Better Health Explorer: Designing for Health Information Seekers

Patrick Cheong-Iao Pang[1,3] **Karin Verspoor**[1,2] **Jon Pearce**[1] **Shanton Chang**[1]
Department of Computing and Information Systems, The University of Melbourne, Australia [1]
Health and Biomedical Informatics Centre, The University of Melbourne, Australia [2]
Victoria Research Laboratory, National ICT Australia (NICTA), Australia [3]
{cipang, karin.verspoor, j.pearce, shanton.chang}@unimelb.edu.au

ABSTRACT
A vast amount of health information has been published online, yet users often report difficulties in locating information in this particular domain. Based on our prior research, we consider four categories of online health information seekers who demonstrate mixed information needs. Although their *searching* needs are often well satisfied by entering keywords into search engines, their need to *explore* information is not so well supported, thus affecting their user experience and satisfaction. In this paper, we propose design principles for supporting the exploration of online health information. We present the rationale and the design process of a web app – Better Health Explorer – which is a proof-of-concept app tailored to health information exploration. This work contributes to the design of online health information systems as well as exploratory systems in general.

Author Keywords
Exploratory search, health information seeking behaviour, experimental design

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION
With increasing numbers of people searching for health information on the Internet, it is crucial to understand their information needs and the challenges they face during the search process. Although search engines are typically used by health information seekers as the starting point to look up information (Spink et al., 2004; Fox and Duggan, 2013), keyword-based searching has been shown to be limited and unsatisfactory for online health information (Keselman et al., 2008; Luo et al., 2008). One particular problem with keyword search is that lay-people are often unable to describe health problems with accurate terminology. Therefore, people may benefit from an exploratory approach where they are able to learn about and forage for information around a health topic, even if they are not sure what they are looking for or what appropriate keywords might be.

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Such exploratory health search is not supported well by current search engines. In a prior study, we observed that health information seekers rarely stay on health websites for long (Pang et al., 2014). Most arrive at a website from a search engine result, read an article or two, exit the website and then return to the search results again. Often, related and useful information exists in the website, but people fail to discover it. This implies that most health websites lack mechanisms to lead visitors to find additional useful information, or to keep them on the site engaged in an exploratory process. We need to reconsider how to design and create health websites that accommodate these use cases.

In previous work, we proposed a conceptual model to describe health information seekers (Pang et al., 2015). Four categories of health information seekers were identified. We argue that health website users may fall into any of these four categories, and indeed may move between them in the course of search. Hence the design of any supporting environment should accommodate the characteristics of all types of health information seekers. We explain more about this model in a later section.

In this paper, we propose six design principles for designing such an exploratory environment for health information. These principles are synthesised from the model of health information seekers and their behavioural patterns observed in our prior study. To illustrate these principles empirically, we describe a web application we call *Better Health Explorer* – a proof-of-concept software for reading and exploring health information. We discuss its design rationale and the features for assisting seeking of health information.

Figure 1 gives an overview of the main contribution of this research: the design principles for supporting health information seeking along with the conceptual model of health information seekers. The figure also depicts major features in the Better Health Explorer, and how these features are backed up by the design principles.

The remainder of this paper is structured as follows: we review the current literature about online health information and introduce our proposed design guidelines for health websites. Then we discuss the design of the Better Health Explorer, describe future research plans to evaluate its effectiveness and finally conclude the article.

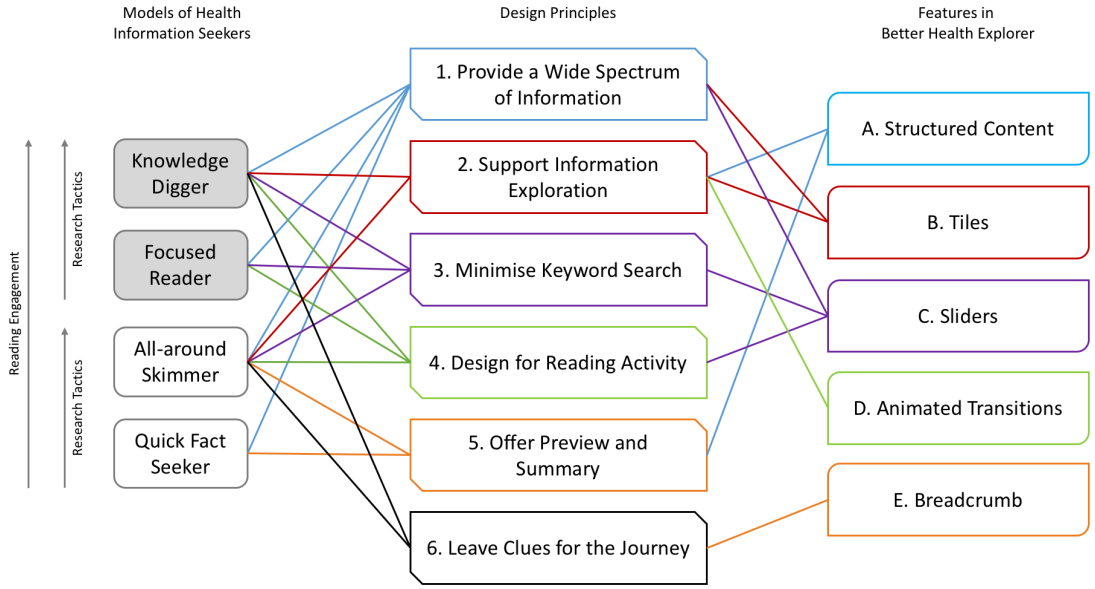

Figure 1. Overview of the conceptual model, six design principles and their implementations in this paper.

