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INNOVATION IN DESIGNING HEALTH INFORMATION WEBSITES: RESULTS FROM A QUANTITATIVE STUDY

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Abstract

A wealth of health information exists on the Internet, but successfully finding that information is not easy. One of the issues causing this is the lack of tools for exploring information and assisting in navigation within health websites. As a result, relevant information cannot be easily discovered. We hope to rectify this issue from the design perspective. Based on previous work, we have created a prototype website called Better Health Explorer to better support such information seeking behaviours. This paper reports on a quantitative study evaluating this prototype. The results demonstrate several improvements in health information seeking supported by the tool. Furthermore, we have identified three general design characteristics that should to be considered when designing consumer health websites. These findings have design implications for health information seeking applications, as well as identifying directions for further research.

Keywords: Health information seeking behaviour; health information seekers; exploratory search; information needs; serendipity.

1 INTRODUCTION

Many Internet users have some experience looking for health information online (Fox & Duggan 2013; Fox & Jones 2009; European Commission 2015). While the research of health information seeking behaviour is ongoing, the problem of low findability of health information remains persistent (Eysenbach 2005; Johnson & Case 2012). This creates extra burdens for health information seekers and lowers the overall user experience. Consequently, online health information cannot be fully discovered and utilised, and people disengage with health websites (Hardiker & Grant 2011; Palotti et al. 2015; David Johnson 2014). We argue that the provision of health information has to be clear, approachable and appealing to users.

Studies have uncovered that one problem affecting many health websites is that they do not adequately address the needs of health information seekers (Sherer 2014; Pang, Verspoor, et al. 2014), who are the real users of these websites. However, deriving better support for them is not an easy task. Health information seekers require different features at different times and their behaviours will change in various scenarios (Pang, Verspoor, Pearce, et al. 2015; Pang, Verspoor, Chang, et al. 2015b). Based on prior research, we have created a prototype website called Better Health Explorer using a user-centred design approach, for testing the support for health information seekers in different ways (Pang, Verspoor, Pearce, et al. 2015).

This paper reports on an evaluation of Better Health Explorer. The evaluation is a lab observation study with 31 participants. We included a comparison of this prototype with an existing live health website in this evaluation. The quantitative results demonstrate a number of improvements in supporting health information seekers when compared with the current approach of finding information; meanwhile no significant performance degradation was detected. Based on the collected data, we have identified three general factors to be considered in the design of future consumer health websites, as well as health information seeking applications, namely (1) the communication of health information needs, (2) information diversity, and (3) serendipity.

The rest of this paper is structured as follows: we will review the current literature about online health information and then briefly introduce our prototype software. After that, the detailed design of the evaluation will be reported, followed by the evaluation results. Finally, we will discuss the contributions and summarise this paper.

2 RELATED WORK

2.1 Online Health Information Seeking

Research has shown that Internet users are increasingly using the web as a source of health information (Fox & Jones 2009; Fox & Duggan 2013; European Commission 2015). Health information seeking on the Internet involves a number of different information needs, from specific medical conditions or symptoms, causes and treatments of diseases, diet information, to healthy lifestyle tips (Pang, Chang, et al. 2014; Andreassen et al. 2007; Alzougool et al. 2013). The Internet is deemed as a quick, economic and convenient source of health information (Donnelly et al. 2008; Horgan & Sweeney 2010; Jones et al. 2014). Online health information has also been used to assist in seekers' decision making processes (Davison et al. 2002; Hersh 2009), making it crucial for relevant accurate health information to be easily accessible.

Despite the widespread use of online health information, health information seekers still face significant problems when accessing the information. Using search engines is the primary method for retrieving health information on the Internet (Spink et al. 2004; Fox & Duggan 2013). However, scholars have suggested that keyword-based search is limited for health information. First of all,

search engines are not optimised for health queries (Berland et al. 2001; Benigeri & Pluye 2003). More importantly, lay people generally have insufficient medical knowledge to describe health problems accurately and thus get unsatisfactory search results (Chapman et al. 2003; Keselman et al. 2008; Luo et al. 2008). So far, health information seeking is often described as a trial-and-error process (Toms & Latter 2007). In addition to issues of finding the information, lay-people are observed to be less engaged and less persistent with health websites due to various design and usability problems (Hardiker & Grant 2011; Palotti et al. 2015; David Johnson 2014). People with low health literacy appear to have more problems finding health information (Agree et al. 2015; Bickmore et al. 2016; Lam & Lam 2012). Because health information seekers have a diverse range of needs, different levels of skills and health literacy, designers of health websites need to understand their information seeking behaviours and their strategies for finding information.

