Medical image resources used by health care professionals

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Abstract

Purpose- Medicine is heavily dependent on images and health care professionals use medical images for clinical, educational and research purposes. This paper investigates the resources used by health care professionals whilst searching for medical images.

Design/methodology/approach- The research is based on a qualitative study that uses the Straussian version of Grounded Theory (GT) and involved 29 health care professionals from various health and biomedical departments working within Sheffield Teaching Hospitals NHS (National Health System) Foundation Trust. Data collection was carried out using semi-structured interviews and think-aloud protocols.

Findings- Our findings show that health care professionals seek medical images in a variety of visual information sources; including those found on-line and from published medical literature. We also identified a number of difficulties that health care professionals face when searching for medical images in various image resources.

Originality/value- To the best of our knowledge there have been fewer studies that investigate the image resources used by health care professionals. Thus, the study helps to contribute to our understanding of medical image resources and information needs of health care professionals. A clear understanding of the medical image information needs of health care professionals is also vital to the design process and development of medical image retrieval systems.

Keywords Image retrieval, health professionals, Medical images

Paper Type Research Paper

1. Introduction

Digital image resources are highly important in domains such as medicine, where digital imaging has become a vital component in a number of applications within current clinical settings (Glatard et al., 2004, Müller et al., 2004, Eakins and Graham, 1999). According to Eakins and Graham (1999), medical images are utilized by a variety of users, such as medical students, lecturers in medical departments and clinicians; each with different levels of subject knowledge and experience. Access to digital images is commonly mediated through systems such as DICOM[1] or PACS[2]. Although research into the effectiveness of such systems is extensive much of the research focuses on one particular image retrieval system (Müller et al., 2005b). There is less investigation of the image information needs and image resources used by professional users who search for medical images as part of their daily work. Revere et al. (2007) reported that the information seeking process is situational, contextual and unique to the information seeker; knowledge regarding the motivations and medical image information needs of health care professionals is also vital in the design and development of effective medical image retrieval systems. The information resources used by health care professionals were investigated in a number of previous studies (Covell et al., 1985, Gorman, 1995, Shelstad and Clevenger, 1996). Findings showed that the information needs of health care were usually met by medical literature, such as textbooks, and by asking colleagues. The main conclusions reached from this previous work showed that health care professionals look for up-to-date information to quickly answer questions about patient care. To complement these previous studies we have carried out a study in the UK on the medical image resources used by health care professionals and this paper[3] reports our findings.

[1] Digital Imaging and Communications in Medicine

[2] Picture Archiving and Communications System

[3] This paper presents a portion of the findings of a PhD project entitled 'Relevance criteria applied by health care professionals for medical images, a grounded theory study '; see Sedghi et al. 2008 and Sedghi (2009).

2. Studies on image resources used by image users

Sklar (1998) examined the need for and use of images by architecture and design students. The study found that students look for images in a variety of sources, including journals, books, planning reports, maps, drawings, plans, and sketches. Sklars (1998) also examined the type of images sought by users reporting that the students mainly looked for diagrammatic images (maps, site plans, soil surveys, census data, zoning and regulatory information) and drawings or sketches.

Cobbledick (1996) investigated the information needs of four artists. She reported a heavy reliance on printed materials and their own personal art collections whilst searching for visual materials. Cobbledick added that artists used images from their own collections as well as images retrieved from public and institutional libraries.

Challener (1999) reported that professors of art history and studio art obtained images from a variety of resources to illustrate their slides when teaching their students. She found that the art professors used images obtained from departmental collections, their own personal collections, magazines, museums, and books. These findings were reiterated by Hemmig (2009) who noted that books, magazines, photographs, as well as digital images, were used by artists as the main image resources to satisfy their visual information needs.

Beaudoin (2009) examined the image resources used by 20 participants, including archaeologists, architects, art historians and artists. The findings of the study revealed that participants used various kinds of image resources, including books, non-digital image libraries, magazines, museums, image databases, personal collections, and websites. She also reported a preference for using images obtained from online resources.