BACKGROUND

Online Health Information Seeking

As reported in different studies, Internet users are increasingly using the web as a source of health information (Fox and Jones, 2009; Fox and Duggan, 2013). The searches they perform reflect a wide spectrum of information needs, from specific medical conditions or symptoms, causes and treatments of diseases, diet information to healthy lifestyle tips (Bessell et al., 2002; Nicholas et al., 2003; Andreassen et al., 2007; Zhang and Fu, 2011).

The use of search engines is the primary method for retrieving health information on the Internet. Researchers find that a majority of web surfers use search engines as the starting point for their journey of hunting health information (Spink et al., 2004; Fox and Duggan, 2013). However, it has been shown that keyword-based search is limited in health information seeking scenarios. Some have suggested that search engines should specifically optimise health search queries (Berland et al., 2001; Benigeri and Pluye, 2003). Lay people generally have insufficient medical knowledge to describe health problems accurately, and thus search results are often unsatisfactory due to the poor quality input to search engines (Chapman et al., 2003; Keselman et al., 2008; Luo et al., 2008). Toms and Latter (2007) even go as far as to describe searching of health information as a "trial-and-error" process.

So, in spite of the rapid advances in search engine technology, there still remain challenges to be solved in the design of tools to support people searching in this specialised domain of health information.

Health Information Seeking Behaviour

In addition to the design of search tools, we need to consider the motivations behind health information seeking behaviour (HISB), so that they can be better supported. There are many facets to this. Wilson (1997; 2006), for example, argues that people look for additional information when feeling stressed and threatened. As such, an exploratory search in the health domain is often triggered by one of these situations. For some, the process of finding health information is simply a sense-making one in which they seek to learn unknown or unfamiliar knowledge (Wilson, 1997; Wilson, 1999). Curiosity may also be a factor that motivates the search for health information (Case, 2002). In other cases, people may be alerted to some alarming health concern (such as hearing of the death of a celebrity on the radio) and this may trigger HISB as well (Alzougool et al., 2008).

Whatever motivates the desire to seek health information, there will be differences in the knowledge that users bring to bear on the search. Some will have a good understanding of the domain in which they wish to search; these are referred to as having recognised needs (Alzougool et al., 2013). Others may have a more vague search target, as they have little or no idea about the health scenarios they are dealing with (Pang et al., 2014).

This variety of motivations and knowledge generates different search approaches and provides us with additional challenges in designing user interfaces that better support discovering and reading online health information.

Exploratory Search

Studies of exploratory search have led to increased understanding of people's information seeking behaviour. Marchionini (2006) coined the term "exploratory search" for a search approach that includes learning and investigation activities in addition to lookup efforts. White and Roth (2009) added that users undertaking an exploratory search are often unfamiliar with the knowledge domain of their search targets, and may be unsure of how to achieve their goals. As exploratory search is often observed in health information seekers (Pang et al., 2015), insight into exploratory search is valuable for studies of health information seeking.

There are significant differences between general iterative

search and exploratory search (White and Roth, 2009). Figure 2 illustrates the two approaches. Given an information space, general iterative search is performed around a static search target, whereas exploratory search involves a number of queries across a larger information space. Additionally, for iterative search, the searcher narrows down the search scope in the process; an exploratory searcher targets a wide range of results in the greater information space and tends to broaden out before narrowing down. While iterative search is well supported by search engines, the development of user interfaces for exploratory search is still an active focus of research.

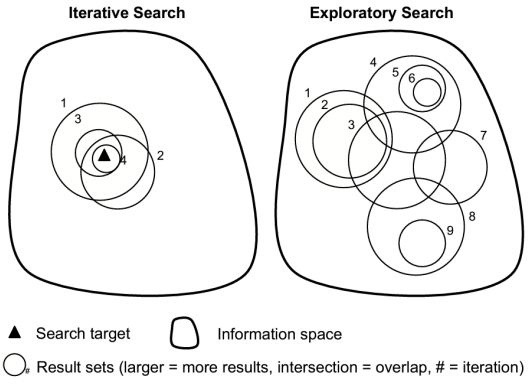

Figure 2. Illustration of different search approaches (excerpted from White and Roth, 2009)

User Interfaces for Exploratory Search

Exploratory search needs novel user interfaces to support the different behavioural patterns and activities shown in the seeking process. There have been a few previous efforts to design a UI to support exploratory search. SeCo is a system using web application mashup to provide exploration in multiple dimensions such as spatial and temporal data (Bozzon et al., 2013). The web app iFISH provides an engaging environment for playful exploration of restaurants (Pearce et al., 2012) and library books (Pearce et al., 2014), in which the usage of search keywords is eliminated. Pang et al. (2014b) attempted to use computer-generated maps for knowledge exploration in classes. Exploration Wall is a touch-based software for incremental exploration and sense-making in a large information space (Klouche et al., 2015). The Bohemian Bookshelf is a public information display to support book discoveries in a library by serendipity (Thudt et al., 2012). This series of work gives many insights in designing for exploratory search in other contexts.