2.2 Health Information Seeking Behaviour

In order to design for health websites and health information seeking applications, we have reviewed the current understanding of health information seeking behaviour (HISB). HISB is a series of interactions to reduce uncertainty regarding health status and construct a social and personal cognitive sense of health (Tardy & Hale 1998), and a sense-making process to understand health issues (Wilson 1997; Case 2002). Curiosity is also another factor to motivate HISB and subsequently may lead to the demand of learning new information (Case 2002; Alzougool et al. 2008). From the literature cited above, we understand that knowledge learning and acquisition have a large role in health information seeking behaviour, and require special attention in the design phase.

HISB is different from general information seeking behaviours in many ways. HISB frequently introduces uncertainty and stressful mental states (Wilson 1997; Johnson & Case 2012). Health literacy affects the outcomes of HISB (Agree et al. 2015; Bickmore et al. 2016; Lam & Lam 2012), whereas general types of searching do not require a threshold level of literacy. HISB is used to handling threatening situations and to making decisions (Lambert & Loiselle 2007; Pang, Chang, et al. 2014; Case 2002), which are more serious than most cases of general information seeking. Hence, the design in the consumer health context is different from in general contexts, and has to be sensitive to the variety of different user information needs and scenarios.

Different health information needs and scenarios will lead to different information seeking behaviours (Pang, Chang, et al. 2014; Alzougool et al. 2013; Alzougool et al. 2008). For example, people will tend to do a comprehensive search if searching on behalf of others, because they want to be correct and useful when passing on the information to the others. Whereas searches driven by curiosity tend to be conducted in a more casual manner since there is less urgency involved. These examples show different information needs driving different health information seeking behaviours. Subsequently, different user interfaces are needed to support these different behaviours.

2.3 Focused and Exploratory Search

There are different search approaches for finding information. In most cases we perform "focused search" or known-item search (White & Roth 2009; Singer et al. 2011), in which we have a clear search target and a narrower search scope (Pang, Verspoor, Chang, et al. 2015b; White & Roth 2009). On the other hand, "exploratory search" is often found when an individual tries to address unfamiliar or unknown problems (Pearce et al. 2012) and associates with ill-formed search queries and a wider search scope.

Exploratory seekers often are unfamiliar with the knowledge domain and unsure about the search goals (White & Roth 2009), therefore learning and investigating activities are carried out in addition to just locating the information (Marchionini 2006). Drawn from the literature, exploratory search is highly relevant to HISB because of the similarity of uncertainty and the lack of medical knowledge. Research has shown that exploratory search is used in health information seeking under certain

scenarios (Pang, Chang, et al. 2014; Pang, Verspoor, Chang, et al. 2015b; Pang, Verspoor, et al. 2014; Cartright et al. 2011).

Designing user interfaces for exploratory search requires special techniques. Below we introduce some example projects for supporting exploratory search. Multi-dimensional data is often used in exploratory search hence a mashup web application was created for supporting exploratory search (Bozzon et al. 2013). In other projects for finding restaurants and library books (Pearce & Chang 2014; Pearce et al. 2011), a playful and engaging environment was created to enable exploration with personal preferences using slider controls. Sliders, immediate responses and continuous display of results are found useful in visual information seeking (Ahlberg & Shneiderman 1994). Some other studies used tablet computers to facilitate information exploration with gestures, allowing users to freely navigate within the information space, such as Wikipedia and a library catalogue (Thudt et al. 2012; Pang, Si, et al. 2014). Wilson have summarised several principles (such as helping seekers to create queries, using metadata, giving users the control over results, etc.) to build a better search user interface (Wilson 2011). These projects have guided us to design and implement a system for exploring health information.

Research has found that focused and exploratory search are both used in health information seeking (Pang, Chang, et al. 2014; Pang, Verspoor, Chang, et al. 2015b). People do not adhere to a single search approach or behaviour in their search processes. Instead, they choose the most appropriate approach for them, due to the different circumstances, situational relevance and personal preferences. Therefore, health websites and health information seeking applications need to prepare for both search approaches, and the design needs to cater for them.

2.4   Serendipity

Serendipity can play a role in the information seeking process where accidental discovery in browsing leads to valuable findings (Apted & Choo 1971). It can also lead to discovering useful information with randomness and pleasure (Thudt et al. 2012) as well as enhancing user experience (Leong et al. 2012). Health information seeking involves certain degree of serendipity since seekers have to look into the unfamiliar knowledge domain (Case 2012; Johnson & Case 2012). We have applied various strategies to generate serendipitous findings in this and previous research (Pang, Verspoor, Chang, et al. 2015a; Pang, Verspoor, Pearce, et al. 2015).

