Query Behavior: The Impact of Health Literacy, Topic Familiarity and Terminology

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Abstract. We conducted a user study to analyze how health literacy, topic familiarity and the terminology used in past queries affect query behavior in health searches. We found that users with inadequate health literacy have less success in web searches and show more difficulties in query formulation. These users and the ones not familiar with the topic use medico-scientific terminology less often than users with more health literacy and topic familiarity. We conclude that search engines should help these groups of users in query formulation and, since technical documents stimulate the use of medico-scientific terminology in query reformulation, mechanisms like query suggestion can have long-term benefits.

Keywords: Web search; query formulation; health literacy; topic familiarity; user study.

1 Introduction

There are mismatches between the terminology used by health consumers and the one used in standard medical vocabularies and health documents [1], and this may be an obstacle to successful health searches. The development of techniques to improve the communication between health professionals and consumers and the proposal of initiatives to help consumers understand health information are receiving a large attention nowadays. The first was recently discussed in a workshop of the 2013's Conference on Human Factors in Computing Systems (CHI) entitled "Patient-Clinician Communication – The Roadmap for Human-Computer Interaction" and the second was discussed in a panel of the Association for Information Science and Technology (ASIST) 2010 annual meeting [2].

Two user characteristics influence the amplitude of this terminology gap. One is the health literacy, that is, "the degree to which individuals have the capacity to obtain, process, and understand basic health information and services needed to make appropriate health decisions" [3]. The other is topic familiarity, i.e., user's general knowledge about the topic of a search task (e.g.: diabetes). Note that these two features are distinct. A health consumer with good health literacy is expected to be unfamiliar with several health topics.

We are convinced that higher levels of health literacy (HL) and topic familiarity (TF) give users the ability to formulate medico-scientific queries in addition to lay queries and therefore a higher probability of finding the necessary information. Moreover, we think the above characteristics influence the query reformulation behavior after an initial iteration where technical documents, i.e., documents containing medico-scientific terminology, are accessed. The characterization of these behaviors may help search engines decide if and how search assistance mechanisms like query suggestion or ranking algorithms can be personalized.

2 Related Work

In the following subsection we describe the main work regarding the influence of topic familiarity on query formulation behavior. The lack of studies considering health information literacy made us describe, in the other subsection, studies that explore users' information literacy on Information Retrieval (IR) behavior.

2.1 The Influence of Topic Familiarity on Query Formulation

Several works explore the influence of topic familiarity in IR. In the health domain, Wildemuth [4] examines the search behavior of medical students that were observed on three different occasions: at the beginning of a course, at the end of the course, and six months after the course. The author concluded that individuals with less domain knowledge were less efficient in selecting concepts to include in search queries and performed worse in search modification. Moreover, although it improved performance in all occasions, system assistance during query formulation was considered more useful on users with less knowledge on the topic.

Two different studies explore the influence of topic familiarity on the use of a thesaurus for query expansion. Sihvonen and Vakkari [5] conducted a study with 15 users having knowledge on the topic and 15 users without this knowledge, concluding that the use of the thesaurus was helpful for the experts but not for the novices. This conclusion contradicts Wildemuth [4] conclusions. In the other study, Shiri [6] analyzed how topics familiarity affected users behavior on thesaurus use and concluded that "searches involving moderately and very familiar topics were associated with browsing around twice as many thesaurus terms as was the case for unfamiliar topic".

2.2 The Influence of Information Literacy on IR Behavior

Birru et al. [7] observed low literacy adults searching for health information. The search terms used to find health information were one of the analyzed items. Authors concluded that, without guidance, users had difficulty "generating original search terms that would yield specific results", which constitutes a barrier to

getting specific and targeted web health information. Note that this study explores users' information literacy and not users' health literacy. As defined by the National Forum on Information Literacy, information literacy is "the ability to know when there is a need for information, to be able to identify, locate, evaluate, and effectively use that information for the issue or problem at hand" [8].