Faceted search interfaces are often associated exploratory search tasks (Ferré and Hermann, 2011). Faceted search interfaces provide mechanisms to filter search results using hierarchical metadata, at the same time allowing users to browse through the search result list (Hearst et al., 2002). This aids exploratory search through query formulation and refinements (Kules et al., 2009). However, faceted search only supports bi-directional manipulation (i.e. narrowing and broadening) of search results with the current query. The characteristics of exploratory search, such as multiple and dynamic search topics across the information space, cannot be handled by faceted search interfaces.

To the best of our knowledge, current research has not moved much beyond developing a theoretical understanding of exploratory search in the health context. Cartright et al. (2011) propose that exploratory health search can be categorised into evidence-based and hypothesis-based queries, and that different search interfaces and algorithms are needed for each type. Zarro (2012) suggests that exploratory health search can be analysed from a social psychology perspective. Lee et al. (2014) reviewed the current literature of HISB and argue that future studies should focus on the navigational needs of health information seekers. Studies such as these have motivated us to implement an exploratory system and thus carry out empirical studies in this domain.

Serendipity

Serendipity can play an important role in the information seeking process. Oxford English Dictionary (2015) defines serendipity as "the faculty of making happy and unexpected discoveries by accident". From the perspective of information retrieval, serendipity suggests the scenario of discovering useful information with randomness and pleasure (Thudt et al., 2012). The concept of serendipity is reported by multi-discipline research as an additional factor to aid information seeking (Foster and Ford, 2003) and exploratory search (White et al., 2006). In contrast to traditional information retrieval methods, supporting serendipity requires a fuzzy approach to responding to search queries, instead of returning exact matches (Toms, 2000). With a suitable environment and approach, designing for serendipity can even enhance user experience (Leong et al., 2012).

HEALTH INFORMATION SEEKERS

In this section, we briefly explain our previous study addressing health information seeking on the Internet. We have observed the diverse information needs of health information seekers and various exploratory search behaviours in the usage of health websites. The discussion then leads to a conceptual model of health information seekers which can be used for designing better health websites.

The Prior Study

We conducted a lab observation study with the aim of understanding the actual behaviour incurred when finding online health information. Participants were requested to search on the web with two pre-defined goals: (1) caring for a person with health conditions; and (2) a more open-ended search task for a health topic. A retrospective semi-structured interview was conducted after these tasks. Web activity logs, screen recordings and interview transcripts were reviewed and analysed by the researchers. 20 participants with diverse backgrounds and demography were recruited. The findings of this study have led to the conceptual model of health information seekers described below. Details about the study can be found in (Pang et al., 2014).

Model for Health Information Seekers

Information seekers display distinctive behavioural patterns in the process of HISB. We have analysed these patterns and derived a robust model of information seekers, classifying them into four categories according to

their levels of *Reading Engagement* and the *Research Tactics*, as displayed in Figure 3 (Pang et al., 2015). This model conceptualises the attributes of health information seekers across demographic factors, i.e. age, gender and education level, which is desirable for designing websites for all kinds of visitors, rather than a specific group of people.

Reading Engagement describes the duration of reading and the level of immersion in the reading. For example, skimming through a web page summary is described as lower engagement, whereas reading and engaging with a detailed information is considered high engagement.

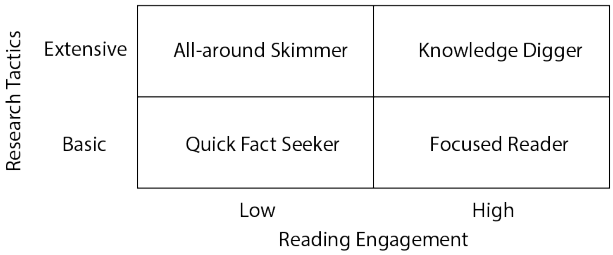

Figure 3. A model of health information seekers (excerpted from Pang et al., 2015).

Research Tactics represents the eagerness and motivation for digging out in-depth information. A seeker, for instance, who chases hyperlinks and searches with many queries, is demonstrating extensive Research Tactics. In contrast, people with basic Research Tactics will be satisfied with a small amount of information that can explain the health issue. They may not care about details or continue to read more.

With various combinations of Reading Engagement and Research Tactics, four types of information seeking behaviour can be identified. Each quadrant in Figure 3 describes a set of behavioural patterns for one of these types. We will examine the characteristics of each below.

Quick Fact Seekers have a clear understanding of the topic. They know which parts of the information are missing or exactly what information is needed. This type of seeker has concrete information needs, so that they will quickly go through the material to locate the relevant information. The information seeking process will stop once the knowledge is found.

All-around Skimmers are similar to *Quick Fact Seekers* in the forms of quick reading, but they have a different purpose. This type of seeker has a fair understanding of the problem and wants to investigate issues more deeply within minimal time. With the variety of content and quality of online information, much information may not fit the seeker's needs. They perform a lot of quick reading before investing further time and effort. Once suitable information is found, they will extensively explore for relevant topics.

Focused Readers put in significant effort to read a small number of materials, and tend to concentrate only on these materials. They may lack skills to properly use a search engine to get other information; or lack skills to discover further readings within the current web site; or they may have found a lengthy and rich document which meets their information needs (such as a journal paper or a fact sheet in PDF format) so that they continue read on. This category of seekers aims to improve their intellectual understanding with the information seeking.