Hersh et al. (2005) studied the pictorial information needs of 13 medical searchers including clinicians, researchers, educators, librarians and student[4]. The results of Hersh's study showed that the medical image needs of biomedical professionals were categorized into four groups: research-related; patient care-related; education-related; and other (Hersh et al., 2005). However, they did not inspect the sources of medical images that biomedical professionals used to meet their medical image needs.

Paling and Miszkiewicz (2005) studied the image resources used by 34 dental faculty members and clinicians. The results indicated that participants looked for images in a variety of sources, such as search engines, personal collections, digital textbooks, digital journal articles, database and CD/DVDs. The authors reported that a substantial number of the participants preferred to find and use digital images from online dental image collections, and that none of the participants indicated an overall preference for physical slides. Participants preferred to access higher quality images that could be manipulated and that had metadata describing image contents, such as the name of a disease or injury.

Studies of image resources used by health care professionals investigated the use of information resources for solving medical problems that arise during consultation. However, to the best of our knowledge there have been fewer studies that investigate the image resources used by health care professionals when searching more generally.

3. Method and subjects

To investigate the image resources used by health care professionals and their information seeking behaviours for visual materials, we adopted a qualitative approach to the research as suggested in (Maglaughlin and Sonnenwald, 2002, Ingwersen and Järvelin, 2005, Hirsh, 1999, Park, 1994, Myers, 1997). Suitable tools and techniques for data collection and data analysis

[4] Using a similar methodology and questionnaire, Muller et al., (2006) conducted a repeat study.

were based on using Grounded Theory (GT), specifically the 'Straussian version' of GT explained in Strauss and Corbin (1998). This helped us to undertake a more in-depth understanding of the phenomena under study within its real-life context.

Strauss suggested that the site of study or the research population must be selected according to the research questions (Strauss and Corbin, 1998, p. 214). Therefore and according to the research questions of the study, we selected Sheffield Teaching Hospitals NHS Foundation Trust as the site of our study. Sheffield Teaching Hospitals NHS Foundation Trust consists of about 11,689 staff, including medical, dental, scientific, therapeutic, technical staff, nursing, midwifery, health visiting staff, health care assistants and other support staff (Sheffield Teaching Hospitals NHS Foundation Trust, 2007). The sampling method for the interview stage of the study was purposive non-random sampling, a theoretical sampling (as suggested by Strauss and Corbin (1998) and described in the following paragraphs). In describing this method, Strauss states that in grounded theory the researchers must collect the data in a non-random purposive, convenient manner and should continue collecting data until data saturation is reached Theoretical sampling is sampling on the basis of "*concepts that emerged from analysis and that appear to have relevance to the evolving theory"* (Strauss and Corbin, 1998, p. 202)..

Ethics approval to allow recruitment and interviewing of participants was obtained from the NHS[5] National Research Ethics Service and Sheffield Teaching Hospitals NHS Foundation Trust. Health care professionals were sought who used any kind of medical image in their daily work; who were skilled knowledgeable computer (and Internet) users; and held a degree in health or in bio-medical sciences. To recruit participants, invitation letters were emailed to nearly 1,200 subscribers of a Sheffield-based health and biomedical mailing list and by

[5] National Health Service in the United Kingdom

traditional postal services (letters of invitation were posted to 250 people). Of 33 interested respondents, 29 participants were then selected and were interviewed based on their suitability for this study. A local research contact from Sheffield Teaching Hospitals NHS Foundation Trust facilitated our access to interviewees.

According to Strauss and Corbin (1998) in grounded theory data collection, data analysis and building the theories are regarded as reciprocally fused. Guided by some initial research questions, we selected the research population, the type of data and the data collection method. Then we collected the first piece of data. At that point, we could start the analysis process using a constant comparison method. After the first set of data was analysed, the second set was collected using the directions that emerged from first data analysis. This is the principle of theoretical sampling. According to Strauss, the researcher continues the cycle of alternation between data collection and data analysis until theoretical saturation is achieved. Strauss and Corbin (1990) stated that saturation is achieved when no new concept or category emerges, and the researcher has identified the main category and established the relationship between the main category and others. Using theoretical sampling and after interviewing 14 participants, it appeared that we reached data saturation; however we continued the recruitment and data collection processes to ensure this was the case. In total 29 health care professionals participated in our study, with the mean average of 13 years and 3 months work experience (range: 2 to 35 years). The mean interview duration was approximately 42 minutes (range: 28 to 92 minutes), and the majority of participants, except two (P4 and P11), mentioned that they had several roles other than a clinical role at the time of interview.