Kodagoda and Wong [9] also focused on information literacy and studies how low literacy users search for information. They compared the retrieval performance of high and low literacy users and concluded that low literacy users take more time to complete the search task, are less accurate, spend more time on each web page, are less informed by webpages, have less focused search strategies, have a greater t4endency to re-visit web pages and more likely get lost than high literacy users. In agreement with Summers and Summers [10], Kodagoda and Wong [9] concluded that low literacy users often prematurely abandon their searches, judging they reached their goal. In domains like health, where inappropriately interpreted information may have impact on the life of the user or someone they care, this can be problematic. The consequences on users' life, the importance of successful health searches for an informed health consumer and the prevalence of health web searches distinguish the health domain from others, where query behavior may have been studied in the light of users' familiarity or literacy.

To learn how to make web health contents more usable and accessible for users with low health literacy, Summers and Summers [10] compared the reading and navigational strategies of users with different health literacy skills. Among several conclusions, they found that users with low literacy often avoid search because it requires proper spelling and typing capabilities and because they have difficulties processing search results pages. Considering users' information literacy, Kodagoda et al. [11] proposed Invisque (INteractive VIsual Search and Query Environment), a system that allows users to create queries and search for information in a visual manner. The system was evaluated using three measures: search outcome (successful, unsuccessful or abandon), time spent and number of pages visited. Authors concluded that low-literacy users benefit from the system in terms of time spent and number of pages visited. However, users with higher literacy have a slightly worse performance with this system.

To the best of our knowledge, there are no works exploring the influence of health information literacy in web searches.

3 User Study

Our study involved 40 medically lay persons (25 females, 15 males) with a mean age of 22.25 years (sd = 6.42). The health literacy (HL) of these users was evaluated through an adaptation of the Short Assessment of Health Literacy for Spanish-speaking Adults [12]. This health literacy test incorporates a comprehension test with 50 multiple-choice questions and it is easy and quick to administer. It has a threshold that allows the differentiation of users with inad-

equate health literacy. We grouped users in three classes: Inadequate (9 users), Elementary (13 users) and Good Health Literacy (18 users), based on the threshold proposed in the test and through hierarchical clustering for the users above the test threshold.

Initially, besides completing the health literacy test, users had to fill a questionnaire where they were asked about demographic information, how they rated their success in general web search and in health web search and their knowledge about the medico-scientific terms related with the information situations.

Users were assigned a sequence of 8 tasks using a a Latin-square like procedure that assured that all users assessed the relevance of all information situations, but only once each and of queries of both types of terminology, the same number of times. To preempt users' fatigue, each task had to be performed in different days, that is, tasks had to be separated by an interval of, at least, 24 hours. Users did not have time limits to perform each task. In each task users had to propose a treatment for a disease/condition associated with an information situation, given a set of documents provided by the researchers. The information situations were defined based on questions submitted to the health category of the Yahoo! Answers service. From the list of open questions of this category and, in a decreasing order of popularity, we selected the questions about treatments to a symptom/disease in which the underlying medico-scientific and lay terminology was different, based on a glossary of technical and popular medical terms [13]. For instance, a disease like *diabetes* would be excluded because it is expressed with the same term in both terminologies. The following information situations were defined:

1. About 3 days ago, I started having a burning feeling every time I urinated. How should I treat this?
2. For the past 5 days my head has been very itchy and I don't have lice. What can I do to stop the itching?
3. I have high uric acid (8.0 mg/dL) with reference units 3.6 - 7.7. How can I lower my uric acid level?
4. I am suffering with an inflammation on my lips and mouth area for more than a year. I have difficulties eating. What can I do to treat it?
5. My father got bit by a dog and is in the hospital with a bone infection. How is this treated?
6. I frequently get heartburn even when I stay away from spicy stuff. What can I do to prevent it?
7. I have been noticing lots of hair coming out from my head. Usually I only comb my hair once a day. What can I do to stop losing my hair?
8. I'm on the computer all day so I type a lot and use the mouse. My right pointing finger is starting to give me some joint pain. How I can treat my finger?