Knowledge Diggers are willing to devote time and effort to investigate problems they are facing. At the same time, they demonstrate relatively better skills at discovering and exploring for more possibilities to enhance their understanding of the issues. Oftentimes these seekers are motivated by emotional investment. For example, if the health issues are related to important people or themselves, this type of extensive search is more likely to occur.

While four types of health information seekers display different HISB, we notice that both exploratory search and focused search approaches are used by all of these information seekers. We explain this further below.

Transitions Between Exploratory and Focused Search

Health information seekers have both exploratory search and general focused search needs. We can illustrate this by considering a woman suffering from a cough and runny nose. Her hunt for information might proceed through these three stages:

Stage 1: She performs an initial search by entering her symptoms into a search engine. As she has little knowledge at this stage, she will examine all the information returned by the search engine (it could be flu, whooping cough, hay-fever, etc.) and demonstrate an exploratory approach at this time.

Stage 2: She continues to read and digest the information. After reading for a while, she starts to get a sense of her probable ailment (realising it is more likely a flu) and searches around the topic (flu), where a focused approach is adopted.

Stage 3: While investigating the focused topic, she may encounter other relevant topics that are unknown to her (remedies of flu, flu prevention, etc.). In such a case, her search approach turns to exploratory again for learning about these new topics of interest.

In fact, she may iterate through these stages of information seeking behaviours during the process of researching her ailment. In our previous work (Pang et al., 2015), we argued that exploratory search and focused search co-exist in the duration of an information seeking process. During the process, the search will demonstrate transition from exploratory to focused, if information seekers learn and make sense of the information encountered; whereas the search can also change from focused to exploratory, when they start to see unfamiliar concepts or unknown knowledge that come to their attention (Figure 4). The alternation may continue throughout the entire information seeking process.

In recognising the above transitions, we propose that designers need to cater for both exploratory and focused behaviours in any supporting web app. Health websites should provide mechanisms to assist in effective transitions between the two search approaches.

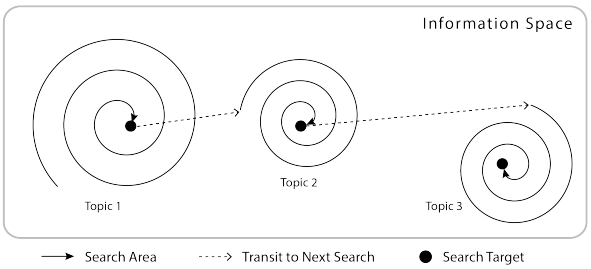

Figure 4. Transitions between exploratory search and focused search (excerpted from Pang et al., 2015).

DESIGN PRINCIPLES

We have used the behavioural patterns and the characteristics of health information seekers to develop six design principles as follows:

1. *Provide a Wide Spectrum of Information*
2. *Support Information Exploration*
3. *Minimise Keyword Search*
4. *Design for Reading Activity*
5. *Offer Preview and Summary*
6. *Leave Clues for the Journey*

1. Provide a Wide Spectrum of Information

As we identify that transitions between exploratory search and focused search happen during the process of HISB, the spectrum of information needs is broad for all types of information seekers. That is, comprehensive and wide-ranging information is required to enable information discovery for the exploratory search approach, and highly relevant and specific information is needed for people performing focused search. Therefore, the system should be able to provide both broad and targeted information to users at the same time, so that the two flavours of search approaches can be supported. This also enables ease of transition between the two search approaches.

2. Support Information Exploration

Extensive Research Tactics seekers perform a number of lookup activities in various places within the possible information space, as illustrated in Figure 2. This requires some "gates" for travelling to other parts of the information space. To facilitate this in a web-based interface, the design needs to highlight the visual connections to further information, e.g. by providing hyperlinks to other possible destinations. Serendipity is also a desirable factor that encourages discovery of unexpected information. The visual representation could include loosely connected information for encouraging potential exploration.

As shown in existing exploratory search systems (Pearce et al., 2012; Bozzon et al., 2013; Pearce and Chang, 2014), information exploration is usually performed across multiple dimensions. Examples include: relevance of content in the information space, geographical data, personal preferences, temporal information, etc. An effective design should allow users to select and traverse freely among these different dimensions.

3. Minimise Keyword Search

While keyword search is a fast and intuitive way to find information for general topics, it is one of the main challenges in HISB. In many health scenarios, seekers do not know the correct keywords for searching, and actions are taken to learn the possible keywords and reformulate search queries. Thus, it is crucial to have features for accessing information with minimal use of keywords.

Information seekers with a range of research skills gain benefits from the removal of keyword search. For people with good research skills, it can be more convenient to explore different areas within the information space without having to enter keywords. On the contrary, people with limited research skills will find a lower barrier to accessing more information, as the cost of learning and thinking up new keywords is eliminated.

4. Design for Reading Activity

Reading is the main activity associated with browsing, learning and exploring information. For this reason, the system should provide an environment to allow users, particularly seekers with higher Reading Engagement and more extensive Research Tactics, to engage with reading, and this can be elaborated in two aspects.

Firstly, modern web design practice is a good starting point for a comfortable reading environment. Designers should make the content easy to read. Some techniques include building an uncluttered interface, selecting appropriate fonts and font size for reading, clearly distinguishing headings and content, etc. If the content is long, consider showing long text in sections or tabs.

Secondly, the language used in the information needs to take account of the literacy level of the readers. Health information seekers often encounter information that they find difficult to understand (Birru et al., 2004; Lam and Lam, 2012). The system should avoid this mismatch by understanding the audience and providing the information with suitable readability. Allowing users to choose their reading levels is highly desirable.