3   THE PROTOTYPE – BETTER HEALTH EXPLORER

Based on previous work (Pang, Verspoor, Chang, et al. 2015b; Pang, Verspoor, Pearce, et al. 2015; Pang, Chang, et al. 2014), we have designed and implemented a prototype website called Better Health Explorer for addressing different issues of health information seekers. It also aims at providing an interactive and engaging experience in the health information seeking process.

Figure 1 shows a screenshot of Better Health Explorer. The user interface of Better Health Explorer looks similar to an ordinary health website, but the exploration panel on the right gives a different experience of finding and exploring health information. Sliders (bottom-right of screen) are used for generating and refining queries. Health information that matches the criteria are displayed as coloured tiles at the top right of the screen. Colours denote the category that the information belongs to. Therefore, the colour pattern also offers an overview of the composition of the results. The web application also has a summary and a table of contents for previewing the content and the structure of the current page (top left), checkboxes filters for narrowing down information (centre right), and a breadcrumb history bar for memory aid (top right).
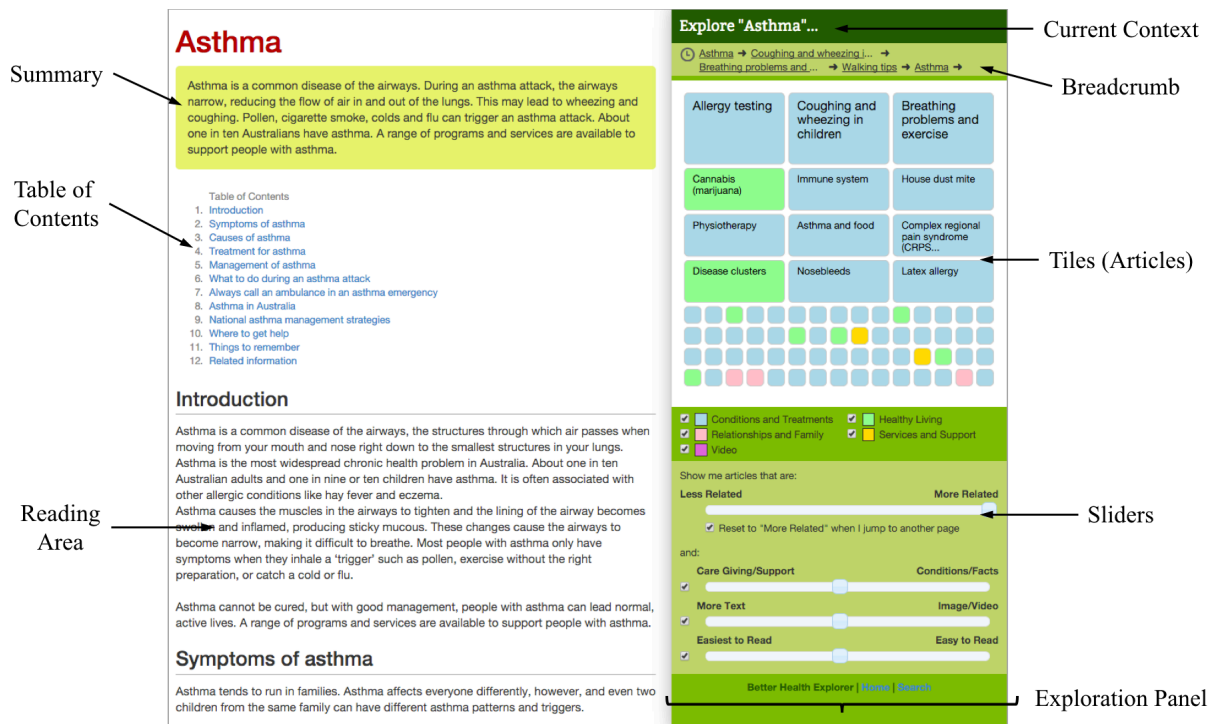
Figure 1.   *A screenshot of Better Health Explorer.*

Sliders are the primary mechanism to interact with the website for finding and exploring health information. Similar to previous work (Ahlberg & Shneiderman 1994), users can immediately change the input and adjust the criteria for exploring information with sliders. These four sliders correspond to four different criteria which are often used for retrieving health information; they are derived from other research (Pang, Chang, et al. 2014; Pang, Verspoor, Chang, et al. 2015b). In this way, the website can provide a broad range of information with hundreds of combinations of slider values based on the context currently viewing. A useful feature of this approach is that this is not an exact search like we have become used to with search engines, but rather an interactive and real time browsing through relevant health concepts. Therefore unexpected items may serendipitously appear when playing around with the sliders. The slider-based design adds interactivity to the website. It displays real time changes of results when seekers adjust the sliders, so that seekers can iterate through the cycle of observing changes, perceiving the meaning, and responding. In the process they adjust the inputs and learn.