3.1. Data collection protocols

The data collection took place over approximately five months. We used interview and think-aloud protocols in order to investigate participants' perspectives. Most of the time, participants

conducted medical image searches during the interview to explain their image search behaviour and other activities. In the first stage of the study, we used a semi-structured interview protocol and we asked health care professionals to describe one of their recent medical image needs. A similar approach was used by Yang (2005). Additionally, the experiments obtained from each interview helped us to revise the interview protocol. Thus the questions in the interview protocol became directed and more focused through theoretical sampling (Strauss and Corbin, 1998). Since the interview was a semi-structured interview, we constantly checked whether all the questions on the protocol had been responded to. Before starting the data collection, a brief training session about think-aloud was given to the participants. The participants were informed about our interest in the way they formulated queries and selected medical images, but that there were not specific guidelines for participants on what we wanted them to talk about or how they should express their thoughts. We asked each participant to perform a series of medical image searches based on information needs that were developed independently by participants and that they discussed in the interview session. Participants were allowed to search for medical images in any way they found useful or natural. We encouraged them to search as they would normally. Participants could use any available image search tools such as image search engines, personal knowledge of the image sources (e.g. useful medical image collections), or databases. Therefore, there was no restriction placed on the search strategy that health care professionals would apply as suggested by Tombros et al. (2005). Whilst searching for images we encouraged participants to comment on their activities. This helped to provide insights into their thought processes during the search tasks.

4. Results

4.1. Image information needs

In a number of studies, researchers investigated the users' image queries. Yang (2005) cited Panofsky (1972) and reported that Panofsky distinguished between three levels of

comprehension for images: pre-iconographical, iconographical and iconological. Pre-iconographical understanding is related to the general subject matter of the image (e.g., a dog). It requires only an everyday familiarity with objects and events. The second level, iconographical understanding, relates to the specific subject matter of the image (e.g., John F. Kennedy), and requires additional domain knowledge or linguistic cues. Hence, iconographic meaning is culturally determined. Iconological meaning relates to emotional, abstract meanings and symbolic aboutness and denotes the intrinsic, personal meaning of an image (e.g., he is my idol). Thus, iconology is both personal and cultural.

Enser et al. (1993) analysed users' image requests at the Hulton Deutsch Collection Limited in Europe. They found that users' requests can be grouped in two main categories: unique, and non-unique. Unique requests were defined as those concerned with named persons, one-off events, objects or locations. An example of a unique query is 'George III'. An example of a non-unique query is '5-6 year-old boy in silhouette'. They report that both classes of query require refinement in terms of time, location, action, event or technical specification.

Fidel (1997)'s study also provides valuable classifications of users image queries. She categorizes images retrieved for 100 actual requests, submitted in an agency, which had a large collection of stock photos, into two groups: the 'data pole' and the 'objects pole'. She explained that images are considered as sources of information at the 'data pole'. For example, a physician may need to use a slide of a normal foot to help decide if a patient's foot is flat. On the other hand, images are used as objects at the 'objects pole'. For example, a slide librarian may be asked to find slides that represent a specific idea or object. There are also some in-between cases such as medical instructors and art historians who want to retrieve images both as information sources and as objects.

Markkula and Sormunen (2000) classified journalists' queries in four categories: concrete objects (i.e. named persons or places), themes or abstractions interpretable from the images, background information on the photograph (such as documentary information), and known images. Choi and Rasmussen (2002) analysed requests submitted by faculty and students of American history searching for images in the American Memory image collection. Their investigation demonstrated that most users looked for general/nameable images. They also reported that date, title, and subject descriptors are key factors representing images.