5. Offer Preview and Summary

As illustrated in the model of health information seekers (Figure 3), the *Quick Fact Seeker* and the *All-around Skimmer* would like to check and evaluate the relevance of information quickly. As such, the design needs to facilitate this need of "peeking" at the information. For example, the system can provide a preview or a summary of the information, so that the reader can rapidly gain an overview of the contents and evaluate whether the information suits.

6. Leave Clues for the Journey

Exploratory health search is a relatively lengthy process that stimulates many readings of different topics. As a result, it leads to frequent navigations between web pages, especially for people using extensive Research Tactics. It is important to provide enough clues for the seekers so that they can easily perceive where they are currently located within the information space. Additionally, seekers travel back and forth in their web browsing history, thus the design should include mechanisms which can take the users backward (and forward) along the information journey path, for resuming exploration from earlier stages when necessary.

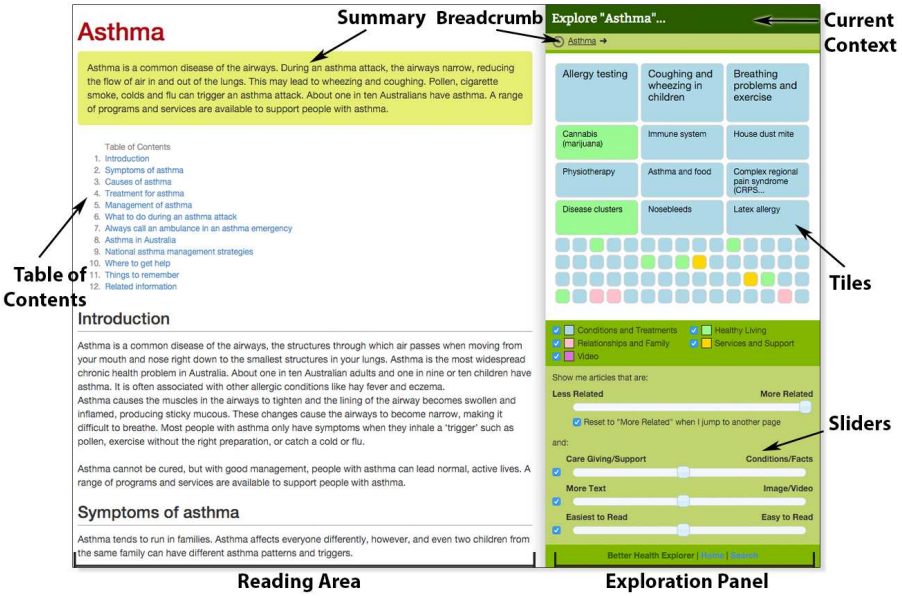

Figure 5. The user interface of Better Health Explorer.

Summary

This section introduces six design principles that better support the needs of health information seekers. Since seekers may shift from one type to another in the search process, it is impractical to design for a specific type of health information seeker. Hence, we recommend designers to implement all design principles so that seekers will be better supported in all scenarios.

APPLICATION OF DESIGN PRINCIPLES

Following the design principles presented above, we have designed and implemented a web-based prototype for exploring health information – the Better Health Explorer. Our aim here is to illustrate our theoretical design principles by applying them in practice and then carry our research to evaluate their effectiveness.

The Case of Better Health Channel

We worked with Better Health Channel (BHC) [1] for the purposes of building the prototype. BHC is a consumer health information website established by the State Government of Victoria, Australia since 1999. With this cooperation we obtained their health information dataset and Google Analytics[2] reports.

According to the Google Analytics report of April 2015, they recorded 4.3 million user sessions with 3.4 million unique users in the month, which made them one of the most popular health-related websites in Australia. Only 8% of these visits were direct access (using web address or bookmarks), while 6% were referred by social networks or other websites. The remaining 86% of traffic originated from search engines, consistent with previous studies (Spink et al., 2004; Fox and Duggan, 2013).

Despite the high volume of visits, BHC users demonstrated a high bounce rate at 89%, meaning that a large portion of users left the website after reading just a single page. This was also reflected in an average 1.21 pages read per session. Many bounced users return to their previous search results (Pang et al., 2014) and use the search engine as a "teleporting" tool to navigate to another information source (Alhenshiri et al., 2013). The high bounce rate implies very few users try to explore the contents. This makes BHC an ideal environment on which to experiment with the design of an exploratory health search system.

The health information dataset used in our prototype is a subset of BHC articles, covering more than 250 health and medical topics for lay-people in five categories, namely Conditions and Treatments, Health Living, Relationships and Family, Services and Support and Video. Data types include articles in plain text, images associated with articles, and videos. This gives us a variety of topics and information types for supporting information exploration.

Overview of Design

Figure 5 shows a screen capture of the Better Health Explorer. The left of the screen is the reading area, facilitating requirements for Reading Engagement. The exploration panel is located on the right hand side, providing features to support different Research Tactics. Together, they provide information seekers with a number of features to support reading, learning, and discovery of information, in a single screen. While search engines are mature keyword-based search technologies, our prototype focuses on features targeting the needs of exploration.

The earlier example of the woman with a cough and runny nose can be used to illustrate how her experience would differ using our prototype. The beginning of the story remains the same – she enters a keyword into a search engine and arrives at our prototype. Then, after reading the initial content, she starts to explore more topics by moving the sliders in the exploration panel.