Using a computer, for each task, users had to: (1) provide the elements to calculate topic familiarity, (2) provide the query they would use, in a text-field similar to the ones used in search boxes, (3) assess the relevance of 30 documents

provided by the researchers in an URL format, (4) answer the question included in the information situation and (5) provide two additional queries using text-fields. The documents assessed in the third step were obtained by the researchers using Google as a black-box search engine and either a medico-scientific or a lay query. A medico-scientific query is a query including one or more medico-scientific terms like *pyrosis*. A lay query is a query that only contains lay terms like *heartburn*, the lay synonym for *pyrosis*. Henceforward, tasks in which the user assesses documents retrieved with a lay query will be referred as lay sessions or lay tasks. On the other hand, tasks involving documents retrieved with medico-scientific queries will be referred as technical sessions or technical tasks.

Topic familiarity (TF) was evaluated through the combination of three elements, explicitly provided by the user in each task: familiarity with the topic, previous searches on the topic, knowledge about the medico-scientific term associated with the topic. Pairs "user, topic" are distributed by topic familiarity categories as follows: not familiar (161 pairs), somehow familiar (113 pairs) and familiar (46 pairs). Through this distribution we can also see that the majority of tasks presents a topic unfamiliar to the user. To analyze the relationship between health literacy and topic familiarity, we applied the chi-squared test of independence and found we could not reject the null hypothesis that both variables are independent ($\chi^2(4)=5.66$, $p=0.23$). This helps to sustain the claim that both variables are different.

The two following research questions guided this research.

1. How is health query formulation behavior affected by health literacy and familiarity with the topic?
2. How does the access to lay and medico-scientific content affect query reformulation in general and at different levels of health literacy and topic familiarity?

4 Data Analysis

To address the first research question, we characterize the queries initially formulated by users pertaining the presence of medico-scientific terminology, advanced operators, spelling errors and also the format of the query. We do it in a general way and also by health literacy and topic familiarity. We consider the query has medico-scientific terminology if it contains the disease/condition technical term as defined in the glossary of technical and popular medical terms [13]. For example, for the information situation "About 3 days ago, I started having a burning feeling every time I urinated. How should I treat this?", the query had to include the term *dysuria*. As advanced operators we consider the OR operator, phrase search (""), exclusion of terms (-) and fill the blanks (*). A query is considered to contain spelling errors if it includes at least one misspelled term. This is particularly important in health queries because medical terminology, mostly the scientific one, is hard to spell by users that are not health professionals. If the query begins by question words like 'how', 'what', 'when', 'where', 'who', 'why' or ends with a question mark, it is considered to be in a question format. To

address the second research question we analyze how the access to content with lay and medico-scientific terminology affects the subsequent queries with respect to terminology.

To compare the number of terms employed by users with different health literacy and topic familiarity levels, we have used the ANOVA test. In all the other comparisons, we have used the test of equal proportions between pairs of samples. For example, to compare the inadequate HL group with the elementary HL group regarding the use of medico-scientific terminology, we compare the proportion of queries that include this type of terminology in the first group with the proportion of queries that use it in the second group. Although we present the chi-squared value for the proportion tests, note that, when comparing two samples, the chi-squared test for equality of two proportions is the same as a z-test. In fact, the chi-squared distribution with one degree of freedom is the square of a normal deviate one. Since we are performing multiple comparisons, we applied the Bonferroni correction in these tests, dividing α by 3, the number of tests performed. We use a ** to represent significant results at 0.01 and * for significant results at 0.05. To compute the Confidence Intervals (CI) we use the t-student statistic in the mean number of terms and the chi-squared distribution in the remaining ones.

4.1 Query Formulation Behavior

The mean number of terms in the initial query was 4.1 (95% CI: [3.9, 4.3]) with a standard deviation of 1.8. From the initial queries, 7.2% (95% CI: [4.7%, 10.7%]) included medico-scientific terminology, 26.6% (95% CI: [21.9%, 31.8%]) included advanced operators, 12.5% (95% CI: [9.2%, 16.7%]) were formulated in a question format and solely 1.2% (95% CI: [0.4%, 3.4%]) contained spelling errors. As expected, the proportion of initial queries with medico-scientific terminology is significantly higher in users who already knew the term: 22.1% (95% CI: [14.5%, 32%]). Still, most of these users formulate an initial query without medico-scientific terminology. The proportion of spelling errors is higher in queries formulated with medico-scientific terminology (4.3%) than in queries without it (1%), yet this proportion difference is not statistically significant.

