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Executive Summary

The rapid worldwide proliferation of mobile technologies and medical mobile applications (or apps) is having an immense impact on medicine. Enhanced mobility and access to information has the potential to improve the way that physicians perform health care and communicate with patients. This deliverable presents a review of the mobile requirements of health searchers and health-care professionals and describes two mobile applications, that were build using the resources, services and infrastructure developed within the Khresmoi project.

The use of mobile devices among the European public when searching for medical topics is discussed and a set of requirements is identified on which a mobile application for Khresmoi for Everyone should be based. The most important requirements identified are query completion and result previews. The prototype for the mobile version of Khresmoi for Everyone is based on the existing web application and has been developed using HTML, JavaScript and CSS. It supports spelling correction, autosuggestions, definitions of search terms and searching for images.

Research on mobile use of European physicians and their response to existing medical search applications is used to identify requirements for a mobile search applications for health professionals. The need for offline access and the importance of local resources and multilingualism is highlighted. Interface requirements emphasize the need for clear referencing of resources, categorisation by medical speciality and an intuitive, multilingual interface that allows users to organise saved information. Furthermore, an integration of social media and communication platforms is suggested to encourage open sourcing of knowledge and content evaluation among health professionals.

The prototype for health professionals is based on the existing infrastructure for Khresmoi Professional and uses a Java backend. The multilingual client has been developed as a native Android app with support for autosuggestions, query translation, a personal collection of results and sharing results with colleagues.

The conclusions show how the prototypes already support many of the important requirements and thus represent successful first tailored versions of the mobile Khresmoi search applications.

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Abbreviations

AJAX	Asynchronous JavaScript And XML
CME	Continued Medical Education
CPU	Central Processing Unit
CSS	Cascading Style Sheets
CUNI	Charles University in Prague
EPG	EPG Health Media (publisher)
EU	European Union
ezDL	easy access to Digital Libraries
GPS	Global Positioning System
HON	Health On the Net
HTML	HyperText Markup Language
HTTP	HyperText Transfer Protocol
JAX-RS	Java API for RESTful Web Services
JSON	JavaScript Object Notation
JS	JavaScript
JVM	Java Virtual Machine
MeSH	Medical Subject Headings
OS	Operating System
PC	Personal Computer
PDF	Portable Document Format
REST	REpresentational State Transfer
SDK	Software Development Kit
STD	Sexually Transmitted Disease
SUS	System Usability Scale
SVN	Subversion
UDE	University of Duisburg-Essen
UI	User Interface
URL	Uniform Resource Locator

1 Introduction

Internet usage within the general population has continued to rise over the last years. 63% of the European population currently use the Internet [9]. Part of this rise could be attributed to the rapid worldwide proliferation of mobile technologies. The fact that mobile devices such as smartphones or tablets are affordable, portable, and easy to use is likely to be responsible for their booming popularity.

According to the “Mobile Health 2012” survey on the use of cellphones for healthcare among the general population “half of smartphone owners use their devices to get health information and one-fifth of smartphone owners have health apps” [15]. Usage of mobile devices among medical professionals for professional purposes has dramatically increased over the past years. Smartphones and tablets are frequently used at point-of-care, during patient consultations, travelling and meetings [19, 13, 12]. Their uses include looking up information, browsing articles, watching videos and educating patients [38]. Mobile devices encourage physicians to access medical information online [19, 10]. Physicians using mobile devices primarily, seek practice recommendations (treatment, diagnosis), drug information, medical education, journal publications/abstracts, news, social media, medical reference tools, medical calculators and forums [38, 13]. However, information accessibility is dependent on mobile usability of key medical resources.

The extensive benefits of mobile devices have created an ever-growing demand for mobile medical apps. As the number of offered apps and resources grows, it becomes increasingly impossible to identify *trustworthy* apps [37]. Many prefer to access websites they know rather than spend time searching the internet [12]. Colleagues remain an important help for physicians in choosing what information and medical applications are trustworthy [13]. Social media, communication, open-sourcing of knowledge among health professionals is growing [10, 13, 12, 11]. Categorization by medical speciality has been successful in enabling easier access to relevant information for different subgroups of physicians [28]. However, “cost” is the most important determinant in whether people will download medical apps.

In section 2 we take a look at general requirements for mobile (health) search, with a focus on the needs of the general public. The aim of section 3 is to give insights on the physician requirements for a mobile search system that displays accessible, relevant and trustworthy information. Research on how physicians use their mobile devices and respond to current medical search applications will be discussed in relation to the creation of a user-tailored mobile version of Khresmoi Professional. In sections 4 and 5 the two mobile search applications for the general public and for physicians are described, and the last section shows how the developed systems compare to the requirements gathered from the literature.

2 Mobile Requirements for the General Public

The goal of the EU project Khresmoi is to develop a search tool to access health-related and biomedical information for physicians and also the general public. The result of three years of work aiming at a search tool for the general public is a web prototype, “Khresmoi for Everyone.” At the moment, efforts have been directed into the development of a mobile version of the already developed web/desktop prototypes. Hence, the objective of this section is to understand the peculiarities of mobile health search compared with desktop search, and to emphasize the most important features of the prototypes to be included in their mobile versions.

2.1 Mobile use in Europe

Use of mobile devices has been growing in Europe in recent years. In 2012, according to [17] in 16 selected European countries¹ from 22% (Belgium) to 54% of each country’s total population had a smartphone. The most widely used operating systems were Android and iOS. In most countries iOS still has the highest prevalence (52% of all smartphones in Switzerland, 48% in Sweden and 46% in Denmark). Nevertheless, there are countries where Android is more popular, as for example the Netherlands (33% of all smartphone owners) or Norway (39%). Compared with 2011, in a few countries the penetration of iOS has increased

¹Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Ireland, Italy, Netherlands, Norway, Poland, Spain, Sweden, Switzerland, the UK

(Austria from 27 to 41% of all smartphone owners) while in others it remained the same (52% in Switzerland) or decreased (Italy from 26% to 17%, Spain from 24% to 14%, the UK from 37% to 30%). As for Android platform, for the countries where data was available there was always an increase in use, i.e. from France where the penetration increase was only 1% from 24 to 25% of all smartphones to Germany and the UK where the increase was from 15% to 29% and Spain from 17% to 34% of all smartphones.

According to [17], the main reasons for using the Internet on smartphones are getting information when away from PCs and passing time while waiting. Another quite popular reason is that smartphones can provide immediately relevant information and answer questions quickly. A majority of smartphone owners uses the devices at home and the vast majority of them uses a search engine on a smartphone on a daily basis. They also tend to look for local information weekly or monthly.

2.2 Mobile search

Mobile search has been a subject of numerous studies on the past years, however the research is still very limited and the technology and its adoption is relatively recent. Most of the studies focused on the differences between the web search and mobile search and its implications.

First of all, in a mobile context, new types of searches appear, as described by some researchers. In addition to well-known types of web search (informational, navigational and transactional [44]), some authors also identify leisure search (Westlund [45]), geographical (Church/Smyth [6]) and personal information management search (Church/Smyth [6]), which are typical for mobile device users.

Westlund also distinguishes novice and advanced users in respect to mobile search [45]. He notes that novice users would use mobile search on the go, in circumstances when there is absolutely no access to web search and they have a pressing need. Novice users would use portals. Advanced users tend to use mobile search in various circumstances while having alternatives such as a desktop computer at home or at work. They tend to prefer bookmarklets, search engines and mobile apps.

Information needs are most commonly identified via log analysis. European mobile search logs showed a major popularity of adult content, while in Japan health queries are one of the top searches. However, the prevalence of “adult” queries has decreased with time. The popularity of “adult” queries is explained by the fact that mobile devices are perceived as more personal and personalized, since it is uncommon to use other people’s mobiles, and users prefer to do more “sensitive” searches privately.

According to Westlund [45], the added value of mobile devices is that they are personalized and offer context-based services. It is commonly assumed that to make mobile searches successful, the features mobile devices offer should be exploited, and hence users can benefit from more personalized information and location information. However, it also poses significant challenges for security of data and privacy. According to Westlund [45] again, some users may voice privacy concerns, however they do not really pay attention to how their data can be used and manipulated while using the devices. This might gradually change in the future as users are becoming more educated and empowered.

In 2008, Church published a large scale study of European mobile search behaviour [7]. The main findings were that regional differences do exist (although not explored in this research). An average mobile search session contains 8.6 queries, while average query is 2.2 terms and 13.4 characters length. In 60% of cases mobile users type a single unique query. For the remaining 40%, it is two or more unique queries: 73% of them identical (checking the second, third page of results); 12% are initial and 14% are modified. Most of the users modify queries by swapping a word, and less frequently adding or removing a word (hence, narrowing or expanding a query accordingly). As for the queries themselves, most of the queries are transactional, only 10.2% are informational, and 29.4% are navigational. On average, mobile users select the 6th result, while more than 60% of selected results are among the top three positions.