As she moves the sliders, the tiles on the screen spring

[1] http://www.betterhealth.vic.gov.au/

[2] Google Analytics is a service for tracking and reporting on web site traffic. http://www.google.com/analytics

into action. Some move up; some down; some appear to jostle their positions. Her attention is grabbed by a large tile near the top labelled "Influenza (flu)" so she mouses over it and reads a summary description. She explores in this manner for a while but then, intrigued by the interaction between her slider movements and the animated tiles, she notices a particularly interesting tile about flu prevention. After clicking on it, the main screen changes to reflect this new topic, a new set of tiles appears and she continues to explore without having to exit the website. Her reading history is recorded and displayed as "breadcrumb" menu links so that she can easily go back to her previously viewed information.

Implementing a design such as this illustrates how we can draw on our design principles to give users an engaging, extended and enjoyable exploratory experience.

Features for Health Information Seekers

In this sub-section we will demonstrate five features in the Better Health Explorer for health information seekers:

A. Structured Content
B. Tiles
C. Sliders
D. Animated Transitions
E. Breadcrumb

We will provide a detailed explanation of each feature and describe how these features are linked to the suggested design principles.

A. Structured Content

The content in the original BHC dataset is mainly unstructured plain text which is unsatisfactory for both data processing and a user-friendly presentation. We generated structured metadata (such as summary text, lists of sections, etc.) by pre-processing the text in the dataset. These metadata help to add extra user interface elements to the prototype.

With the metadata, we can provide a summary and table of contents features to readers each constituting an overview of an article. This complies with the design principles *2. Support Information Exploration* and *5. Offer Preview and Summary*. Particularly, readers with low Reading Engagement (i.e. *Quick Fact Seeker* and *All-around Skimmer*) benefit from these features because they can review the contents at a glance before committing to a deeper read. Moreover, the links in the table of contents can be used to explore the content and jump between parts of a long article. This provides a mechanism for exploring information, even within a single web page.

B. Tiles

Tiles in the exploration panel list the articles recommended for further exploration, addressing the needs of *1. Provide a Wide Spectrum Information* and *2. Support Information Exploration*. This is similar to the concept in the iFISH exploratory engine (Pearce et al., 2012; Pearce and Chang, 2014).

Tiles are coloured with different colours according to the categories of the article. The colour pattern of tiles acts as an information visualisation for the result list. At a glance, the colour pattern illustrates the composition of articles that match with the slider input in terms of the type and nature of the information.

The tiles are arranged in an order that corresponds to the match with the user's input of exploration criteria, i.e. the more highly recommended tiles are placed on the top. Health information seekers can explore articles of interest from this set of tiles.

The sizes of tiles also serve as a visual clue for how strongly each is recommended. Articles with stronger recommendation are displayed as bigger tiles and in larger font size, indicating their significance. Less recommended articles are smaller.

Each tile corresponds to an article in the database. A popup window is shown when the mouse pointer is moved over a tile (Figure 6), in which summary information of the article is displayed. Seekers can then click on these tiles to navigate to other content. This is a design decision supporting users with low Reading Engagement, by offering preview before showing the substantial content (*5. Offer Preview and Summary*).

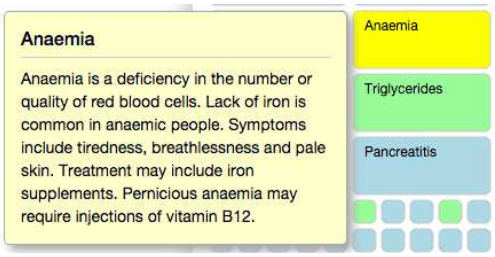

Figure 6. Displaying a popup summary when hovering a tile.

C. Sliders

Slider controls facilitate the multi-dimensional exploration in the information space without requiring keyword input. Figure 7 shows the dimensions assigned to the sliders in the Better Health Explorer. Seekers can adjust each dimension to reflect their personal preferences at any point in the search process.

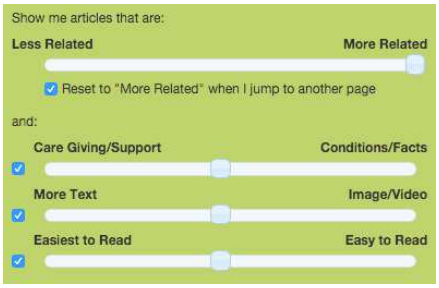

Figure 7. Sliders in Better Health Explorer.

Each article in the dataset is associated with a score for each of these dimensions. The software compares the slider input and article scores in the dataset, and return closest matches for reading recommendations. Sometimes users may wish to explore with fewer dimensions. They can then select or deselect the checkboxes for the sliders to consider or ignore the respective dimensions.

These dimensions for exploring health information were derived from the observations and feedback of the participants in our previous study. These dimensions are subjective perceptions of the information and hence hard

to express in traditional keyword search queries. Details of these dimensions are discussed below.

"Less Related" – "More Related": This dimension specifies the information scope in terms of the relevance to the current reading article. In other words, if they move the slider towards More Related, the system will retrieve information with higher relevance to the current article, and vice versa. The reason behind this is to allow setting the focus of the exploration, either be closer or further, in terms of the current context. This facilitates varying the search scope of both exploratory and focused search, as demonstrated in Figure 2.