An analysis by health literacy shows no significant differences in the number of terms and spelling errors by health literacy level. Regarding medico-scientific terminology, we found that good HL users use it significantly more than elementary HL users ($\chi^2(1)$=10.6, p=5.7e-04**). We also found that inadequate HL users employ advanced operators less often than elementary HL users ($\chi^2(1)$=8.3, p=2e-03**) and good HL users ($\chi^2(1)$=9.4, p=1e-03**) and design their query in a question format more often than good HL users ($\chi^2(1)$=10.7, p=5e-04**).

Results regarding the use of advances operators make us suspect that health literacy and web search expertise may be related. To verify this, we decided to analyze the relation between users' health literacy and the degree of success they think they have in general web search (Fig. 1) and in health web search. In general web search, evaluated in a 5-value scale where 1 corresponds to the

lowest success rate and 5 to the highest success rate, the median of the web search success is 4 in all levels of health literacy. However, the proportion of answers beneath 4 is higher in the inadequate health literacy level. Through the Chi-Squared test of independence, we found that web search success and health literacy are related ($\chi^2(4)$=54.3, p=4.6e-11**) having a weak positive association with a Spearman correlation of 0.34. In terms of health web search success, assessed in the same scale as web search success, its median is lower (2) in the inadequate HL level than in the other levels (3). Plus, we found that these variables are related ($\chi^2(6)$=32.3, p=1.4e-05**) with a positive, but low, Spearman correlation (0.19).

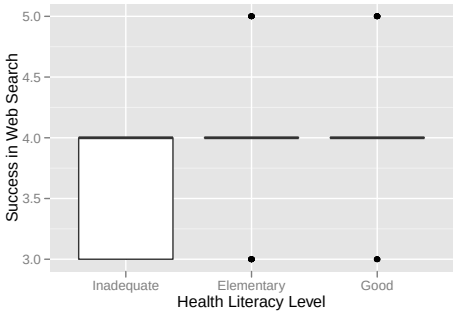

Fig. 1. Success in web search by level of health literacy

In terms of topic familiarity, we found that the number of terms does not significantly differ between levels of familiarity with the topic. We found that users who are not familiar with the topic use medico-scientific terminology less often than somehow familiar users ($\chi^2(1)$=16, p=3.16e-05**) and familiar users ($\chi^2(1)$=7.4, p=3e-03*).

4.2 Query Reformulation Behavior

After assessing documents retrieved with medico-scientific queries, the proportion of subsequent queries using medico-scientific terminology is 19.4%, while in lay sessions this proportion downs to 7.8%, a significant difference ($\chi^2(1)$=17.2, p=1.65 e-05**). After search tasks without medico-scientific terminology the proportion of queries in question format is 13.4%, higher than in tasks with it (12.5%), but not significantly different. Since queries in the format of a question indicate user's difficulties in the search task [14], this may that indicate medico-scientific content helps in query reformulation and is probably richer in alternative terms.

Table 1 shows the proportion of queries with medico-scientific terms in query reformulation. Similarly to the initial queries, users that already know the scientific term, use medico-scientific terminology significantly more than the other

users. In a global perspective, 24.7% of the post-search queries, formulated by users who knew the scientific term before the search session, use medico-scientific terminology. In contrast, in users who did not know the scientific term, only 8.9% of the post-search queries include this type of terminology. This difference is statistically significant, in general, and also after lay and medico-scientific sessions, what shows the importance of knowing the scientific term to the use of this type of terminology in future queries. However, lay sessions discourage the use of medico-scientific terminology even in users who already know the scientific term. In these users the proportions lowers from 34% in medico-scientific sessions to 14.4% in lay sessions.