An example of a concerned mother can further explain the innovative experience of seeking health information. The mother wants to find some information about a common cold for her child; she looks for it in Better Health Explorer. After some initial reading about colds, she needs more information about this topic and therefore adjusts the sliders. As the sliders change, the items start to move and jostle their positions. Her attention is grabbed by an item labelled "pneumonia". She clicks on it and the reading area is updated with information about pneumonia. Meanwhile a new set of tiles pop up based on the new topic (pneumonia), so that she can explore further. The "journey" of exploration repeats again with the similar steps.

4   RESEARCH DESIGN

The purpose of this study is to verify that the proposed design for different health information seeking behaviour is effective, and to discover which elements contribute to the effect. A lab-based observation study was conducted from September to October 2015. Participants were invited to the lab to perform different tasks of searching health information, and complete a questionnaire after each

task. No incentive was given for this experiment. The experiment was approved by the Human Research Ethics Committee of the University.

Volunteers were recruited using a number of channels (the university mailing list, electronic bulletin boards, physical flyers in student lounges and the student union building). Social networking platforms such as Facebook and Twitter were also used for recruitment. Adults with previous experience of searching on the Internet were targeted for this study.

4.1   Websites Used

Two websites were used in this study. The first one was a general consumer health website called Better Health Channel (http://betterhealth.vic.gov.au/), used as the baseline of the evaluation. This is one of Australia's largest health websites established with millions of visits per month (Pang, Verspoor, Pearce, et al. 2015). The measurements with Better Health Channel were used as a baseline of general health information seeking behaviour given their large extent of visitors and public usage. Figure 2 illustrates the user interface of the baseline – Better Health Channel. The other website used for this study was our prototype for finding health information – Better Health Explorer. Both websites shared the same contents in this experiment.
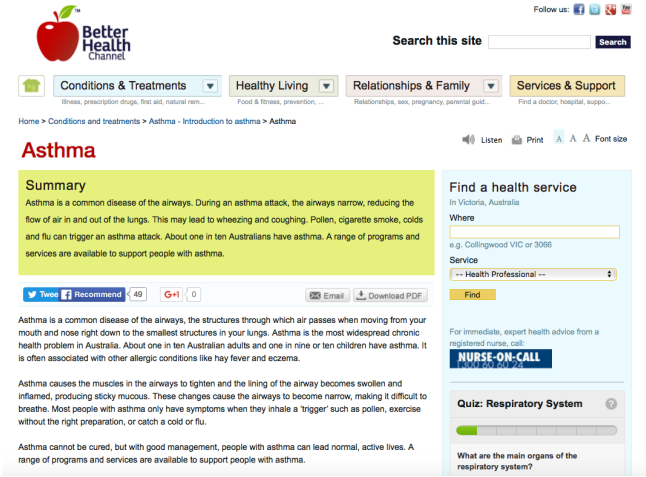

Figure 2.   A screenshot of the baseline website Better Health Channel in the study for the comparison purpose.

4.2   Search Tasks

Two categories of search tasks (i.e. focused and exploratory search) were evaluated in this study, reflecting their existences in different health information seeking scenarios (Pang, Chang, et al. 2014). This setup also facilitated the observation of differences between two search approaches (Kules et al. 2009). Table 1 displays sample task instructions for both focused and exploratory search tasks.

Type	Task Instruction
Focused	Imagine one of your family members has recently been diagnosed with Type 2 *Diabetes / hypertension / osteoporosis / asthma*. As you're living together, your daily life might need to be changed in different ways as well. Please identify three kinds of changes that might be needed in your everyday life.
Exploratory	Imagine you are going to a party and will discuss health information with your friends. Use the website provided by us to identify some interesting health topics. Continue reading until you think it is enough for the discussion.

Table 1.   Task instructions used in the study.

While these search tasks might not fully reflect the real-world scenarios, these tasks were purposefully designed to probe into different aspects of health information seeking. In the focused search tasks, a pre-defined diagnosis was given. This information acted as a clear search target and the task emulated the scenario of known-item search (Singer et al. 2011). In contrast, the exploratory tasks posed an open-ended scenario as suggested in (Wildemuth & Freund 2012). In such cases seekers would have a vague search target and ill-formed problem definition, and thus needed initially to explore for a brief understanding of the topic, before knowing what exactly to look for. The scenario involving social discussions was also found to be helpful for generating exploratory search (Hendahewa & Shah 2015).