2.3 Mobile search for health and medical topics

According to Pew [15], in 2012 85% of the US population owned a cell phone, while a third of cell phone owners (31%) have used their phone to look for health information. Two years before, only 17% of cell phone owners looked for such content on their phones. Most of such users own a smartphone and 19% of them have at least one health application on their smartphone. Unfortunately there is no such data available for European countries.

Mobile health applications are booming at the moment. In the United States, the most popular ones are dedicated to exercise, diet and weight loss. Little is known about applications focused on a search for health information.

Based on the classification mentioned above, health-related mobile search can be of the following nature:

1. information search (find drug or disease description, medical news, etc.),
2. transactional (find a phone number to call a hospital or pharmacy, etc.)
3. navigational (e.g. WebMd ² in the USA or Doctissimo ³ in France).

The capacity to perform such searches depends on the quality and quantity of the resources indexed.

Overall, at the moment health search in general does not seem yet to be popular among mobile users. Few studies mention health topics among users' interests. Some surveys show that people would still prefer going to the non-mobile web to research about health conditions. This can be explained by screen size limitations and the awkwardness of using multiple open tabs in a mobile browser. Another possible explanation could be that such users do not yet feel at ease with a "full-time" research about health matters with their mobile devices, due to the fact that they are still novice users and perceive their mobile device to be used "on the go," while health information research should be done thoughtfully. However, mobile devices can be very useful and convenient to search for definitional or factual information, or to perform a navigational search as mentioned before.

Based on Westlund's classification of users, we can assume that users searching for health information on their mobile devices will likely be advanced users. Novice users would rather look for health information on desktop computers, unless there is a particular urgency and no access to a stationary device. Fix and Duggan [15] confirm this by showing that most of the users searching for health information on their mobiles own a smartphone and at least some have downloaded a health application.

The analysis of mobile search logs in a health domain also confirms the observation that users tend to use their mobiles to look for more personal and sensitive information compared to the desktop. For example, the top health mobile queries refer to STDs and mental health. The interest in such topics can be also explained by overall younger users compared to web search users. Healthline has provided the top 10 health related searches done via mobile devices during 2011 [20]:

1. Chlamydia
2. Bipolar disorder
3. Depression
4. Smoking/quit smoking
5. Herpes
6. Gout
7. Scabies
8. Multiple Sclerosis
9. Pregnancy
10. Vitamin A

2.4 Khresmoi for Everyone mobile app requirements

As our starting point for application development is a web prototype, it is important to identify the main features of Khresmoi for Everyone which are likely to be used by the mobile users. In deliverable 8.3 ([22], section 3.4) a table with user requirements satisfaction demonstrates which requirements have been satisfied as of August 2012. In the newer version of the deliverable (8.5.1) this table is updated. Those requirements most crucial for the mobile version of Khresmoi for Everyone have been identified and ranked by importance.

- Query completion/support: it appears to be of much importance to provide query completion and autosuggestions on a mobile app due to screen size limitations and small letter size of the keyboard.

²<http://www.webmd.com>

³<http://www.doctissimo.fr>

- Results preview: it is also an important feature, especially taking into account that once a search result is clicked on, a web site opens in a mobile browser, which slows down the search process
- Image search: it is an important feature for information lookup and should be kept in a mobile app.
- Collaborative tools: these tools are not available for the web prototype, aside from standard URL-based sharing functionality. However, it seems to be quite important to be able to share search results with peers for both web and mobile versions.
- Resources: the mobile app makes use of the same list of resources as the web prototype, hence we can consider that no additional work is required specifically for a mobile app.
- Classification/filtering: this feature seems to be important for the mobile users as it helps to quickly filter out information and find a result.
- Ranking: the mobile app makes use of the same ranking approach as the web prototype.
- Interface layout: a simple interface in the user's mother tongue is a must, especially taking into account the size limitations of mobile devices' screens.
- Link description: the same as of the web prototype, i.e. document title, snippet and URL.
- Translation tools: currently it is unlikely that mobile users will take the time to look up automatically translated health information due to the general tendency that users tend to research using their desktop PCs, and it is more likely they will check definitional or concise information about disease or drug in their mother tongue, than accessing more complex information which has been automatically translated. This is possible to change in the coming years.
- Suggested links: it is a useful feature when users do not know exactly what they are looking for and want to expand their knowledge about the domain. It has not been implemented for the web prototype, and does not seem to be crucial for the mobile app, at least at the moment, due to the fact that mobile users tend to look up definitional, easy and quick-to-access health information, and save thoughtful research for their desktop computers.

There is another important feature which is of less importance for the web prototype, but appears to be important for mobile users: location tracking. Indeed, it is very advantageous to use GPS information about the mobile user's location, however it poses multiple risks to data privacy and security, which for security conscious users may run counter to providing a trustworthy source for health content.

To sum up, the following requirements should be specifically addressed in the mobile app on the top of a good resources base and ranking mechanism:

- Filters and classification of results
- Query completion and suggestions
- Collaborative tools
- Image search
- Results preview

3 Mobile Requirements for Health Professionals

Usage of mobile devices is prevalent amongst health professionals [19, 38, 10, 12, 13, 37]. Four out of five European physicians have been estimated to currently access the Internet using a smartphone and 47% using a tablet [10, 13]. 26% of European physicians spend over 2 hours/day using their smartphone [13]. Apple's iOS and Google Android have remained the dominating operating systems for all mobile devices used by physicians [10].

3.1 Professional use of mobile devices

The majority of medical health professionals agree that their mobile device helps them to practice more efficiently and helps them in both diagnosis and prescription [19]. In a survey, carried out in 2011 as part of deliverable 8.1.2 [19], 84% of those owning mobile devices used them to access medical information or to do medical updating. Figures on mobile usage for professional purposes are similar in recent surveys [10, 12, 13]. Most physicians using mobile devices regard it as important for a search system to be accessible from a mobile platform [19]. 86% of those who use mobile devices download apps to access medical information [13]. 65% of European physicians have downloaded at least three work related apps [13]. Recent findings suggest that 14% frequently access their smartphone and 9% their tablet during patient consultations [13].

Both Apple's App Store and the Google Play Store for Android have a "Medical" section, devoted to apps for the general public as well as physicians and health care professionals. With over 800,000 apps, Android is currently ahead of Apple regarding the number of apps for download [30, 33]. However, mobile iOS devices have been cited as more common among health care professionals [38, 13, 33, 24]. Named reasons have been an initial lack of controls in the Android system as well as the uniformity, simplicity, readability and emphasis of an intuitive user experience of Apple products [33, 25, 24]. Nevertheless, the usage of Android devices has experienced the more dramatic increase over the last two years. A recent study by EPG showed that within two years, the usage of Android devices among European physicians increased from 2% (2010) to 29% (in 2012) [13].

3.2 Barriers to searching on mobile devices

Lack of time, perceived information inaccessibility and lack of trustworthiness, have remained dominant barriers to successful online medical information retrieval [19, 34]. Physicians therefore often devote a substantial amount of time *finding* as opposed to viewing online information and are forced to use the accessible rather than the best answer [38]. With regard to mobile devices, one out of five physicians (19%) report that lack of time prevents them from accessing medical apps. At least 1 out of 10 physicians reported that lack of accessibility of drug information, images, videos and accredited CME prevented them from their using mobile devices more frequently [13].

3.3 Towards an ideal search application

The general requirements of physicians have been described in detail in deliverable 8.1.2 [19].

However, it is crucial to adapt the mobile version of Khresmoi to the usability demands of physicians using mobile devices. Usability has been described as being "the ease with which people can employ a tool or other human-made object in order to achieve a particular goal" [40]. The usefulness of a mobile search system is indicated by its applicability in medical practice.

Research on the requirements of what physicians consider as relevant, trustworthy and as an adequate user interface will be discussed and solutions of their successful implementation will be proposed. Most of the available data on mobile usage is provided by large-scale industry reports carried out by medical websites and institutions such as ManhattanResearch [38], Elsevier [10] and EPG Health Media [12, 11, 13]. In addition, physician reviews written by imedicalapps [30, 31, 29, 24, 27, 26, 23, 32, 28, 33, 25], encompassing advantages and shortcomings of current mobile search applications provide valuable user feedback.

3.4 Medical applications: Current solutions and problems

Perceived benefits and professional usage of mobile devices has decreased in Europe over the last two years [13]. Information overload and lack of relevant, credible search apps are likely reasons [12].

It has become increasingly difficult for physicians to identify credible apps [37]. Usually more apps are downloaded than actually used [13]. A significant proportion of the available medical apps are targeted towards non-professionals [24]. There remains a shortage of apps based on a scientific foundation or that have been developed under the supervision of clinicians [24, 42, 21]. For example a study on drug safety, evaluating the accuracy and reliability of opioid conversion apps, found that less than half of the analyzed

apps reference their methods from journals, guidelines or textbooks [42]. As a consequence, credibility and accuracy of some medical apps has been questioned due to lack of scientific backup of presented information [24, 42, 21].

