are too complex to fit within such a basic sequence. However, as we shall see that even this simple sequence presents several constraints on the user that may be challenging. Most of the literature focuses on the information seeking process in a large search oriented task, rather than on small tasks.

1. Identify an information need
2. Locate and open the search engine interface
3. Express the information need with words to form a query
4. Type the query in the query box
5. Press the “OK” button to get results
6. See a page of results (maybe with 10 blue links and snippets)
7. Read until identifying the first result
8. Read the title of the first result
9. Decide if possibly relevant, if unsure read the snippet and decide if possibly relevant. If decided possibly relevant, follow the substeps, otherwise go to step 10:
   a. Click on the title (in blue) so that it opens the actual document
   b. Read the actual document (if not too hard) and gain information.
   c. If no information gained, return to the search results page to find another candidate
10. Read the page until identifying the first result after the previous one (identify that the previous one has already been explored)
11. Go back to step 9 until useful information found (decide that useful information was found)

3.2 Physical Skills

Physical skills of the users impact mainly the graphical user interface, and are often considered by universal web design guidelines [5] such as the Web Accessibility Initiative (www.w3.org/WAI).

- Fine motor control: search processes require users to type words with a spelling close enough to the intended query. Navigating using buttons or links can also present challenges as they generally require reaching a small portion of the screen.
- Speech (enunciation): when alternative to typing are proposed, they generally suggest using speech recognition techniques, which in turn require good enunciation as they are not very robust to variations.
- Sensory abilities: Vision is the main physical requirement of search systems, although it can be replaced by hearing.

3.3 Cognitive Skills

3.3.1 Abstraction

As suggested in the discussion on existing interfaces, the search process requires an abstract understanding the steps required to a) express an information need and b) navigate a set of candidate responses to the information need.

Many users with intellectual disability who can use language to communicate are actually quite good at using search engines to find images of interest. They describe what they would like to see and its characteristics (e.g. “a pink cake”), which is enough to allow the user to browse through candidate images to find one they like. Part of this is because the query is a concrete description

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of what they want, and the other part is due to the fact that the whole document is presented in the results list, rather than an elegant description of it (e.g. a blue title and a few words). However, when it comes to information seeking tasks, such as looking for available accommodation in an area or looking for providers of services for a particular need, this may be a lot more difficult to express and navigate.

3.3.2 Task Sequencing and Prioritisation
The series of steps required to find a simple document for a simple information need is extremely sequential, and an individual who has difficulties in processing sequences or remembering these processes may have difficulty in doing so [4].

Many adults on the autism spectrum (following the model of weak central coherence) have difficulties with focusing on tasks at a global scale and rather on parts only [9]. This is often evidenced by difficulties in discriminating amongst large amounts of information at once. The search process requires an understanding that not all documents are necessarily relevant, and that a deep investigation into each of the candidate results may not be necessary. This suggests that one may want to consider several candidate results (ordered in the results list) before selecting the most interesting of those, to then go on and explore it further. Similarly, on the results page, not all sections are necessarily relevant and a focused information need may only be satisfied with a section of the page, which a skilled user can get to very rapidly by scanning the page as opposed to reading it all.

3.3.3 Task Switching
Another trait of the search process is that it requires steps that are very different from one another, from typing to reading to pressing buttons, and maybe returning to earlier tasks.

3.3.4 Reading
Processing text to understand the information it carries constitutes a range of cognitive abilities (including those mentioned above). However it is important to note that difficulties in reading may have a range of causes and that identifying these causes can help support users to find information that they can read at their level. An example outside of the field of disabilities is knowledge of vocabulary, where simple readability measures based on word frequency can be used in ranking functions.

4. DESIGN GUIDELINES
4.1 Interface
In addition to the usual universal web design guidelines defined by the Web Accessibility Initiative, a number of specific interface guidelines to search engines are necessary to facilitate interactions for users with intellectual disability.

4.1.1 Configuration
Any interface for all should be customizable. This is because every individual has a different set of skills to build on, and a different set of preferred approaches. Customization needs to be simple and easily understood by support persons, who are generally not technology experts.

4.1.2 Words vs. images vs. icons
Stock et al. [10], showed that the timing of visual cues is much more powerful than if a cue was there all along. So, wherever possible, the interface should make use of timely animated images rather than words or icons. For example, an animated hand showing how to go on the search button once a query is entered would be more beneficial than the words “Google search” or a magnifier icon.

4.1.3 Presentation of search results
Search results as thumbnails were once proposed in search engines but were not adopted by the vast majority of users, so these functionalities were removed. However, they are likely to be more useful to users with intellectual disability than links on the title, although more evaluation is required in the area of results presentation to understand what works best around issues of abstraction. Focusing directly on what is relevant in a web page would also help users navigate results and make decisions on relevance [5].