The findings of the current study, however, indicate that the image information needs of health care professionals could be categorised into two broad categories, general and specific medical images, based on the type of images sought:

- **General medical images**: this is when participants looked for general medical images on a particular topic, for example looking for images of anatomic organs (such as images of female reproduction organs). Thus we believe that this type of image request is equal to pre-iconographic as Panofsky (1972) mentioned. This type of image query also could be classified as non-unique as suggested by Enser et al. (1993). Participants mentioned that they mostly looked for this type of image for educational purposes, and they used general medical images to illustrate their presentations. They described this type of image by expressions such as *'generic images'*, '*common medical images*', '*classic picture*', *'general images'*, *'images of common issues'*, *'educational images'*, *'a typical picture'*, *'common medical conditions'* and *'something popular and well-known'*. The findings of our study show that participants could find general medical images more easily than finding specific medical images.

- **Specific medical images**: this is when participants looked for images to illustrate their research findings and publications. They also used specific medical images for clinical purposes. Participants used expressions such as *'specialized medical images'*, *'something rare or not common'*, *'odd things'*, *'rare cases'*, *'detailed images'*, *'specific images'*, *'clinical images' and 'images for rare conditions'* when they wanted to distinguish between general and specific medical images. Since the health care

professionals were concerned with the specific subject matter of the image, this type of image resembles the iconographical or unique type of image query suggested by Panofsky (1972) and Enser et al.(1993).

Participants usually looked for specific medical images to compare their research findings to, or to make clinical decisions. Thus the participants wanted to obtain the best and most recent images available to them. For example, a participant who looked for images of TLR-3[6] in fallopian tubes mentioned that he needed these images to compare his research findings with the findings of other researchers. He mentioned that due to the novelty of the topic he could not find images in web-based resources, but he found them in medical journals.

Participants seemed to have difficulties when they looked for specific medical images. The difficulties can arise for various reasons including the time that participants might spend to find images, the availability of the relevant published papers in the field, novelty, and rareness of the topic. Additionally, our findings support the idea that participants might make decisions about the image resources they use with regard to the type of image they required. Further investigation of the interviews revealed the fact that the health care professionals tended to use images published in papers and personal collections when they looked for specific medical images.

Other findings indicated that participants cared about visual attributes of images more than other attributes when they looked for general medical images. However, when they looked for specific medical images they seemed to consider attributes such as textual information addition to visual attributes. Sometimes the participants mentioned that they considered credibility of the image source to compare and decide about the appropriateness of images for their information needs. We noted that participants wanted to ensure that they had found the most relevant

[6] Toll-like receptors

images when they looked for specific medical images to illustrate their scientific publications or when they needed similar specific medical images to compare their research findings with other researchers' findings. We conclude this section by saying that the type of images requested and the queries used, indicate that health care professionals use medical images as sources of information and as objects. This finding corresponds with the results of Fidel (1997)'s study that image users evaluate images as a source of information or as an object. For example, the participants considered medical images as a source of information when they applied topicality as the minimum requirement for the judgment of images. Medical images were also regarded as objects when the participants considered properties such as 'image quality' or dimensional size of images.

4.2. Image resources used by health care professionals

Our study shows that participants used a variety of resources to find the medical images they wanted. One of the major findings of our study was that online medical image collections were not a common resource for images used by health care professionals, although the participants were aware of such collections. Based on the results of the present study, it appeared that despite the recent progress in medical image collections, health care professionals preferred to look for medical images in Web-based resources using Google image search, or images published in medical journals. Figure 1 gives the list of resources used for medical images. The total does not always add up to one hundred percent because more than one resource might have been used. As shown in Figure 1, the Web-based resources were used the most, followed by using images from papers and personal collections.

Figure 1: Frequency of resources used by health care professionals for medical image retrieval (participants used more than one resource to find images they required; total number of participants=29).

In addition to Web-based resources, health care professionals also used papers (both electronic and printed versions) published in medical journals, found via PubMed, to find the medical

images they required. Personal collections were commonly the third resource participants chose to find images. Books seemed to be another important resource for health care professionals to obtain medical images. Although images obtained from the books were not new, they could be used for educational purposes[7]. The following sections detail the image resource used by participants.