Every participant was asked to perform four tasks: two focused and two exploratory tasks. In each type of search task both the baseline website and Better Health Explorer were tested. The task order for every participant was allocated using a 4x4 Latin Square (Williams 1949), for counter-balancing learning and ordering effects.

Multiple diagnoses were prepared for focused search tasks (as underlined in Table 1). These health concerns were sourced from the most frequent searched list of the Better Health Channel website. This particular setup was to avoid repeats when testing different websites, and to avoid prior knowledge affecting the outcomes if participants had suffered from that particular sickness before.

4.3   Protocol

Participants began with a brief introduction to the study and the two websites used, followed by a demographic questionnaire. At this stage, participants were asked to select one of the tasks that they had no prior experience with. Search tasks were then conducted on a desktop computer.

Tasks started with the home page of the corresponding website that listed popular health topics and provided a search input box. Participants were allowed to browse or search within the website freely. The only restriction was that they cannot open and use websites other than the testing one. After completion of a task, participants were asked to fill in a single-page questionnaire. All responses were in the format of 5-point Likert scales, measuring from "strongly disagree" (1) to "strongly agree" (5).

4.4   Questionnaire Design

The questionnaire included 14 questions (Table 2) to capture different perspectives, covering knowledge acquisition (for evaluating the efficiency of exploratory search) (Marchionini 2006; Hendahewa & Shah 2015; White & Roth 2009), how to find information (Pu et al. 2011; Pang, Verspoor, Chang, et al. 2015a), and user experience (Brooke 1996; Pu et al. 2011).

No.	Question
1	I was uncertain about what information to look for before starting the task.
2	The design of the website helped me to figure out what information I should look for.
3	I learnt new knowledge throughout the task.
4	I was successful in getting the information I needed.
5	I found it easy to tell the website what I needed.
6	I was presented with diverse information on the topic through the design of the website.
7	I was presented with topics that I hadn't thought of before but was interesting to me.
8	I had enough time to look for the information I needed.
9	I found using the website enjoyable.
10	I felt engaged with the website.
11	I felt the website was easy for me to use.
12	I would use the website at home if it were made available.
13	Overall, the website was useful.
14	Overall, I was satisfied with the website.

Table 2.   Questions in the post-task questionnaire.

4.5 Data Analysis

Data was analysed using R version 3.2.3 with two statistic tests. Wilcoxon Signed-rank Test was used to verify the differences between the baseline website and Better Health Explorer (Wilcoxon 1945). This test can be applied on non-normalising data and ordinal data (such as Likert scale) (McDonald 2014). Moreover, Spearman's correlation was used for identifying the relationship between the elements in the proposed design for health information exploration and the actual results.

5 RESULTS

Thirty-one participants completed the experiment, including 15 (48%) male and 16 (52%) female. The mean age was 33.9 (SD=12.67) and the median was 29. Ages ranged from 20 to 72. Among the participants, 19 (61%) of them were university students, whereas 10 (32%) were staff, and two (7%) had no relations to the university.

5.1 Focused Search Tasks

Table 3 shows the responses for the focused search tasks for comparing the baseline website (BL) and our prototype (BHX). For the perceived level of uncertainty for the two focused search tasks (#1), the average scores were similarly low (less than 3.0). This means that the validity of the instructions for focused search tasks was verified with the participants' responses, as they could understand the clear and specific search goals in the tasks.

The figures also suggest that, for focused search tasks, participants found that BHX outperformed BL in the areas of: Helping to find the needed information (#2); Presenting more diverse information (#6); Showing serendipitous items (#7); Enjoyably using the website (#9); and Ease of use (#11).

For the task outcome, BHX was better than BL in: Task success (#4); Learning new knowledge (#3); Engaging with the website (#10); Usefulness (#13); and Satisfaction (#14). The differences between these measurements were statistically significant. There was a particularly strong difference in Satisfaction (#14) with a large effect size (r=0.510).