Table 1. Proportion of reformulated queries with medico-scientific terminology by type of session in users who previously knew/knew not the scientific term.

Type of session	Know	Know not	Know > Know not?
All sessions	24.7%	8.9%	$\chi^2(1)$=27.2, p=9.02e-08**
Technical	34.0%	12.7%	$\chi^2(1)$=18.6, p=8.16e-06**
Lay	14.4%	5.2%	$\chi^2(1)$=6.4, p=0.006**

In reformulations including medico-scientific terminology, we also analyzed the reasons for this change. This type of terminology could have been excluded in the first query because it is part of users passive vocabulary and not of its active vocabulary. On the other hand, the documents assessed in the first iteration might have introduced new terminology to the user. Since, for each user, we are aware of his prior knowledge about the scientific term, we can use this information to distinguish both cases. As can be seen in Table 2, users who previously knew the scientific term used it in 44.3% of the post-search queries. Consequently, this is the proportion of cases where the scientific term was not included in the first query because it is part of users' passive vocabulary. From the 95% confidence interval, it is not possible to conclude that this proportion is significantly different from 50% and, therefore, significantly different from the proportion of cases due to terminology learning.

In Table 2 it is also possible to see that the first post-search queries including scientific terminology were mostly formulated by users who had the scientific term in their passive vocabulary. The opposite happens with the second post-search queries, that is, the majority of the users using medico-scientific terminology in the second query have just learned the term in the search session. Similarly to what happens with the global post-search query analysis, through the confidence intervals, we cannot conclude these proportions are significantly different from 50%.

In terms of health literacy, after medico-scientific tasks, good HL users are more likely to use medico-scientific terminology (22.2%) when compared with elementary HL (16.4%) and inadequate HL (18.1%) users. None of these dif-

Table 2. Proportion of post-search queries with medico-scientific terminology formulated by users that knew the scientific term and did not use this terminology in the pre-search query.

Post-search query	Scientific term known	95% CI
First	57.9%	[34%, 79%]
Second	39.2%	[26%, 54%]
Either first or second	44.3%	[33%, 57%]

ferences is significant. We also found that, in all levels of health literacy, the majority of the users (proportions between 62.5% and 69.4%) formulated one of the subsequent queries with medico-scientific terminology. Moreover, although in a very low proportion, only users with elementary (1.9%) and good health literacy (1.4%) formulated both queries with medico-scientific terminology.

An analysis by topic familiarity shows that the use of medico-scientific terminology after medico-scientific tasks increases with the topic familiarity (9.5% for not familiar, 26.8% for somehow familiar and 34% for familiar users). In terms of significant differences, we found that users who are not familiar with the topic are less prone to use medico-scientific terminology after medico-scientific sessions than somehow familiar ($\chi^2(1)$=12.9, p=1.6e-04**) and familiar ($\chi^2(1)$=15.7, p= 3.7e-05**) users.

Analyzing the number of subsequent queries with medico-scientific terminology, we found that the proportion of users with 2 medico-scientific queries increases with topic familiarity (from 0.6% to 0.9% to 4.4%) and the opposite happens with the proportion of users with 0 medico-scientific queries (from 40.4% to 23.9% to 21.7%). The majority of users in each level of topic familiarity wrote 1 medico-scientific query but, in users not familiar with the topic, this proportion is much lower than the proportions in the other groups of users.

5 Discussion

We verified that health consumers rarely use medico-scientific terminology and that, as expected, users who know the scientific term use it more often. However, even these users include it in only 1 out of 4 health queries. Moreover, we found that users with good health literacy use it more often than elementary health-literate users. In terms of topic familiarity, users who are not familiar with the topic use medico-scientific terminology less often than other users. This is in accordance with previous studies [4, 7] that conclude that users with less knowledge on the topic and less literacy have less ability to include specific terms in queries.