Physicians have a large variety of information needs, when searching for online information [19]. Current medical apps typically address one or two information needs (e.g., Epocrates – access to drug database, Laborwerte pro – explaining lab parameters) or are focused on one type of resource (e.g., PubMed) [36]. Good medical search apps are a rarity, often associated with payment like UpToDate or a lack of local relevance such as Medscape [23, 28]. As a consequence, most physicians in Europe using smartphones search for information via a mobile browser [13]. In the compared US sample most physicians used medical apps to find diagnosis and treatment information [13]. Lack of locally relevant apps in Europe appears to force physicians to consult search engines via the web browser.

3.5 Information requirements: Towards relevant content

One of the first aspects that physicians use to decide whether a search application is useful is whether the presented content is relevant to the query. Most physicians use mobile devices for browsing the Internet to understand a condition or get help in diagnosis, and they expect to find information on drugs, diagnosis, treatment and prescription [13]. The majority of physicians seek journal publications, drug databases, practice recommendations, medical news and medical education [19, 38, 10, 12, 11, 13]. CME is especially important, as 95% of European physicians regularly pursue CME activities and 19% of CME activities are pursued online [11]. Drug information is important, but often lacks necessary perceived credibility to influence prescribing behavior [11, 13].

In line with the mentioned information needs, the most popular apps across the Apple and Android stores are medical reference tools, drug information repositories and anatomical maps. UpToDate has been praised for its medical News (“What’s New”) section providing concise articles summarizing recent medical updates on practice recommendations [28]. In the Khresmoi survey medical calculators were attributed a moderate importance [19]. However, as a tool on a mobile device, medical calculators have proved popular [28].

3.5.1 The digital colleague: The role of social media and communication

The importance of social media as a repository for professionals to share ideas and thoughts is growing [12, 11]. Recent research emphasized that the majority of physicians access social media for professional purposes, are members of at least one online community/network and spend substantial amount of time using online networking sites for professional purposes; primarily to communicate with other physicians [11]. In particular self-employed general practitioners like to communicate with colleagues via physician networks [19, 36]. In addition it has been found that physicians like to have the option of physician quality ratings [19, 36] and access medical websites that have the facility for comments or discussion [11]. Colleague opinions/ratings (who else uses/recommends it) play a central role in the extent to which a physician views a medical application as credible [13]. Thus, the integration of social media, physician quality ratings, discussion, comments and a physician network platform is an important requirement.

3.5.2 The role of local resources

A substantial proportion of European physicians prefer to access websites intended for physicians in their own country and in Europe [11]. A recent study by EPG found that 55% of European physicians prefer to access local websites, 50% European websites and 48% mostly used websites created for physicians in their own country [11]. The extent to which local resources are preferred is likely to differ, like the resource requirements, among different subgroups of physicians [36]. For example, general practitioners, who have been found to express less interest in journal papers, and lower competence of English comprehension are more likely to be drawn to local resources than a research physician seeking to pursue scientific updating [36]. Guidelines, treatment procedures and drug names vary across different countries. For example a drug suggested on an American website may fail to have relevance to a physician practicing in Europe.

3.6 Towards trustworthy content: Resource requirements

The trustworthiness of displayed resources is one of the key aspects that determine the usability of a search engine [19]. In particular for information such as drug data and treatment guidelines, many physicians find it difficult to evaluate the credibility of medical apps [13, 37]. Overall, physicians are most likely to trust mobile apps that have been funded by Medical Associations, University/College bodies, public health organization, government organizations and Medical Publishers [13]. Low levels of credibility are assigned to apps funded by advertising, mobile manufacturers and those that required payment to download [13]. However, when determining app credibility, physicians often rely on colleague opinions/ratings which they search for via search engines rather than sticking to providers they view as credible [13]. The quality of displayed information is usually determined on the basis of its source and physicians prefer to be directed to websites they know and trust [19, 12, 11, 13].

Information that displays references is preferred [32, 28]. Part of the success of medical applications like UpToDate has been attributed to referencing of all of its supplied information [28].

3.7 User-friendly experience: Insight on format and interface requirements

A user tailored interface should enable content to be found with ease. Physicians frequently use their mobile devices in time-constrained context making speed of use paramount [12]. For physicians with more browsing time, as often is the case with tablet users, additional tools, multimedia, forums and CME should be accessible [10]. However, in most cases, physicians using mobile devices do not want to be overwhelmed by too many choices and distractions when trying to access a feature. Simplicity of functionality and organization of content are crucial [10].

3.7.1 Format

- (a) **The role of multilingualism:** Content comprehension is one of the most crucial features determining its usefulness. With regard to language it has been found that despite an overall good English competence of European physicians, the majority of European physicians prefer to use websites in their own language [11, 19, 36]. Recent research showed that as much as 62% of the European physicians use their mother tongue when using a search engine, and 15% are not happy to use English websites [11].
- (b) **Multimedia enhancement:** The importance of multimedia (images, videos) treatment of diseases or conditions and clinical procedures in medical search applications is well documented [29, 11]. In particular tablet users like to access content in different media formats [12]. In a recent study by EPG, 30% of the questioned physicians reported the lack of availability of medical videos [11]. In UpToDate one of the most praised attributes is that all articles are supplemented by graphics and tables [28]. The absence of PDF viewing has been criticized in past reviews, their inclusion being viewed as essential since most guidelines are in PDF format [26].
- (c) **Device specific format:** With regard to the format of displayed content, reviews of current solutions have emphasized that the tablet version should be more than a mere expansion of the smartphone version [29]. The content displayed should adapt to screen size. A criticism of the PubMed mobile version was that text was lost when flipping the mobile device from landscape to portrait [23]. Smartphones are primarily used for accessing social media, drug, diagnosis and treatment information, e-mail, abstracts and short texts [10, 13]. Tablets are, on the other hand, often used for watching videos, educating patients and comprehensive research and as reference tools at point of care [10, 38]. Physicians have been found to often use their tablets to access medical websites containing rich content, such as journal articles, entire journals, magazines and book chapters [10]. In addition, they expect to view advanced multimedia enhancement and be able to pursue medical education on their tablet [10, 13]. Overall, the preferred resources on tablets are apps or websites that provide access to journals, magazines, multimedia, medical websites or medical online portals, and which allow patient education [10, 13, 38]. Smartphones should offer mobile websites or apps that primarily provide access to shorter texts or abstracts and focus on a simple overview [10, 13]. Tablet platforms should encompass a more comprehensive search function [31].

3.7.2 Interface: Display and number of clicks

Physicians using mobile devices prefer a simple, intuitive interface that ideally requires no training. The click-through rate has been found to be high among physicians using mobile devices, especially on smartphones [10]. However, reviews of existing apps indicate that physicians favor interfaces where the needed number of clicks is kept to a minimum [23]. In a recent review on Medscape the click-through issue was criticized and it was suggested that ideally the entire exploration of a disease or drug description or an article should be visible on one screen rather than having to click through several pages [27].

Another successful solution which caters to time-constrained users while maintaining an overview has been to include a “summary” option or present sophisticated articles as a collapsed menu [28]. As a consequence navigation is made easier and less overwhelming. However, in cases where only the abstract is presented, embedded web links to the full text article (for users with extra browsing time) have been regarded as essential [26].

3.7.3 Navigation: Guidance, categorization and ranking

Subgroups of physicians have different types of information and resource requirements [36]. As a result, physicians like help in data selection while retaining the freedom to organize content according to their needs [19]. The inclusion of features where users have the freedom to rank and sort content have been popular among users of mobile devices [26]. On the other hand, solutions guiding the user by interlinking related topics and including a recommended articles feature have been praised. [28]. In addition, the majority of physicians prefer to access information that is pre-categorized by their medical specialty [11]. The absence of this feature is one of the main criticisms against the app “Feedly” [29]. Existing solutions that are carefully categorized based on clinical settings have been well accepted [28]. Of moderate importance was a categorization based on treatment, condition and type of source [11]. Furthermore, medical apps that included main content categorization such as medical news, CME, medical education, medical calculators, patient education, practice guidelines and medical references were popular [23, 28].

3.7.4 Accessibility of content: Cost, registration and offline support

Inaccessibility of information is a frequently cited barrier to online search behavior among physicians [19, 36]. Prevention of access to a mobile application can take place on three levels: requirement of payment, requirement of registration, and dependence on permanent online access.

In the Khresmoi survey it was found that the majority of physicians prefer to access free, advertisement-funded content [19]. Physicians want credible apps but are not willing to pay for it [13]. Cited as more important than source or quality, recent research showed that 64% of European physicians report that cost is important in helping them to decide whether to download a medical app [13]. For 1 out of 10 physicians payment prevents them from downloading medical apps [13]. The popularity of costly medical applications such as UpToDate is usually restricted to settings where the employer is carrying the charges [36]. However, the majority of physicians prefer free or advertisement driven solutions [19]. Thus usage of apps requiring payment is likely to be restricted to a small group of physicians which have purchasing employers [36].

Another barrier and criticism of some existing medical applications (e.g., Epocrates, Medscape) is the need for registration. Some physicians who would like to perform an anonymous search or test the application are likely to be discouraged from the use [27]. Registration could be encouraged with associated benefits such as user-tailored search and the library.