"Care Giving/Support" – "Condition/Facts": Our dataset (similar to other health websites) contains content belonging to a variety of health information categories. Some articles present facts about diseases or health conditions, which are more scientific and precise, whereas others address caring for a patient or handling a health problem, which is more experience-based and social. In different scenarios seekers need to access one or other of these two types of information. This slider therefore caters to the needs of both cases, which aligns to the principle *1. Provide a Wide Spectrum of Information*.

"More Text" – "Image/Video": Some people are comfortable reading a significant text, whereas others prefer less text and more images. Also, in certain cases, an article accompanied with images is better at explaining the facts. This slider provides a way to include this preference in the exploration process. This complies with the principle of *4. Design for Reading Activity* by providing readings that match certain user preferences.

Reading Level: The health literacy of information seekers plays an important role in interpreting online health information. Users with poor literacy might have difficulties in understanding health information presented in a technical or professional manner (Lam and Lam, 2012). This option assists the system in providing information that suits their reading level by explicitly catering to their preferences. This feature also addresses a part of principle *4. Design for Reading Activity*.

The advantages of the use of sliders are two-fold. It can provide a wide range of health information to users (principle *1. Provide a Wide Spectrum of Information*). By introducing four sliders, users can explore hundreds of combinations with different slider settings. Secondly, sliders can eliminate the need for keyword search (*3. Minimise Keyword Search*). By using the sliders, information seekers are able to explore a large space by setting up search foci with different emphases.

D. Animated Transitions

Animated transitions are a key element to provide responses and hints of actions in interaction design (Chang and Ungar, 1993; Baudisch et al., 2006). The Better Health Explorer also incorporates animated transitions in the UI design to enhance the experience of information exploration.

The user interface animates changes in response to user actions. For instance: tiles newly included or removed from the exploration results are shown in slide-in/out effects; recommended articles are enlarged with transitions of tile sizes; changes in higher/lower rankings are displayed as swapping tiles on the screen.

The series of on-screen animations gives a sense of how attributes of each article are connected with the slider settings, as well as the connections between articles. Information seekers, for example, can realise the articles no longer fit in the current slider settings when they see tiles drop off from the screen. This provides a visual clue to an implicit overview of the entire information space that can be perceived by meticulous information seekers, which can help in the process of information exploration (*2. Support Information Exploration*).

E. Breadcrumbs

We employed a breadcrumb history bar for recording and displaying the track of articles visited by the users. This applies the principle of *6. Leave Clues for the Journey* in two ways. At first, while information seeking tasks are seen as trial-and-error processes (Toms and Latter, 2007), often seekers need to revert to previous steps and make new decisions during the exploration process. As such, the breadcrumb bar allows fast navigation back to previous web pages as well as earlier slider settings. Also, exploratory health search can be a lengthy process (White and Roth, 2009; Pang et al., 2015) and users may forget how they arrive at the current location and hence feel lost. Thus, this feature serves a purpose of reminding seekers of the path that led to the current context.

Summary

With the discussion of the features in the Better Health Explorer, we have shown the possibility of transforming abstract design principles to actual UI design. We plan to evaluate the effectiveness of the web app in multiple ways. Bounce rate and reading time can be measured and compared to current web technologies. Support for exploratory search will be evaluated by observing user interactions with the exploration panel and their movement through the information space.

CONCLUSIONS

In this paper, we have introduced six design principles for building consumer health websites that better support health information seeking behaviours. These principles enable a systematic approach to designing health websites that suit general users. We introduced an experimental prototype – Better Health Explorer – to illustrate these design ideas empirically. Both the design principles and the prototype are valuable for building better health information seeking environments. Our future research will evaluate the effectiveness of the design principles and how they shape health information seeking behaviour.

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REFERENCES

Alhenshiri, A., Watters, C., Shepherd, M. and Duffy, J. Information gathering tasks on the Web: Attempting to identify the user search behaviour. In Proc. WEBIST 2012, LNBIP 140 (2013).

Alzougool, B., Chang, S. and Gray, K. Towards a comprehensive understanding of health information needs. electronic Journal of Health Informatics, 3, 2 (2008).

Alzougool, B., Chang, S. and Gray, K. The nature and constitution of informal carers' information needs: What you don't know you need is as important as what you want to know. information Research, 18, 1 (2013).

Andreassen, H.K. et al. European citizens' use of E-health services: A study of seven countries. BMC Public Health, 7, (2007), 53.

Baudisch, P. et al. Phosphor: Explaining transitions in the user interface using afterglow effects. In Proc. UIST'06 (2006), 169–178.

Berland, G.K. et al. Health information on the Internet: Accessibility, quality, and readability in English and Spanish. JAMA, 285, 20 (2001), 2612–2621.

Benigeri, M. and Pluye, P. Shortcomings of health information on the Internet. Health Promotion International, 18, 4 (2003), 381–386.

Bessell, T.L. et al. Prevalence of South Australia's online health seekers. Australian and New Zealand Journal of Public Health, 26, (2002), 170–173.

Birru, M.S. et al. Internet usage by low-literacy adults seeking health information: An observational analysis. J. Med. Internet Res, 6, 3 (2004), e25.

Bozzon, A., Brambilla, M., Ceri, S. and Mazza, D. Exploratory search framework for web data sources. The VLDB Journal. 22, 5 (2013), 641–663.