If queries in question format indicate difficulties [14], the formulation of health queries is harder for inadequate health-literate users than for good health-literate users. Furthermore, the former class of users employs advanced operators

less often than other users, which indicates they may have less search experience and less ability to fully exploit the potential of search engines. The weak positive association found between web search success and health literacy agrees with the above findings. Moreover, this is in accordance with Summers and Summers [10], who found that low health literacy users avoid searches because they have difficulties formulating queries and processing results' pages. Since users with inadequate health literacy are ill prepared for conducting health web searches, search engines should focus their attention on this group of users, providing special help mechanisms in health query formulation.

Concerning query reformulation, we found that access to documents containing medico-scientific terminology encourages the use of this type of terminology in subsequent queries. In fact, after medico-scientific sessions the proportion of subsequent queries using scientific terminology is significantly higher than after lay sessions. This happens in users who didn't know the scientific term and in users who knew it. The former learn the scientific term through the documents assessed in the search session and the latter use it from their passive vocabulary.

We found that about half of the queries reformulated to include medico-scientific terminology were a result of terminology learning. The other half had to do with forcing the use of passive vocabulary where the scientific term was included. Through the analysis that distinguishes the first and the second post-search queries, we found that users who have learned the scientific term in the search session tend to use it more in the second query than in the first. This shows that these users have reluctance to use it and only do it as a further alternative.

After the medico-scientific sessions, users who are not familiar with the topic are less prone to use medico-scientific terminology than more familiar users. For this reason and because they use medico-scientific terminology less often in the initial query, these users' health query formulation should also be given special attention by search engines.

If search engines understand the differences between low and high health literacy users and between users familiar and not familiar with a topic, they can develop strategies to better support each type of user find the information they need. Strategies include new interfaces or new features that leverage users' understanding of the information retrieved (e.g.: providing definitions of medical terms). The Invisque system [11] is an example of a visual interface developed to help low literacy users overcome search difficulties. In addition, systems can also adjust the ranking of the documents or develop query suggestion mechanisms in which the terminology of the suggested query is adjusted to users' knowledge. Queries can be a simple translation of the initial user query or can introduce new related terms. Both low and high health literacy/topic familiarity users can benefit from such a system. The former type of users probably benefit from translations from medico-scientific to lay terminology which can, for example, happen when users don't understand the terminology used by clinicians or the one included in medical reports and want to inform themselves. Moreover, they can benefit from lay queries using synonyms or related terms. On

the other hand, users with more knowledge can also benefit from translations to medico-scientific terminology. Considering the query reformulation findings, the benefits of a query suggestion system might be twofold. It not only provides access to documents that wouldn't be reached without the given suggestions but also stimulates the use of different terms in subsequent queries. Nonetheless, to guarantee that users understand the retrieved documents, it is important to adapt the query suggestions to users' health literacy and topic familiarity.

6 Conclusion

In this work we analyze how the type of terminology used in past queries affect query formulation and reformulation in users with different levels of health literacy and familiarity with the topic. If not the first, this is one of the first works dealing with health literacy in the information retrieval domain. Although some of the results are predictable, we consider important to have their empirical demonstration.

We found that, although consumers rarely use medico-scientific terminology in their queries, the ones with higher health literacy or topic familiarity do it more often. Users with low health literacy or topic familiarity were found to have more difficulties in query formulation, not only selecting and typing the appropriate medical terms but also on general aspects like the inclusion of advanced operators. The contact with documents using medico-scientific terminology encourages the use of this type of terminology in future queries. Although this is statistically significant in every user, users who did not know the medico-scientific term from the beginning seem more reluctant to use this type of terminology.

Analyzing behaviors of users with different characteristics can help search engines to define how they can provide a better experience for each type of user. This can be done in query formulation, in ranking or at the interface level. As expressed above, we believe a personalized query suggestion system that translates queries between the medico-scientific and the lay terminology can be beneficial to consumer health information retrieval.

As future work we intend to analyze which type of terminology should be used in query suggestions for users with different levels of health literacy and topic familiarity.

Acknowledgments Thanks to Fundação para a Ciência e a Tecnologia for partially funding this work under the grant SFRH/BD/40982/2007. Thanks to Dagmara Paiva, M.D., and to Michael Luís, M.D., for their contribution on the evaluation of the medical accuracy of users' answers.

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