Medical applications that cannot be accessed while offline make up the third accessibility barrier.

Offline access of content and ability to save searches is often demanded by physicians [12]. Recent research by EPG indicated that two thirds of the questioned European respondents using mobile devices would like offline access to saved information [12]. Several existing mobile apps have been praised for the inclusion or criticized for the absence of an offline mode [31, 29, 32, 33]. UpToDate has impressed with its mobile addition of a bookmarking and history tracking option [28]. A logged search history with the search results accessible offline and full offline access to saved full-text articles is a crucial feature.

3.8 User requirements

The research discussed in the previous section suggests that European physicians have distinct information, resource and user-interface requirements. A multilingual interface that supports different types of resources, addresses a large variety of information needs, is simple while maintaining overview is required. The prioritization and identification of locally relevant content helps in content evaluation through a clear indication of source or authorship, and access to colleague support (ratings, forums and social media tools such as twitter) seems crucial. At the moment, an all-in-one medical search app with localized content for the European region has remained absent. Existing solutions are either inaccessible (e.g. UpToDate), restricted in type of content offered, restricted in resources or targeted at the U.S population. (e.g. Medscape). Furthermore, while there is an overall app overload, medical apps considered as credible are rare.

Khresmoi should ideally consolidate different resources, provide multilingual access, address all information needs whilst maintaining local relevance to provide physicians with an one-in-all app on the latest clinical discoveries.

Based on the findings of the studies discussed in the previous paragraphs, the following solutions and requirements for an ideal medical search app are proposed:

3.8.1 Resources and format

- **Resources:** The search app and mobile browser should be able to display and be interlinked with known key resources such as PubMed (scientific), medical association websites (guidelines) and Wikipedia (overview) [4]. Emphasis on scientific foundation, referencing is essential.
- **Multimedia support:** Videos, images, tables and PDF files should be searchable and viewable. Articles with supplementing graphics, tables and videos should be accessible.
- **Device-specific format:** On smartphones, focus should be on displaying abstracts/references and short texts. Provision of links to full-text article on mobile web browser is essential. On tablets, advanced, comprehensive search should be possible. Multimedia usage and research should be facilitated.

3.8.2 Interface

- **Multilingualism:** The interface can be set in English as standard but should be changeable to mother tongue. Query recognition, spelling correction, translation tools should be integrated on a multilingual level.
- **Categorization:** Cater for physicians preferring specialty websites: A pre-categorization or manual filtering by specialty should be possible as an advanced search option. The option for logged in users to automatically access specialty websites may be useful.
- **Display of content:** Maintenance of content when flipping from landscape to portrait mode is essential, the Entire exploration of articles should be possible on one screen, rather than requiring clicking through several screens. Lengthy texts can be presented in the form of a collapsed menu. A summary button for time-constrained users has proven popular.
- **Links:** Authorship and credibility should be clear, conflicts of interest should be disclosed before the user opens the website. Source of displayed information and references should be visible
- **Navigation and integration of social media:** Interlinking of related topics, a recommended articles feature may help users navigate. The integration of social media tools to perceive colleague evaluation of content. Ratings, twitter, forums, secured communication/case and topic discussion among physicians should be integrated.
- **Organization of content:** Physicians should be able to organize (sort, rank) articles within the application and print articles. This could be enabled through the implementation of the existing tag function in the personal library. Utilization of cloud services/sufficient storage capacity of content, multiple ways to sort searched and saved content could be beneficial.

3.8.3 Filter

- **Filter by credibility of resources:** The option of filtering information based on credibility and source (filtering by type of source) can further improve perceived trustworthiness of displayed resources. Option to filter resources by credibility (peer reviewed, HON certified) or physician ratings should be present if content is collated from a variety of sources.
- **Filter by content:** Practice recommendations (treatment, diagnosis), drug information, medical education, journal publications/abstracts, news, medical reference tools, medical calculators, forums should be included and identifiable as a separate entity
- **Filter by format:** PDF, Powerpoint, web pages, images, videos

3.8.4 Ranking

- **Automatic prioritization of local of content:** Local resources should be displayed first. Country specific content should be displayed before all other content; EU content should be displayed before worldwide content. To address the need of certain subgroups (e.g., research physicians, physicians in training) physicians should have the option of a “global search” where the localized and language ranking can be deactivated.
- **Automatic prioritization of query language:** Output matching the language of query input should be displayed first. Option of deactivating this for users performing a global search.
- **Automatic prioritization of recent content:** Output which has the most recent publication date should be displayed first

3.8.5 Accessibility

Physicians prefer free access to content. The requirement of registration can pose a barrier to initial app access. Physicians like to have offline access of the app of saved articles, tracked offline access to search history and an organization feature (sort, rank content) within the personal library.

- **Payment:** Free advertisement sponsored access should be maintained. Payment can be required for users preferring advertisement free access.
- **Registration:** It should be possible to use the Khresmoi app without registration. However, registration can be encouraged by offering additional benefits such as a tailored search experience based on the information provided at registration, storage of full text articles and a secured physician platform.
- **Offline access:** The use of the application should be possible in offline mode. Personal library for logged in users and offline access of saved content. History tracking with tracked offline access to search history, bookmarking function

3.9 Summary

Khresmoi Professional should be advertised as a comprehensive medical search engine doctors can trust, cutting out the need to search using general search engines or multiple apps. In addition, the provision of local content, missing in existing solutions, could be valuable to many European physicians who currently have to resort to general search engines via their mobile browser. On smartphones physicians primarily view abstracts and short texts and expect HTML links to full-text articles on mobile web browsers. Tablet users additionally pursue advanced, comprehensive research and expect to view content in different multimedia formats. However, mobile user requirements should take into account that physicians need “on-the-go” information, since most use their devices at point-of-care during meetings and during travelling [19]. Simplicity is therefore paramount for all devices and in many cases information needs are likely to be less “in depth” but more superficial overview. A user tailored experience and comprehensible, simple intuitive navigation remains essential.

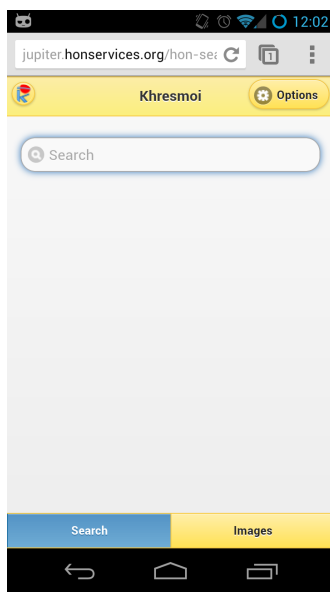


Figure 1: Home page

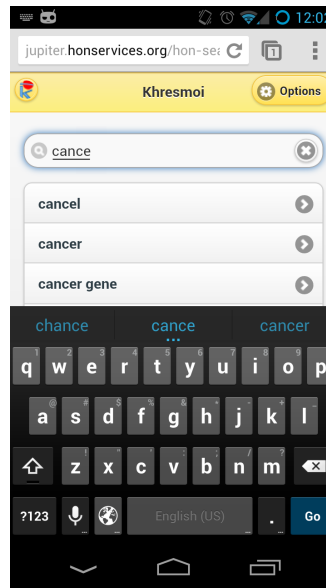


Figure 2: Search autosuggestions

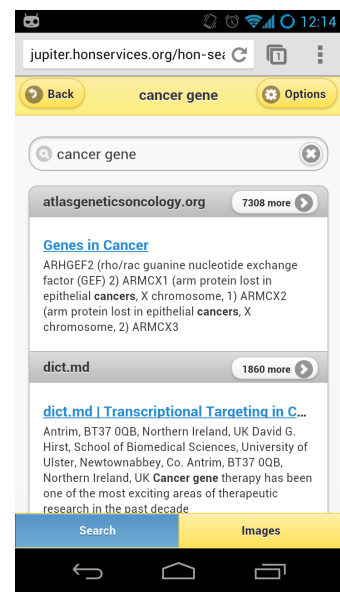


Figure 3: Result list

4 Khresmoi for Everyone

The mobile version of Khresmoi for Everyone is based on the existing Khresmoi for Everyone web application [22]. It uses a standard HTML/JS/CSS web architecture, with a JVM-based server written in Grails ⁴. Using the well-known technique of user agent sniffing, the mobile version of the site is delivered to phone and tablet users, whereas the desktop version is delivered to desktop users.

As with the desktop version, we maintain both a production site⁵ for stable builds and a development site⁶ for bleeding-edge builds.

4.1 Explanation of design choices

In writing a separate mobile web app from the ground up, we chose one particular strategy, at the expense of many others that could have satisfied the requirements just as well. Below, we briefly explain our decisions.

4.1.1 Design choice #1: web vs. native

Our first major design choice for Khresmoi for Everyone Mobile was to develop a standard web application rather than a native app for iOS, Android, Windows Phone, etc. While the performance advantages of native applications are well-known [8], we felt that the benefits of a mobile web app, enumerated below, were sufficient to justify our choice.