Question	Baseline		Better Health Explorer		Wilcoxon Signed-rank Test		
	Mean	SD	Mean	SD	Z	p	r
1. Uncertain about the task	2.19	1.25	2.39	1.50	0.702	0.491	0.089
2. The design helps to find info.	3.23	0.99	3.84	1.07	2.120	0.032*	0.269
3. Learnt new knowledge	3.65	1.11	4.32	0.98	2.505	0.012*	0.318
4. Successfully getting the info.	3.81	1.14	4.42	0.67	2.605	0.009^	0.331
5. Easy to tell what I needed	3.52	1.09	3.90	1.01	1.616	0.112	0.205
6. Presented diverse info.	3.29	1.04	4.06	0.85	2.936	0.003^	0.373
7. Presented serendipitous topics	2.81	1.14	3.84	0.97	3.897	0.000^	0.495
8. Had enough time to find info.	4.16	0.97	4.35	0.88	1.461	0.175	0.185
9. Using the site was enjoyable	3.03	0.87	3.94	0.68	3.888	0.000**	0.494
10. Felt engaged with the site	3.10	0.94	3.94	0.77	3.142	0.002^	0.399
11. Felt easy to use	3.61	1.05	4.39	0.76	2.875	0.004^	0.365
12. Would use again if available	3.68	1.08	4.06	1.03	2.269	0.025*	0.288
13. The site was useful	3.82	0.94	4.39	0.72	2.806	0.005^	0.356
14. Satisfied with the site	3.60	0.88	4.32	0.70	4.014	0.000**	0.510

* p<0.05   ^ p<0.01   ** p<0.001

Table 3.   Responses for focused search tasks.

5.2 Exploratory Search Tasks

Table 4 displays the responses for the exploratory search tasks. The level of task uncertainty was simultaneously higher in both tasks than for the focused tasks, reflecting the vaguer nature of exploratory search tasks. Participants could successfully complete both tasks on average; the system used made no (statistically significant) difference to this. The results of exploratory tasks are similar to the ones of the focused tasks. BHX was found superior than BL in these figures: Helping to find the needed information (#2); Easy to tell the website what was needed (#5); Presenting more diverse information (#6); Showing serendipitous items (#7); Enjoyably using the website (#9); and Ease of use (#11). For the task outcome, BHX performed significantly better than in: Learning new knowledge (#3); Engaging with the website (#10); Usefulness (#13); and Satisfaction (#14).

Question	Baseline		Better Health Explorer		Wilcoxon Signed-rank Test		
	Mean	SD	Mean	SD	Z	p	r
1. Uncertain about the task	3.52	1.36	3.39	1.33	-0.350	0.721	-0.044
2. The design helps to find info.	3.13	1.23	3.97	0.84	2.604	0.008^	0.331
3. Learnt new knowledge	3.74	1.03	4.26	0.93	2.380	0.016*	0.302
4. Successfully getting the info.	3.68	0.98	4.13	0.81	1.654	0.108	0.210
5. Easy to tell what I needed	2.84	1.07	3.42	0.99	2.109	0.034*	0.268
6. Presented diverse info.	3.35	1.28	4.35	0.84	2.947	0.003^	0.374
7. Presented serendipitous topics	3.32	1.22	4.42	0.96	3.211	0.001^	0.408
8. Had enough time to find info.	3.94	1.00	4.13	0.99	0.874	0.414	0.111
9. Using the site was enjoyable	3.19	0.91	4.13	0.72	3.558	0.000**	0.452
10. Felt engaged with the site	3.26	1.03	4.06	0.73	3.101	0.002^	0.394
11. Felt easy to use	3.48	0.93	4.13	0.76	2.436	0.015*	0.309
12. Would use again if available	3.45	1.03	4.00	0.93	2.683	0.008^	0.341
13. The site was useful	3.71	0.82	4.42	0.72	3.427	0.000**	0.435
14. Satisfied with the site	3.52	0.85	4.29	0.74	3.510	0.000**	0.446

* $p<0.05$ ^ $p<0.01$ ** $p<0.001$

Table 4.   Responses for exploratory search tasks.

5.3 Correlations

We used Spearman's correlation to measure correlation of BHX responses in the focused and exploratory search tasks. These results help us to understand potential relationships between the design and the actual outcomes of using the websites. Table 5 shows a number of correlations which are significant ($p<0.05$) or approaching non-significant ($p<0.10$).

Focused Tasks			Exploratory Tasks		
Correlated Metrics	r	p	Correlated Metrics	r	p
3. Learnt new knowledge & 5. Easy to tell what I needed	0.396	0.016*	3. Learnt new knowledge & 7. Presented serendipitous topics	0.725	<0.001*
4. Successfully getting the info. & 5. Easy to tell what I needed	0.281	0.062	4. Successfully getting the info. & 5. Easy to tell what I needed	0.470	0.006*
10. Felt engaged with the site & 6. Presented diverse info.	0.346	0.084	10. Felt engaged with the site & 6. Presented diverse info.	0.074	0.097
10. Felt engaged with the site & 9. Using the site was enjoyable	0.502	0.032*	12. Would use again if available & 6. Presented diverse info.	0.423	0.062
			13. The site was useful & 6. Presented diverse info.	0.483	0.069

Table 5.   Spearman's correlations of the responses (* denotes significance at p<0.05 level).