4.2.1. *Web-based resources*

In response to the question: 'Why do you look for images in Web-based resources?' one of the participants stated:

> *P5: The first source for the images I need is the Internet. The online image searching is interactive and you have the chance to interact with the system, try more keywords, and modify the query easily.*

We noticed that participants obtained images from Web-based resources in two different ways: direct and indirect. In the direct approach, images were obtained from Web-based medical image collections or professional websites. Our findings showed that only 31% (nine out of twenty-nine) of participants were aware of Web-based medical image collections. Medical image collections seemed to be unpopular among participants due to a lack of diversity and the low number of images available in medical image collections.

The indirect approach was by far the most popular method for medical image retrieval from web-based resources and was applied by 90.0% of participants. In this method, participants used image search engines, such as Google Images. These tools always seemed to be the first place that participants searched for images, especially for general or common medical images. This was because of the easy accessibility of image search engines and the fact that participants could visually browse the results and select images quickly.

[7] Twenty-seven participant (out of twenty-nine) stated that they had several roles other than a clinical role at the time of interview.

There are many search engines and many ways to gain access to images stored in online resources. At the moment, however, what is evident from our findings is the high reliance of participants on Google search tools including Google image search. This resembles the findings of Jamali and Asadi (2010) that for many researchers and academicians Google is the first and most of the time the only tool to locate information in the Internet. Google image search was also the most frequently used tool for identifying the images that participants needed. This high reliance on Google image search, and the role it plays in medical image seeking, merits further investigation. Past studies pointed out the use of Google by health care professionals. Tang and Ng (2006) suggested that in difficult diagnostic cases, doctors used search engines, such as Google to find diagnoses and/or treatment. The authors also reported that this use was extending to clinical medicine.

From the interviews, we found several reasons for the popularity and use of Google image search. The main reasons were:

- Google image search is straightforward to use and has useful features such as spell correction.
- It is easy to check the relevancy of returned images.
- Google image search is useful for finding medical images for educational purposes.
- Health care professionals demonstrated a high reliance on the Google web search engine in their daily life. Participants believed that Google made everything searchable even online medical image collections; therefore they believed that using Google image search they could find the images they needed.

Participants, however, were also strongly critical in their use of Google image search in that they were aware of the issues concerning the credibility and quality of medical images. They

mentioned that Google image search often returned too many hits, most of which are irrelevant images for a search, and health care professionals need to be able to filter through the results to find images that suit their information needs. They also emphasized that using Google image search they were unable to find images of rare medical conditions, specialized images, or up-to-date images. There were five main criticisms of Google image search when used for medical image retrieval which emerged from our interviews:

- **Lack of specialty**. Google image search is a general image search engine and is not suitable for finding specialized medical images.

- **Lack of detailed textual information for medical images**. Although participants stressed the importance of textual information for medical images, using Google image search they were not sure whether they could access detailed information related to the images.

- **Poor photographic quality of images stored in Web-based sources.** Although the merits of Google make it an ideal search tool, often participants had difficulty finding high quality images searching on Google. Sometimes the participants who looked for images in web-based resources using Google image search complained about the low quality of images. Therefore they preferred to find images in resources other than web-based resources.

- Some participants used images to illustrate their presentations, therefore they emphasized that they were interested in copyright-free and high quality images to show the desired visual details in their presentations. We noted that sometimes participants printed images before using them to verify the quality of the images.

- **Low precision and the large number of irrelevant hits**. Google image search tended to produce a large number of non-relevant results. Participants were frustrated at not being able to find the right images quickly and easily. Sifting through a large number of irrelevant images to find the images was not only frustrating, but was time-consuming for busy health care professionals.

- **Credibility of images obtained from Web-based sources**. Participants often wanted to make sure that images were from reliable and valid sources. Sometimes participants used image search engines to locate medical images from online repositories; however, general-purpose search engines (e.g. Google) do not distinguish between medically credible and less-credible websites. The findings of this study show that participants always debated the credibility and trustworthiness of images retrieved from web-based resources. Sometimes they declared that they would not use images obtained from websites such as Wikipedia.