1. Native apps must be rewritten using separate languages and SDKs for each platform.
2. Writing a native app binds your fortune to that of the platform, at a time when OS distributions are rapidly changing [17].
3. The strength of the HON team is in JavaScript, CSS, and HTML, rather than Java, Objective-C, or C#.
4. Web browsers run on nearly every kind of illuminated rectangle on the planet. There is no better platform than the web for reaching the largest possible audience (hence “For Everyone”).

⁴<http://grails.org/>

⁵<http://khresmoi.honservices.org/hon-search/>

⁶<http://jupiter.honservices.org/hon-search/>

5. Khresmoi for Everyone doesn't require user data, access to device sensors, a "native" look and feel, or any of the other hallmarks of native apps.

On the other hand, the downsides of a mobile web app may be enumerated as follows.

1. Web apps tend to be less performant than their native counterparts [8].
2. Users have grown accustomed to the streamlined experience of mobile app stores and are intimidated by the concept of typing out a URL [14].
3. HTML5 solutions to the above problem are well-intentioned but poorly implemented [1].

In response to the first concern: our application is a standard search engine that does not require significant graphical wizardry, so the performance handicaps cited in [8] may be safely ignored.

In response to the second and third concerns, web apps with limited dependence on dynamic page generation by the server (such as our own) can easily be distributed alongside native apps using tools like PhoneGap⁷. The HTML, CSS, and JavaScript files are simply bundled with the application, and the server is queried as usual.

This contrasts with the Khresmoi Professional mobile app (detailed below), which requires more engagement from the users and more access to native features.

4.1.2 Design choice #2: web development framework

The second major design choice was made with regard to mobile framework. We ultimately chose to rewrite the client-side code from the ground up, using a combination of JQuery Mobile⁸, Underscore⁹, and Handlebars¹⁰.

Opting for a full rewrite, rather than leveraging the existing client code, was a difficult choice. However, we felt it was justified for the following reasons:

1. The original site was already designed as a single-page AJAX web app, meaning most of the heavy lifting is performed by the server in the form of simple HTTP GET requests and JSON responses. The client-side code is little more than presentation.
2. Although responsive web sites result in less code duplication and often provide better functionality [16], our JavaScript code base had ballooned to nearly 250KB when minified and compressed (about 800KB uncompressed). Small resource size is critical for the responsiveness of web applications [18], and the new mobile site only represents 125KB compressed (400KB uncompressed).
3. It was more fun to rewrite it from scratch. Developer engagement should not be under-appreciated.

As for the frameworks employed, our choices are much easier to explain. We chose JQuery Mobile because it is conceptually simple, and it seems to be the most popular choice for a "one-stop shop" mobile framework. It provides simple AJAX navigation between "pages," cross-platform UI elements such as headers and toolbars, and a mobile-friendly look and feel.

We chose Handlebars because it offers clean templating that can be pre-compiled on the server — another win when designing for wimpy mobile CPUs.

And finally, we chose Underscore because we hate having to write our own `Util` functions just to traverse a map in JavaScript.

4.2 UI Design

The layout of the mobile application should be familiar to anyone who has ever used a search engine. Toolbars at the top and bottom serve to visually separate the advanced options, whereas a big text input with rounded corners, a magnifying glass icon, and the unambiguous command "Search" carries all the modern affordances that users associate with a search box.

⁷<http://phonegap.com/>

⁸<http://api.jquerymobile.com>

⁹<http://underscorejs.com>

¹⁰<http://handlebarsjs.com/>

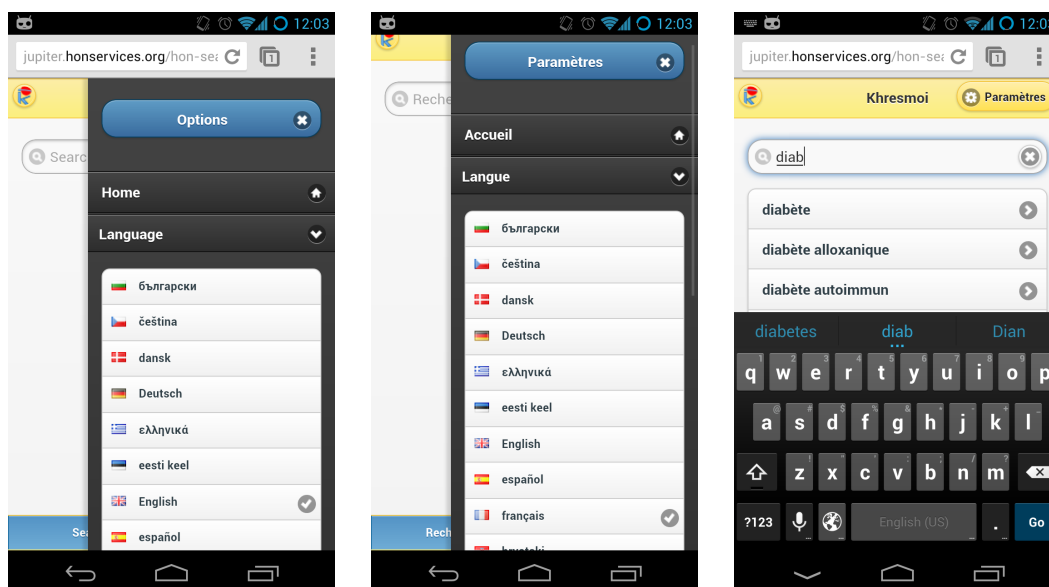


Figure 4: Options drawer **Figure 5: Switching languages** **Figure 6: Suggestions in French**

As the user types, autosuggestions are provided by the server, based on a combination of Solr¹¹ and MeSH [41]. Upon pressing the return key or tapping a suggestion from the dropdown, the user is presented with a page of 10 search results, grouped by domain.

Search results can be advanced forward and back by control buttons at the bottom of the page, and tunneling in to results from a particular domain is offered by the “more” buttons. The “back” and “forward” buttons in the user’s browser, as well as the virtual “back” button (required if the app were ported to PhoneGap), all function as expected.

At this point, nothing in the UI should shock anyone who has ever used a search engine and a smart-phone. The idea was to reinvent as few wheels as possible, and indeed to innovate as little as possible, in order to make the application instantly comfortable to the average user.

4.3 Advanced features

4.3.1 Changing the language

As with the desktop version, all languages of the European Union may be selected in the “options” panel. English is the default, but once the language is changed, the user will be greeted in that language upon their next visit.

The language of the interface is also the language used for the search results and autosuggestions. We found this to be the most intuitive way to internationalize the application. Of course, the drawback with this approach is that not all languages are equally represented (Figure 7).

The text used for the interface labels are sent to the client in the form of JavaScript. Thus, when the user selects a different language, the interface text changes instantly, without a page reload.

These translations use the same system as that for the desktop version. I.e., we maintain a Google spreadsheet¹² with write privileges for a select group of Khresmoi authors. Any changes to this file are automatically committed to the SVN repository on a daily basis. In this way, the normally laborious task of managing translations for 23 languages is rendered a fairly painless process.