6 DISCUSSION

6.1 A Better Environment for Finding Health Information

In general, BHX provided a better result and experience for the participants in the study, when compared with the baseline live health website. Firstly, the result reflects that the design of Better Health Explorer is superior in finding health information in terms of usability, in both focused and exploratory search tasks. Secondly, participants successfully obtained the required information and learnt new health knowledge, suggesting that the core goals of health information seeking behaviour can be achieved with the novel design of our prototype. Meanwhile, no apparent performance degradation with the new design is observed in this study.

Two concepts for supporting different health information seeking behaviours, namely information diversity and serendipity, were found to be improved in the design of our prototype. Many consumer health websites supply information to users using three channels: menus and hyperlinks, search results, and related links (normally at the bottom of a page). These approaches provide a limited range of information based on the context. This is not sufficient for the health information seeking process where broader information and serendipitous findings are needed (Herskovic et al. 2007; Pang, Verspoor, Pearce, et al. 2015). In Better Health Explorer, information is presented as a dynamic list, in which users can explore other content easily with sliders and shift the focus to different areas in the database. In this process serendipity items may appear as sliders are not precise queries like search keywords. This helps users to make discoveries at the very moments when they are not clear as to what to look for. Both information diversity and serendipity are served in our prototype.

The measurements of enjoyment and engagement are higher with our design. The interactive design of BHX contributes to enjoyment and engagement. Interactivity has been found to make online information more appealing and preferable (Niu et al. 2010). Additionally, the increase of interactivity in health websites can lead to more knowledge gained, higher usage time and higher number of page reads (Crutzen et al. 2012), and thus can enhance the overall experience. Moreover, one of the goals of health information seeking is to make sense of health topics and concepts (Wilson 1997; Case 2002). According to Flow Theory (Csikszentmihalyi 1975), people will engage and immerse in an activity if they encounter a positive experience (Pearce et al. 2006), which leads to successful findings and learning more health information.

Different usability metrics of Better Health Explorer are recorded higher than the baseline, showing the feasibility of making such designs available to general users without causing usage problems. An initial concern was that sliders might not be familiar to users, because it is very different from the usual way of making search queries. But the result shows that this approach is still easy to use. In the study users were able to try, observe and learn the function of sliders, thanks to the interactive nature and real time feedback.

In summary, our user-centred design of supporting the needs and behaviours of health information seekers, as implemented in the prototype Better Health Explorer, delivers a better result in both focused and exploratory search scenarios. Next, we will further discuss some directions we generalised from this study for improvements when designing and developing better health information seeking applications.

6.2   Considerations for Design Improvements

6.2.1   *The Communication of Health Information Needs*

The question about how "easy to tell the system what is needed" originates from the field of recommendation systems (Pu et al. 2011). It means the ability of the system to elicit users' preferences and to allow feedback on the recommended results (Pu et al. 2011). We suggest that the same concept applies to health information seeking behaviour. In the context of this paper, it refers to the ability of the search tool to acquire users' information needs, and allow the users to adjust their needs during the progress of their searches for information.

The correlations (C1 and C4) imply that the ease of conveying the information needs to the system can result in a more successful search and learning outcomes. This can further be discussed in two stages: initialising information needs at the beginning of the search, and adjusting the needs in the middle of the search. Below are some current challenges in these two stages.

At the beginning of a search, seekers traditionally mainly rely on using navigation menus and search functions in current health websites to initiate the "journey" of finding information. Both mechanisms have different problems. Navigation menus suffer from the disparity between the medical terms seekers know and those the website use (Samuel et al. 2012), As a result they may not discover the appropriate links when the words used in the menu are not the ones seekers expect. On the other hand, search engines require precise keywords for retrieving results, but lay-people generally cannot describe health issues using proper medical terms (Chapman et al. 2003; Keselman et al. 2008; Luo et al. 2008).

In the middle of the search process, the information needs often need to be adjusted. People will adopt the most appropriate search approach as the search develops (Pang, Chang, et al. 2014; Pang, Verspoor, Chang, et al. 2015b), taking account into the information found and the knowledge still needed. For example, a seeker starts with some search keywords, later finds out that the result is not what they want. In this case the search query has to be changed. Indeed, this query reformulation process is essential in the exploration process (White & Roth 2009). However, thinking up new search queries is difficult for some people, as it requires an adequate level of research skills and additional cognitive workload (Pang, Verspoor, Pearce, et al. 2015).