The fact that Google image search was the first means by which images were found might be because of the broad availability of medical images on the Web. We see that Web-based sources contained a great quantity of images that may be useful for health care professionals. However, locating required images remained a challenging task. This makes it particularly vital to develop medical image retrieval tools to assist health care professionals in specifying image information needs and retrieving images from Web-based resources.

4.2.2. *Articles*

Twenty-four participants obtained medical images from published papers in medical journals (both electronic and printed versions). The participants searched for relevant papers through both scientific databases such as Medline and Ovid as well as publisher based sources such as Elsevier and Springer. The main reason mentioned by health care professionals for obtaining images from academic papers was they tended to contain specialized medical images rarely found on the Web. Another reason given was the participants' preference for locating background information. For some, especially those involved in research projects, academic papers were an important source for current images and the latest information in their field. Such participants used images from papers for comparing the findings of their studies to those of other research groups.

Although papers were the second resource for participants to obtain medical images, our interviews revealed that participants did not use Google Scholar to search for journal papers. The interviewees were specifically asked if they used Google Scholar for finding papers and the majority answered that they did not. When they knew that they were looking for papers, they used medical databases, and particularly PubMed[8] to find relevant literature. Often images were found as a by-product of paper searching.

4.2.3. *Personal collections*

Eighteen out of twenty-nine participants used images from their own personal image collections; the following reasons were given:

- For presenting the results of their research projects.
- As a source for original medical images that could not be found in a web-based resource.
- Their own images were more relevant than images obtained from other resources.
- Due to legal issues such as copyright, participants were not sure whether they could use images obtained from other sources such as web-based sources.
- When a high level of credibility was required, participants preferred to use images from their own collection.
- Participants' personal preferences for using images from their own image collection.

4.2.4. *Books*

On some occasions, mainly for educational purposes, participants used books to find medical images. The majority of participants mentioned that the images were often out-of-date, however, which meant other sources tended to be preferred.

[8] Public access to the Medline database http://www.ncbi.nlm.nih.gov/pubmed/

4.2.5. *Other resources*

There were also some other resources that health care professionals used. For example, eight participants asked their colleagues and friends for images. Seven participants used departmental collections. Two mentioned that they might use images from CDs and DVDs accompanying medical textbooks.

4.3. Image retrieval techniques

We also asked participants to comment on the potential application of image retrieval techniques other than text-based image retrieval. Images (including medical images) can be indexed based on low-level visual features such as colour, shape and texture. This approach is known as Content-Based Image Retrieval or CBIR (Deselaers, 2003). Participants mentioned that they might use different types of medical images for different medical problems. For example, in breast cancer, health care professionals might use plain x-rays, Ultra-sound images, MRIs or CT scans. If users used an ultrasound image as an image query, the system will find similar ultrasound images and not the other types of images such as a Mammogram. Interviewees emphasized the importance of integrating text-based image retrieval with image retrieval process. The complexity of medical images was also stressed by participants, e.g. Figure 2 shows a multi-frame image for which an image retrieval system may not by default be able to handle.

Figure2; an MRI image of a patient includes a set of frames. Image is from http://ecco2.jpl.nasa.gov/data1/matlab/images/imdemos/examples/tform/tform3.html [Accessed in December 2008]

5. Discussion and Conclusions

Our findings indicate that health care professionals search for images in Web-based resources (mainly by using Google image search), journals (both electronic and printed journals) and personal collections. Books seemed to be less important resources. One of the major findings of

our study is that only nine participants used or were aware of online medical image collections. Our investigations indicated that while there was willingness and interest in using medical image collections, participants believed that they could not find the images they needed. In addition, health care professionals believed that the number of images in medical image collections on the Internet was limited. Moreover, health care professionals emphasized that any web-based medical image collection should be easy to use. Although the potential usefulness of medical image collections is apparent, barriers or difficulties in using these collections appeared to put health care professionals off. Previous studies identified barriers to finding text-based information by health care professionals (Ely et al., 1999, Shelstad and Clevenger, 1996, Gorman, 1995). These were: lack of time, lack of access to electronic journals and databases, and lack of information seeking skills. This study, however, found different barriers to seeking medical images. These barriers include: low precision in the image retrieval; lack of domain specific image searching tools; the large number of images in the results set; lack of credibility; low quality of retrieved images; lack of image search facilities; lack of time; difficulties of image search with medical abbreviations and acronyms; and legal issues such as copyright of images. These barriers affected the choice of medical image resources used by health care professionals. For example, health care professionals tended to use journal articles or their personal collections when they could not find specific medical images. Thus we believe that the barriers to seeking medical images can affect the choice of medical image resources by health care professionals. Our findings; however, showed improvements in the barriers identified by previous information (textual) seeking studies. These improvements include: better access to electronic journals and databases, and improved information literacy skills. Lack of time still remained an important barrier to seeking medical images. We also found that there was a preference for using images from personal collections and from journal articles