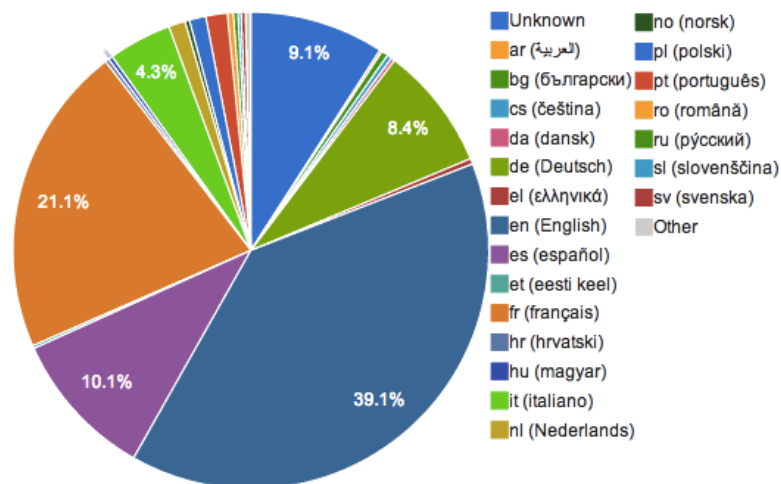


Figure 7: Distribution of the language of crawled HTML documents

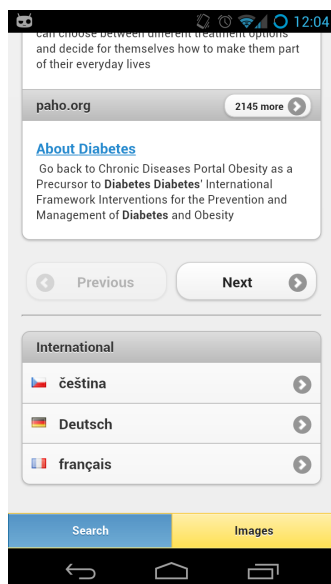


Figure 8: Translation options

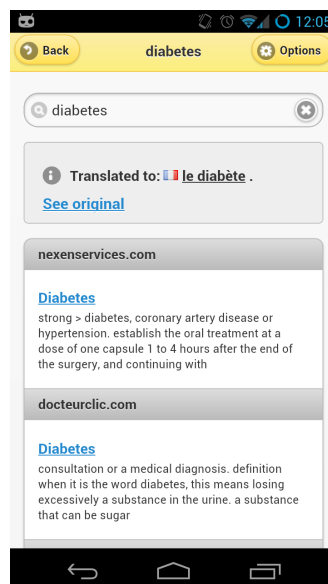


Figure 9: Translated result list

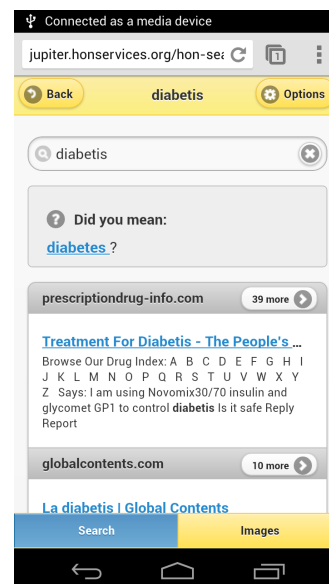


Figure 10: Spelling corrections

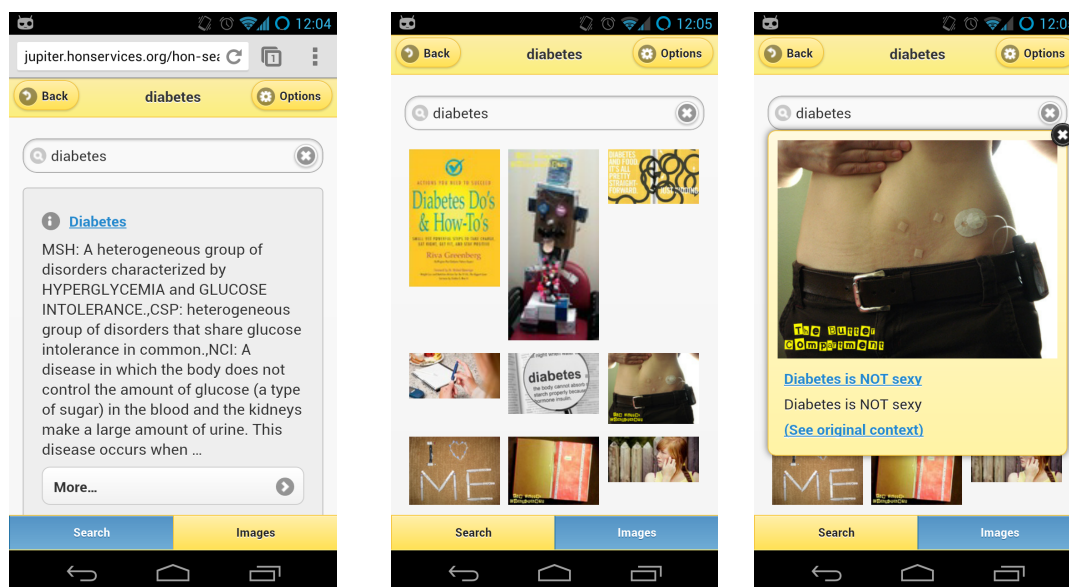


Figure 11: Info box definition Figure 12: Image thumbnail list Figure 13: Image detail view

4.3.2 Translations

Another feature carried over from the desktop version is the ability to dynamically translate pages in foreign languages, using CUNI's translation service. The target language is always assumed to be the same as the interface language. Currently supported language pairs are English to and from each of: Czech, French, and German.

To reduce user confusion, the controls for these translation options are placed at the bottom of the search results. This is also arguably a good workflow, since most users will not resort to searching for foreign pages unless they are unsatisfied with the native results.

4.3.3 Spelling correction

Using the same Solr spelling correction module employed in the desktop version [22], language-sensitive spelling corrections are provided (Figure 10).

To reduce the risk of misspelled suggestions being provided from an unedited set of web-crawled documents, we use a simple heuristic based on the document count of the suggested query compared to that of the input query. Briefly, this heuristic sets a minimum value for the ratio of the document counts for the two queries (currently 0.01), which bars suggestions such as *alzeimer* (about 50 documents) from being proposed for *alzheimer* (about 20000 documents).

This trick also ensures that correctly-spelled but orthographically similar queries (e.g. “test” and “text,” or “cancer” and “cancel”) do not result in unnecessary spelling correction proposals.

This heuristic is also employed by the desktop version of Khresmoi for Everyone.

4.3.4 Definitions

An info box showing English definitions of the input query is sometimes shown at the top of the search results (Figure 11). These definitions are provided by Ontotext's disambiguation service.

Since the definitions are occasionally very long, the text is typically truncated, with a “More” button offering the full text.

¹¹<https://lucene.apache.org/solr/>

¹²<https://docs.google.com/spreadsheet/ccc?key=0AqCxJMc-IDWfdFdMOHUtZGfKb1ZEZG9aV0JwWdJUWxc&usp=sharing>

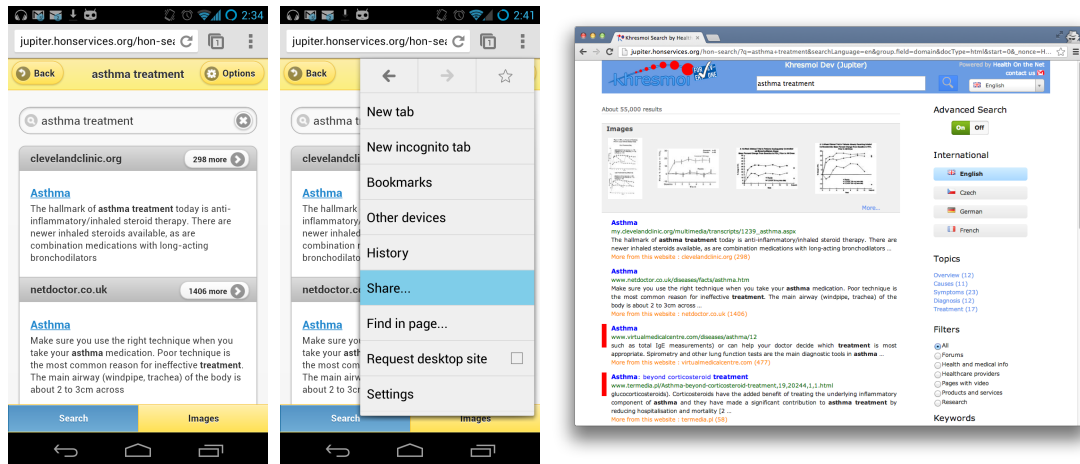


Figure 14: Mobile page Figure 15: Link-sharing Figure 16: The same link opened on a desktop

4.3.5 Images

A thumbnail gallery of images is shown upon selection of the “Images” button in the bottom footer. Selecting an image itself provides a detail view with links to the original image and its source context.

These thumbnails are loaded on-demand and are not saved anywhere on the user’s device, besides the standard browser cache. The full-sized images can only be downloaded by visiting the original site, thus limiting our liability in the case of copyright issues.

4.3.6 Link sharing

The web’s original solution to the problem of collaboration and sharing — the humble URL — is fully embraced by Khresmoi for Everyone. Links shared between the mobile and desktop version, and vice-versa, show the expected list of search results in the proper context. Thus we avoid the embarrassing scenario where a desktop user is greeted with the mobile site, or a mobile user is redirected to the main page.

It may be argued that this is a “non-obvious” feature. However, its support is guaranteed: all web browsers, both desktop and mobile, provide some functionality for sharing URLs. Android is especially adept at this, with its “quiet killer feature”: the universal share Intent [43]. Therefore this mechanism is expected to be familiar and accessible to the vast majority of users.

4.4 Future work

While we consider Khresmoi for Everyone Mobile to be feature-complete for a first prototype, and a worthy sidekick to the desktop version, there are a few features we hope to develop in the future, listed below.

1. The language should not default to English, but rather honour the language specified by the browser’s Accept-Language header.
2. The “translation” feature is admittedly confusing in its current presentation. From the user’s perspective, it’s not clear that the interface language, the language of the retrieved documents, and the target language for translation are three variables that can be separately tweaked. To be fair, though, its desktop analogue is presented in the same way.
3. Many “faceted search” features from the desktop version, such as the “topics” list, the “keywords” cloud and the “filters,” are not supported.
4. Native PhoneGap-based ports for iOS and Android could help boost Khresmoi brand awareness.

5 Khresmoi Professional

Khresmoi Professional is based on the existing ezDL architecture and software framework [2]. It was therefore decided to develop a mobile client that also uses the existing architecture and can share a common server infrastructure with the web-based and the Java desktop clients for Khresmoi Professional.