Designers should create innovative user interfaces for both initial and in-progress stages. This is particularly critical for the health context, as seekers often do not know how and what to search. In our example sliders are used to replace the traditional keyword-based query mechanism, and have yielded a better outcome. Faceted search is another possible solution to relieve the difficulties of query reformulation (Samuel et al. 2012). Another example is using a conversational agent to collect search criteria with a dialog, which is helpful to people with lower health and computer literacy (Bickmore et al. 2016). However, these samples should not limit designer's creativity to ease the process of expressing information needs.

6.2.2   *Information Diversity*

Information diversity is potentially connected to the engagement with a website as observed in this study. While the correlation is not significant at the standard level of $p<0.05$, a marginal non-significance ($p<0.10$) is identified. Health website users lack engagement and persistence when using the online resources (Hardiker & Grant 2011; David Johnson 2014; Palotti et al. 2015), therefore maintaining the engagement is crucial to information providers. From this perspective, information diversity is a direction to consider in the design.

In the context of health information exploration, enhancing information diversity means to provide a wide range of information in addition to what the user asks for (Pang, Verspoor, Pearce, et al. 2015).

This is also a typical requirement for supporting exploratory search (White & Roth 2009; Pang, Verspoor, Pearce, et al. 2015). For instance, if one searches for "asthma", the result should include treatments, preventions, related sickness, and possible consequences of asthma, in addition to the information of asthma itself.

There are several reasons to enhance information diversity. Although not statistically significant, the correlations show the possibilities that the information diversity links to the perceived usefulness of the site and the possibility of revisiting at a near-significant trend ($p<0.10$). We propose that these results are linked to the nature of health information seeking. Research has found that multiple types of information are involved in the health information seeking process (Pang, Chang, et al. 2014; Andreassen et al. 2007). If seekers can retrieve most of the kinds of information required in one place, they will assess the website as being useful and thus have a greater chance of reusing it in the future. Such results suggest the potential benefits of enhancing information diversity.

The reasons of having the approaching significances with information diversity might be the small number of samples, and the limited diversity from the content of a single information source. However, based on the observations in the study and existing literature, there are some clues that information diversity has its effects on health information seeking. Future research can further investigate on the relationships of the information diversity, engagement, usefulness and revisiting of consumer health websites.

6.2.3   *Serendipity*

Serendipity plays an important role in learning new health knowledge in exploratory search scenarios as suggested by the correlation analysis (C3). We also observed a different impact of serendipitous findings in focused and exploratory search tasks. Informed by the literature, lay-people often do not know the right terminologies for searching (Chapman et al. 2003; Keselman et al. 2008; Luo et al. 2008), or they have little idea about what to look for in exploratory search scenarios (Pearce et al. 2012; Pang, Chang, et al. 2014). In this case, serendipitous results aided in suggesting a direction for the exploration. Not only in search activities, serendipity can also lead to accidental discovery of information when doing browsing (Apted & Choo 1971). These help the seeker to expand the understanding and learn more about the health issues.

To facilitate serendipity, designers can adopt the fuzzy approach to handle search queries, by returning similar but not exact matches to the query (Toms 2000). Although librarians or experts might prepare related links for the content, this approach provides a single static perspective of "relevancy" which may not be the same as the seeker's perception. Other sophisticated recommendation systems can also suggest serendipitous findings based on the behaviours of other visitors.

6.3   Limitations and Future Work

We chose to evaluate our subjects as a single group of health information seekers in this study, and did not collect demographic attributes such as education level, occupations, the skill of Internet searching, etc. In the future, analysis focusing on different user groups may discover additional findings distinct to these groups.

In this study we adopted Better Health Channel as a baseline when measuring the performance. While we argue that this is an adequate tool for carrying out our research, it actually limits the comparison to this particular design, content and user interface. Future work may evaluate the design implications in the context of other health websites or health information sources.

This quantitative study allowed us to observe a number of different phenomena in the health information seeking process, but did not provide an in-depth explanation about them. A qualitative study is a better approach to understand the reasons behind the findings. In this regard, a future qualitative study is planned to investigate the detailed effects of different designs.

7 CONCLUSION

This paper presents a quantitative study of Better Health Explorer, which is a prototype tested for two health information seeking scenarios (focused and exploratory). The results show that the prototype preforms better in different aspects than a currently live health website, including displaying diverse information, providing serendipitous findings, and offering an enjoyable and engaging experience. These findings lead to a fresh way of thinking about designing health websites that better support health information seekers and their heterogeneous seeking behaviours. Future work will focus on in-depth investigations of these improvements and the reasons behind those.

Additionally, some design implications have been drawn from the analysis. We argue that the three factors (i.e. the communication of health information needs, information diversity and serendipity) have various impacts on the outcomes of health information seeking behaviour. Designers should further work on these aspects for designing better health information seeking applications.

8 ACKNOWLEDGEMENTS

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