when the health care professionals required images for research purposes. However, additional research is required to confirm these results.

The results of the current study are also favourable for applying content-based image indexing and retrieval methods to medical images. However, the difficulty of developing content-based indexing and retrieval tools is due to several factors. Firstly, in most cases, medical images are intensity-only images containing less information than non-medical images. Additionally, different types of images (e.g. MRI and ultrasound images) may be acquired of the same anatomic area in particular medical conditions. Each type of medical image needs an additional registration procedure (Glatard et al., 2004). Secondly, medical images are usually low resolution and high noise images. Thus, it is difficult to automatically analyze and extract their visual features. Medical images obtained with different devices, even using the same modality, may have significantly different properties (Lehmann et al., 2000). Thirdly, medical images could be indexed on medical criteria that are extremely variable depending on the kind of image acquisition considered (e.g. imaged anatomic area and clinical context). However, medical images interpretation is often difficult even for trained medical doctors. A holiday picture might bear enough information without text; however, for medical images the text is essential. For deeper analysis of medical images, detailed textual information is required because medical images themselves are dependent on the context (Müller et al., 2005a). Low-level visual attributes of images such as colour or size of image were seemed to be important for health care professionals, though sometimes the main focus of the medical image search was on the context information (e.g. technical information) requiring high-level human reasoning. Indexing on a high level of abstraction is currently possible only by using textual descriptions, as Markkula and Sormunen (2000) reported.

The health care professionals in our study used Google image search and medical databases supporting traditional textual query operations. Thus, it is difficult to explain how they would change their medical image searching behaviour if they could execute queries based on the visual similarity of photographs. It is also difficult to prejudge common uses for purely visual queries without textual search keywords. Perhaps the first challenge would be how to formulate a visual query for medical image retrieval. Moreover, the number of medical images on the internet and the heterogeneity of medical images might make content-based medical image retrieval problematic. Nevertheless, a content-based approach can be used in the classification of the set of images retrieved by search keywords or index terms. Within the retrieved set of images, visually similar images could be grouped together and the output of image retrieval could be organised by these groups. Thus, the end user can see different image categories contained in the retrieved set of images.

The health care professionals studied in this study could be sure of the credibility of images when they used images from their personal collections or when they searched for images in books and papers. In other words, credibility was used as a criterion to decide about the potential image resources to use for image retrieval. However, further research is required to know which factors affect health care professionals' decisions concerning the credibility of image resources. These findings of the current study imply that developers of image retrieval systems should focus on the criteria or aspects of images which seem to be important for the end-users.