Case, D.O. Looking for Information: A Survey of Research on Information Seeking, Needs, and Behaviour. Academic Press (2002).

Cartright, M.-A., White, R.W. and Horvitz, E. Intentions and attention in exploratory health search. In Proc. SIGIR'11, ACM Press (2011).

Chang, B.-W. and Ungar, D. Animation: From cartoons to the user interface. In Proc. UIST'93 (1993), 45–55.

Chapman, K., Abraham, C., Jenkins, V. and Fallowfield, L. Lay understanding of terms used in cancer consultations. Psychooncology, 12, 6 (2003), 557–566.

Ferré, S. and Hermann, A. Semantic search: Reconciling expressive querying and exploratory search. In Proc. ISWC 2011, LNCS 7031. Springer Berlin Heidelberg (2011), 177–192.

Foster, A. and Ford, N. Serendipity and information seeking: An empirical study. Journal of Documentation, 59, 3 (2003), 321–340.

Fox, S. and Jones, S. The Social Life of Health Information. Pew Internet & American Life Project (2009).

Fox, S. and Duggan, M. Health Online 2013. Pew Research Center's Internet & American Life Project (2013).

Hearst, M. et al. Finding the flow in web site search. Communications of the ACM, 45, 9 (2002), 42–49.

Keselman, A., Browne, A.C. and Kaufman, D.R. Consumer health information seeking as hypothesis testing. J. Am. Med. Inform. Assoc, 15, 4 (2008), 484–495.

Klouche, K. et al. Designing for exploratory search on touch devices. In Proc. CHI 2015, ACM Press (2015), 4189–4198.

Kules, B. et al. 2009. What do exploratory searchers look at in a faceted search interface? In Proc. JCDL'09 (2009), 313–322.

Lam, M.K. and Lam, L.T. Health information-seeking behaviour on the Internet and health literacy among older Australians. electronic Journal of Health Informatics, 7, 2 (2012).

Lee, K., Hoti, K., Hughes, D.J. and Emmerton, L. Dr Google and the consumer: A qualitative study exploring the navigational needs and online health information-seeking behaviors of consumers with chronic health conditions. J. Med. Internet Res, 16, 12 (2014), e262.

Leong, T.W., Vetere, F. and Howard, S. Experiencing coincidence during digital music listening. ACM Trans. Computer-Human Interaction, 19, 1 (2012), 6:1–6:19.

Luo, G., Tang, C., Yang, H. and Wei, X. MedSearch: A specialized search engine for medical information retrieval. In Proc. CIKM '08 (2008).

Marchionini, G. Exploratory search: from finding to understanding. Communications of the ACM, 49, 4 (2006), 41.

Nicholas, D. et al. The British and their use of the Web for health information and advice: A survey. Aslib Proceedings, 55, 5/6 (2003), 261–276.

Oxford English Dictionary, "serendipity, n.", Oxford University Press (2015).

Pang, P.C.-I., Chang, S., Pearce, J. and Verspoor, K. Online health information seeking behaviour: Understanding different search approaches. In Proc. PACIS 2014, AIS (2014).

Pang, C.-I., Si, S.-S. and Chio, S.-K. A new way to use Wikipedia in education: A pilot study of map-like Wikipedia visualization on iPad. International Journal of Future Computer and Communication, 3, 1, (2014b) 45–49.

Pang, P.C.-I., Verspoor, K., Chang, S. and Pearce, J. Conceptualising health information seeking behaviours and exploratory search: Result of a qualitative study. Health and Technology, 5, 1 (2015), 45–55.

Pearce, J. et al. Search and explore: More than one way to find what you want. In Proc. OzCHI'12, ACM Press (2012).

Pearce, J. and Chang, S. Exploration without keywords: The bookfish case. In Proc. OzCHI'14, ACM Press

(2014), 176–179.

Spink, A. et al. A study of medical and health queries to web search engines. Health Information and Libraries Journal, 21, (2004), 44–51.

Thudt, A., Hinrichs, U. and Carpendale, S. The Bohemian Bookshelf: Supporting serendipitous book discoveries through information visualization. In Proc. CHI 2012, ACM Press (2012).

Toms, E.G. Serendipitous information retrieval. In Proc. DELOS Workshop: Information Seeking, Searching and Querying in Digital Libraries (2000), 17–20.

Toms, E.G. and Latter, C. How consumers search for health information. Health Informatics Journal, 13, 3 (2007), 223–235.

White, R.W., Kules, B., Drucker, S.M. and schraefel, m c 2006. Supporting exploratory search. Communications of the ACM, 49, 4 (2006), 36–39.

White, R. and Roth, R. Exploratory Search: Beyond the Query-Response Paradigm. Morgan and Claypool (2009).

Wilson, T.D. Information behaviour: an interdisciplinary perspective. Information Processing & Management, 33, 4 (1997), 551–572.

Wilson, T.D. Models in information behaviour research. Journal of Documentation, 55, 3 (1999), 249–270.

Wilson, T.D. Revisiting user studies and information needs. Journal of Documentation, 62, 6 (2006), 680–684.

Zarro, M. Developing a dual-process information seeking model for exploratory search. In Proc. HCIR 2012 (2012).

Zhang, Y. and Fu, W.-T. Designing consumer health information systems: What do user-generated questions tell us? In Proc. FAC 2011, HCII 2011, LNAI 6780. Springer-Verlag Berlin Heidelberg (2011), 536–545.