Clear visual transitions between the results list and full size contents could also help the users locate the function required to return to the result list if needed. A swipe approach to navigating between results on a touch screen could also mirror a more natural cognitive mapping and therefore be easier to tackle than going back and forth between a list and actual documents.

4.2 Query Suggestion
4.2.1 Dialogue
Entering effective queries is a difficult task for users, but it is an acquired skill and most users adapt and improve over time. Still, it remains quite difficult for many users and at times all users experience difficulty. The problem is many fold more difficult for users with complex communication needs and limited learning ability. Where natural language can be used (through written or spoken form), a more natural approach to querying via a simple dialogue system would map best to the type of communication interactions users with intellectual disability are used to (prompts). Dialogue systems for IR have been studied extensively [11], and by and large have not been adopted by users because the basic interface of common search engines appears more satisfactory to most users. We however aim to address a different user base for whom the standard interface is unworkable for reasons that are only found with people with disability.

4.2.2 Icons and browsing
Using icons or images to support communication has proven benefits for non-verbal users [4], and have been suggested for the design of non verbal user interfaces [6]. Icons can be a great way to pre-define queries for users, and this could be very useful in the rapidly changing information environments that may have to be repeated often (for example, finding transport timetables or housing listings). However, such a method may end up as restrictive as it would mean using pre-defined lists of links that have been curated for the user.

Image processing is rapidly evolving and increasingly allowing for the recognition of categories of objects from complex images. This could allow a pointing interface to generate searches, where a user could take (or select) a picture and point to the part of the picture they are interested in. Combining pictures could then generate expressions of more complex information needs. How search engines could then translate these complex needs into queries involves an understanding of the context, and of the users themselves to be able to map pointing to a category of object with a query intent.

4.3 Ranking and Relevance
4.3.1 Dimensions of relevance
Ranking functions should adapt not only to users’ capability to read, but should also include an assessment of the authority of
webpages, as many users with intellectual disability may not be able to understand that not all information on the web is necessarily true and trustworthy, as the very notion of lies and deception is out of the grasp of understanding of some.

Readability can be assessed in many ways, but, as mentioned earlier, the measure should adapt to the actual capabilities of the user rather than using a generic approach for estimating reading difficulty. There have been few attempts to include reading levels in ranking, however more research is needed to map such functions to actual user impact.

4.3.2 Communicating ranking and scores
While it may be difficult in the context of web search engines to fully and transparently communicate to the user the motivations for a ranking, more motivation presented on the choices of results would support users’ understanding of how to decide if a document is indeed relevant. If criteria such as readability or legibility were at play, then showing a preview of the page would suffice. If authority is taken into account, then showing that a webpage has been manually verified by support people, or that it has been independently rated to be accurate and appropriate, could provide another means of meeting this need.

4.3.3 Social search
Recommendation can play a major role in supporting better search results for users with an intellectual disability if it can be developed on the same basis as page-rank type approaches. That is, understanding which websites are recommended for people with intellectual disability by support organizations (existing listings), but also which are favored by users within a support organization or across support organizations worldwide, would add trust and interest in such results. This would allow support organizations to draw attention to items of interest while providing the users with the freedom to explore alternatives.

4.4 User Modeling
The ability to very rapidly understand user’s preferences, as well as discriminate between the information preferences of users and their capabilities in varying contexts (with a support person or on their own) should be driving any user modeling approach.

Supporting short-term prediction of every interaction with the system would support independence. Additionally, the ability to replay the most similar previously successful experience would also support the user to independently practice steps they may have been through whilst accessing support. Finding such a similar session is within the abilities of most search systems.

Making suggestions of short cuts (such as icons) for rapid access on behalf of the user, by recognizing recurrent behaviors, would also be extremely powerful. However, an easy way of letting the system know to forget targeted previous interests should also be embedded. For example, a user may have “saved” a recurring search on housing in a given suburb at one point, and then decide to look into a different suburb. If the system had saved the previous search, it should be easy to either cancel or change it without the need for assistance.

5. CONCLUSION AND FUTURE WORK
The preliminary design guidelines for universal search systems we have established in this paper are within reach of state of the art language technologies and machine learning methods and should become more central to their development. We will conduct user studies to exactly define how to best leverage these technologies, and take a participatory design approach to let the users express how they see the settings should be defined. For example, there have been numerous studies on the interactions between dimensions of relevance, and yet there is no common understanding on how to integrated these dimensions within a single ranking function. The social impact of search engines, how support organizations and families can be educated to support adoption, is another area that requires research to ensure large-scale adoption of such novel techniques as those we propose.

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7. REFERENCES