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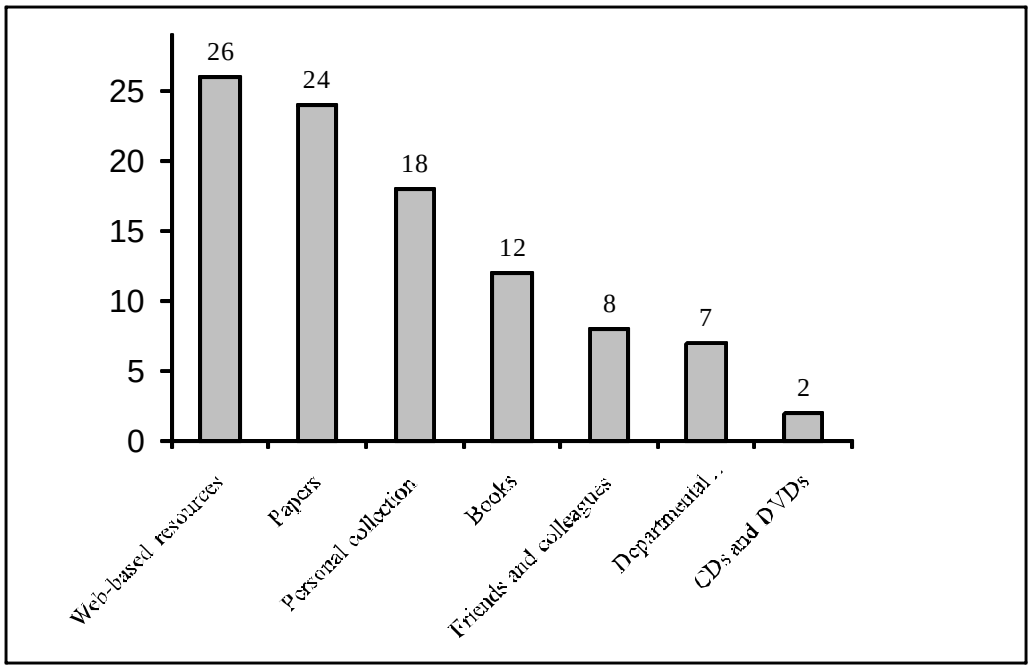

Figure 1: Frequency of resources used by health care professionals for medical image retrieval (participants used more than one resource to find images they required; total number of participants=29)

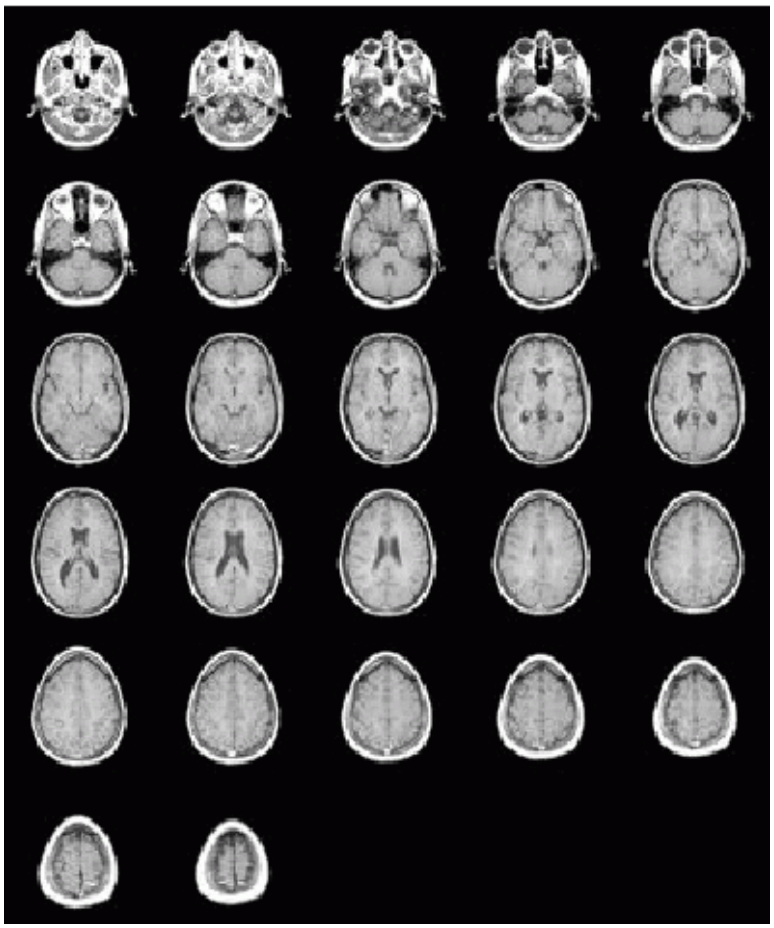

Figure 2; an MRI image of a patient includes a set of frames. Image is from http://ecco2.jpl.nasa.gov/data1/matlab/images/imdemos/examples/tform/tform3.html