The extended requirements of physicians such as offline access made a native mobile application (app) a better choice over a web application. The mobile application for Khresmoi Professional was derived from a general ezDL client¹³ developed by UDE for Android smartphones and tablets (running Android 4.0.3+) [3]. It was adapted and extended for the Khresmoi project and allows search within the same data sources as the other user clients for Khresmoi Professional.

Use of Android 4 over earlier versions was necessary since it is the first Android version that allows development for smartphones and tablets alike (Android 2.2 and 2.3 targeted smartphones, Android 3 targeted tablets only). According to data collected between June and July 2013 by the Google Play Store, 61.2% of all Android devices now use version 4.0.3 and up¹⁴. For apps downloaded from the Medical apps section of the Google Play Store the market share for Android 4.0.3+ is even higher with 63.2%¹⁵. This trend will likely continue over the next year with older Android devices losing market share.

The current version of the mobile application can be downloaded as an apk file and installed for testing on Android devices¹⁶. A Google+ group has been set-up for beta testing and beta testers can directly download the app from the Google Play store.

After the end of task 8.4 the app will be made publicly available in the Google Play store.

5.1 The mobile proxy and communication

While the desktop client and the ezDL backend use a constant connection and communicate by sending messages in the form of serialized Java objects, this method of communication is not suitable for a mobile application. The inherent instability of the mobile connection, as well as incompatibilities between Java and Android, made it necessary to develop a backend proxy and a new message protocol. The backend proxy maintains a connection to the ezDL backend and provides a RESTful webservice implemented with JAX-RS. Requests from the mobile clients are transformed into internal ezDL request objects and send to the backend (which will be described in detail in the upcoming deliverable D3.4, “Final flexible user Interface framework and documentation”). The results are send back in JSON format.

The proxy server can also serve as an additional cache for search results, allowing fast browsing through the result pages.

5.2 General UI concept

To provide the functionalities of the existing desktop application within the confines of a mobile device, a new UI and interaction concept for smartphones and tablets had to be developed [3]. This new UI focusses on space-saving information display which makes the most out of the limited screen real estate and allows easy transition between horizontal and vertical use of the mobile device.

For user interaction, the main UI element is the action bar introduced with Android 3 (for tablets) and Android 4 (for smartphones). The action bar is usually shown at the top of the screen and is composed of four components (see Figure 17). In the left corner an application icon is shown which allows back navigation within the application. To the icon's right the main navigation menu can be used to jump between the different tools of the mobile app. The remaining space of the action bar is used to show action icons, with all actions that cannot be placed in the action bar (because of space constraints) being subsumed by an overflow menu.

¹³ <https://play.google.com/store/apps/details?id=de.unidue.inf.is.ezdl.androidfrontend>

¹⁴ <https://developer.android.com/about/dashboards/index.html> (retrieved on Jul 23, 2013); Eclair (2.1) – 1.4%, Froyo (2.2) – 2.2%, Gingerbread (2.3.x) – 34.1%, Honeycomb (3.2) – 0.1%, Ice Cream Sandwich (4.0.x) – 23.3%, Jelly Bean (4.1.x) – 32.3%, Android 4.2.x – 5.6%

¹⁵ <https://play.google.com/apps/publish/> (retrieved on Jul 23, 2013)

¹⁶ <http://gimlet.is.inf.uni-due.de/khresmoi/app/>

Special consideration was given to the use case of large screen mobile devices (e.g. 7 or 10 inch tablets). The additional screen estate available on these tablets is used to show two linked tools side-by-side, such as the result list and the detail view (see Figure 18), tray and details, or search and search history.



Figure 17: Action bar

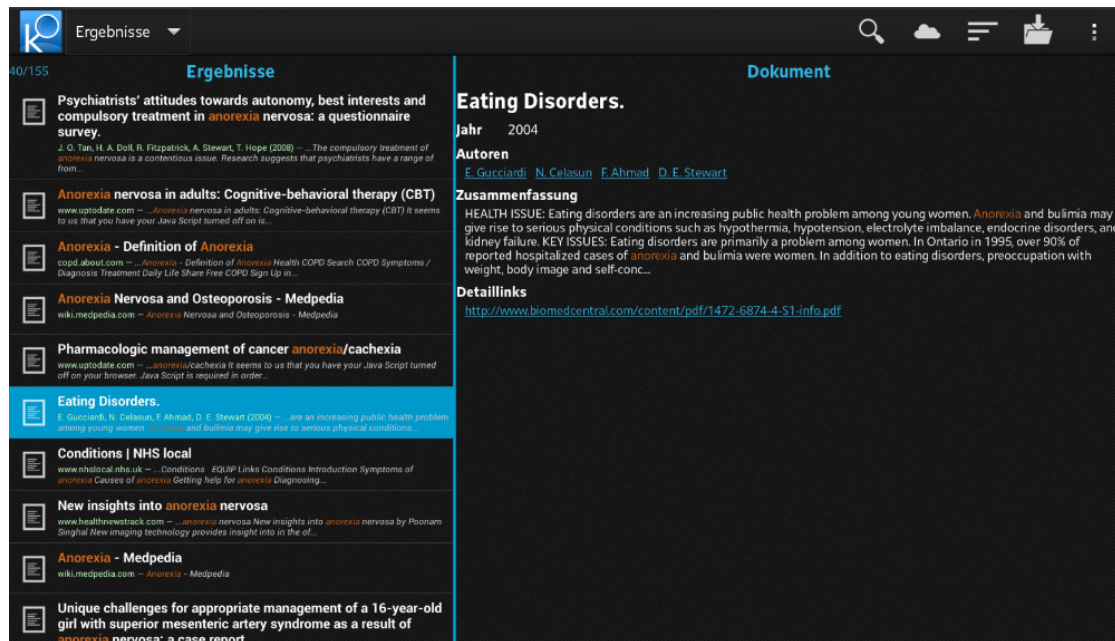


Figure 18: Tablet view of Khresmoi Professional app (left: result list, right: details)

5.3 Available tools

The application starts from a home screen from which the main search function as well as configuration options, source selection and a help function can be accessed (see Figure 19). The app is currently localized for German, English and French, with the UI language being automatically selected based on the UI language set for the smartphone or tablet.

5.3.1 Search

The search tool is the main function of the Khresmoi Professional mobile application and can either offer a simple, one-line search field, or a multi-field search dialog that allows specification of e.g. a range of publication years or author names (see Figure 20). For all fields semantic search suggestions can be offered using the services developed within the Khresmoi project. The suggestion service uses the device settings to provide search suggestions in the user's own language. In addition, auto-completion and spelling correction are provided natively by the Android UI widgets. Auto-completion and other query suggestions are especially important on mobile devices due to the inconvenient methods of text entry (usually virtual on-screen keyboards with small keys).

Additional information about the device (such as display size, UI language or location) can be sent with the search to personalize the search results. Currently only the UI language is used for this, but further personalization and localization of search results are planned.

5.3.2 Result list

Depending on the amount of information given for each snippet, the current result list allows for the display of 5 to 6 organic search result before scrolling is needed (see Figure 21). It is planned to make the specific

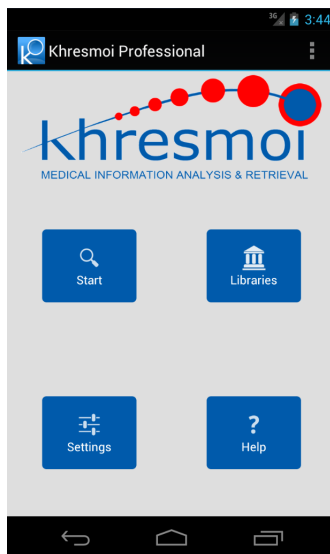


Figure 19: Homescreen

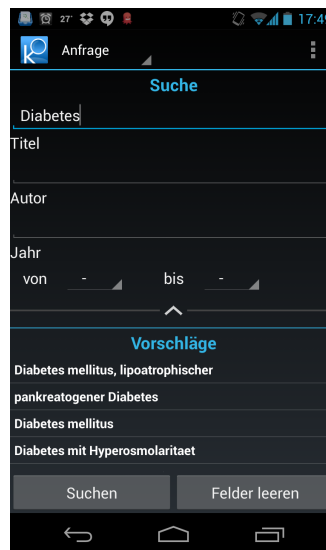


Figure 20: Search screen showing query term suggestions

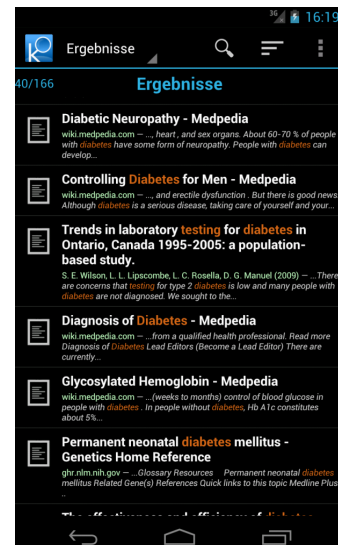


Figure 21: Result list

information shown for each snippet configurable, but the current prototype shows title, publication year, authors where available, or name of the website for web pages without a named author, as well as a short snippet around the first hit. Query terms in title or snippet are highlighted.

Only a limited number of results is transferred at a time, and additional results are automatically fetched if the user tries to scroll beyond the end of the result list. The limited number of results (which can be configured) is a concession to the low and often expensive bandwidth of mobile devices. The specific form of fetching new results was selected to give a smooth experience and avoid fiddly pagination elements which can be difficult to reliably hit on small touch screens.

Users can choose among different sorting options (such as relevance or recency) and can already filter the result list by arbitrary strings appearing in the result surrogate. The addition of result categorization similar to those used for the desktop versions of Khresmoi Professional is planned. This will allow direct filtering by medical categories, content type (drug information, CME, etc.), document type (PDF, web page, video, etc.), or publication source (journal, hospital website, etc.).

5.3.3 Detail view

The detail view shows a short, informative summary of the returned document consisting of document type (journal article, web page, etc.), title, publication year, authors where available or website for web pages without a named author, an abstract or an automatically generated text summary [35], and a link to the full document which can be opened using the default web browser of the mobile device (see Figure 22).

Navigation between different detail views is possible through the use of sliding gesture. Dragging a finger to the left will smoothly slide in the next detail from the result list, while dragging a finger to the right will slide in the previous detail. In addition it is always possible to go back to the result list and select a different item to see its details. Sliding is well-known from e-readers or mobile apps for browsing through media objects and provides an easier navigation methods for those users familiar with it, while the alternative navigation method serves as a fallback.

5.3.4 Search history

A history of all searches is kept and can be used to run a specific search again (see Figure 23). For each query the search history shows the keywords used, the data sources selected and the number of results returned.

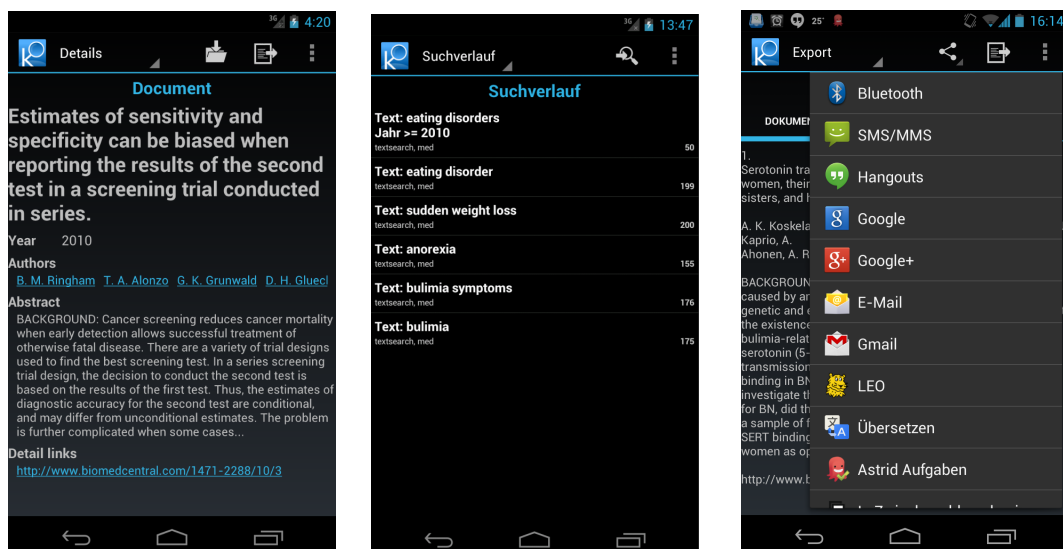


Figure 22: Example detail view Figure 23: Search history view Figure 24: Export and sharing

5.3.5 Tray

Individual results can be sent to the tray, where users can collect interesting search results for later inspection. The tray will be made persistent for offline-access and will later be extended to synchronize with the personal library developed for the desktop and web-based clients. This extended version will then also allow sorting, filtering and tagging of stored documents.

5.3.6 Export and share

Individual results or even complete result lists can be exported into various formats (plain-text, formatted HTML, or bibliographic formats) and then shared using the sharing functionalities of the Android system (see Figure 24). Sharing with other users is an important use case for collaborative work, while using the sharing function to create personal notes or tasks, or to send results to a cloud storage allows the seamless transition between mobile search and desktop work.

5.4 Preliminary usability evaluation

A preliminary, formative usability evaluation of the first mobile prototype was conducted at the University of Duisburg–Essen, using eight participants between the ages of 25 and 30 [39]. All but one participant were already smartphone users. One additional participant had used smartphone apps before, but was unfamiliar with the Android operating system. Half of the participants knew the existing desktop client for ezDL/Khresmoi Professional.

The participants were asked to perform a number of common tasks, as well as some difficult tasks which used all functionalities of the app. To measure the usability the well-known SUS questionnaire [5] was used. The results were generally positive (with a mean of 72.5 points), but with a high variation among participants. Participants without previous experience with (the newer version of) the Android OS had problems while using the actionbar. With growing proliferation of Android 4 these problems will likely decrease. Additionally, while the basic search functionalities were easy to grasp for every participant some of the advanced features offered (such as extraction of terms) were difficult to master for participants with no experience in using the etDL desktop system. These features will therefore likely be removed or reworked for the Khresmoi Professional app.

6 Conclusion

The following two tables summarize which of the user requirements detailed in sections 2 and 3 have already been met by the two prototypes developed and described in sections 4 and 5.

6.1 Requirements for the general public

User requirement	Khresmoi for Everyone mobile prototype
Resources	Contains the same web-crawled documents as the desktop version.
Classification/filtering	Not currently supported.
Ranking	The ranking is the same as on the desktop version.
Interface layout	The UI is optimized for mobile devices and localized to the user's desired language.
Link description	The descriptions are the same as on the desktop version.
Translation tools	The translations are the same as on the desktop version.
Query completion/support	The autosuggestions are the same as on the desktop version.
Collaborative tools	URL-based sharing is sufficient to share search results with peers.
Image search	The images are the same as on the desktop version.
Results preview	Not currently supported.
Suggested links	Not currently supported on either the desktop or mobile version.

6.2 Requirements for physicians

User requirement	Khresmoi Professional mobile prototype
Resources and format	
Should display and be interlinked to known key resources	Searchable index includes PubMed, Medpedia, medical pages from Wikipedia.
Support for videos, images, PDFs	Videos and pdfs are not currently indexed in Khresmoi, images can be searched and support for images is planned for mobile app.
Device specific format, links to full-text article essential	Automated summaries for documents, links allow opening of full-text; longer summaries planned for tablet version.
Interface	
Multilingual interface	Interface is available in English, German and French.
Categorization of results	Planned.
Supporting flipping of view mode	Content is maintained when flipping between landscape and portrait mode.
Minimization of clicks	Auto-fetching of more results and swipe navigation of details reduce necessary clicks; actual article content not viewable directly in app.
Clear authorship of articles, referencing is essential	All content details include a backlink to the original site, authors or publishing websites are displayed in snippets.
Integration of social media tools	Not planned within this task.
Sorting and ranking articles	Different sorting and filtering options are available for result list.
Organizing and tagging search results	Tray tool allows collection of found articles, persistent tray, synchronization with remote service and tagging are planned.
Filter	
Filter by type of resource, credibility, content type and format	Will be covered by adding categorization to result list.
Ranking	
Priorization of local content, query language and recent content	General requirement for ranking method, not specific to mobile client.
Accessibility	
Free access should be possible	The mobile app does not require a specific access scheme. Adding advertisements is possible.
No registration necessary	It is possible to use the app without registration.
Offline access	Users can share results and upload them to various cloud solutions. Offline access within the app is planned for the tray tool.

6.3 Concluding remarks

In this article we have demonstrated the functionality of two mobile applications: Khresmoi Professional and Khresmoi for Everyone. Each app has sought to leverage the existing infrastructure of their desktop counterparts while delivering a user experience that's more friendly for small-screened devices.

As with their desktop counterparts, the two apps have little in common in terms of client-side software architecture:

Client-side software stacks		
	Khresmoi Professional	Khresmoi for Everyone
Desktop	Java/Swing	JavaScript/JQuery
Mobile	Java/Android	JavaScript/JQuery Mobile

However, these differences can be attributed to the apps' separate audiences and goals.

The Khresmoi Professional apps expect an audience of medical practitioners, who would normally not balk at the idea of installing a native application onto their PC or Android phone. They are professionals working in a specialized domain with specialized needs, so they should be willing to go the extra mile to use a tool that meets those needs.

The Khresmoi for Everyone apps, on the other hand, target the general public as their user base. Such

users may be performing ad-hoc search queries or casual browsing of medical information, and cannot be expected to go out of their way to install custom software. Therefore, Khresmoi for Everyone opted for a common web format.

There is no inherent conflict between the two strategies. They have both striven to reach their target user base, and have both made considerable progress to bring Khresmoi technologies into the palms of users' hands.

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