Information Retrieval in the Workplace: A Comparison of Professional Search Practices

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Abstract

Legal researchers, recruitment professionals, healthcare information professionals, and patent analysts all undertake work tasks where search forms a core part of their duties. In these instances, the search task is often complex and time-consuming and requires specialist expertise to identify relevant documents and insights within large domain-specific repositories and collections. Several studies have been made investigating the search practices of professionals such as these, but few have attempted to directly compare their professional practices and so it remains unclear to what extent insights and approaches from one domain can be applied to another. In this paper we describe the results of a survey of a purposive sample of 108 legal researchers, 64 recruitment professionals and 107 healthcare information professionals. Their responses are compared with results from a previous survey of 81 patent analysts. The survey investigated their search practices and preferences, the types of functionality they value, and their requirements for future information retrieval systems. The results reveal that these professions share many fundamental needs and face similar challenges. In particular a continuing preference to formulate queries as Boolean expressions, the need to manage, organise and re-use search strategies and results and an ambivalence toward the use of relevance ranking. The results stress the importance of recall and coverage for the healthcare and patent professionals, while precision and recency were more important to the legal and recruitment professionals. The results also highlight the need to ensure that search systems give confidence to the professional searcher and so trust, explainability and accountability remains a significant challenge when developing such systems. The

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findings suggest that translational research between the different areas could benefit professionals across domains.

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1. Introduction

Professionals in a variety of domains rely upon information retrieval systems to gather the evidence necessary to formulate policy, impart advice and make important decisions. This has given rise to the notion of "professional search" (Lancaster & Fayen, 1973; Tait, 2014) as an activity that focuses on addressing and supporting the work tasks of professionals within a variety of domains (e.g. intellectual property, legal, healthcare, academia, etc.). In contrast to web search (Broder, 2002), site search (Ortiz-Cordova & Jansen, 2014), enterprise search (Hawking, 2004) and other types of search, professional search focuses on the work of paid professionals who are undertaking a work task that is predominately search-related and performed under a number of constraints such as budget and time (Tait, 2014). Such professionals may be referred to as "expert searchers" but may also have job titles ranging from "search specialist" to "information professional" (Jankowski, 2016). The decisions they make often have significant financial, ethical and legal consequences, and depending on the circumstances, may even compromise the well-being of others in their care. In this context, rather than being a discretionary activity performed using consumer-oriented web search engines, search is a task that typically completed within specific constraints using specialist databases and tools (Jankowski, 2016).

However, there are varying degrees of rigor and formality associated with professional search tasks and applications (List, 2013). At one extreme, a healthcare information professional may need to briefly consult an online resource to refresh their memory about a particular topic, while at the other extreme that same individual

may need to systematically search and review a body of literature in order to provide evidence for the formulation of clinical policy and guidelines. In this study, we focus on the latter, where the work task is based around the search task, where the search task can extend over days and weeks, and the professional context means that the task carries with it accountability for its successful execution.

Despite a growing interest in professional search, the majority of previous studies have focused on a single profession or domain (List, 2013). As a result, there has been very little work that spans multiple communities and less still that attempts to apply a shared perspective or common methodology. Hanbury & Lupu (2013) argue that this silo-based approach is inefficient and compromises the adoption of insights and innovations from one domain to another. While a significant amount of attention has been paid to the design and development of professional search systems (Bourne & Hahn, 2003; Lancaster & Fayen, 1973), less attention has been paid to their needs and behaviors.

The work in this paper attempts to bridge this gap by adopting an approach (Liu & Wacholder, 2017), where the characteristics and strategies of users from four different professions are compared and contrasted using a common survey instrument and methodology.

2. Background

In almost all professions there is some need to search for information in order to provide professional services e.g. to represent client interests, recommend appropriate treatments, provide guidance, identify suitable candidates, etc. ~~W~~hile the range of tasks that an individual undertakes may vary, the term "professional search" has been associated with those tasks where the primary component is the search task itself. Various proponents have provided descriptive and behavioral definitions of "professional search" (Jankowski, 2016; Y. Kim, Seo, & Croft, 2011; Koster, Oostdijk, Verberne, & D'hondt, 2009; Tait, 2014; Verberne, Sappelli, Sørensen, & Kraaij, 2013). One of the earliest definitions was put forward by Koster et al., (2009), where professional search:

- Is performed by a professional for financial compensation;
- Is within a particular domain and/or area of expertise;
- Has a specified brief, which is typically well defined but complex;
- Has a high value outcome where the results will reduce risk, provide assurances, etc., and;
- Has budgetary constraints such as time and money.

Typical examples of professional search contexts and work tasks include: academic research (Niu & Hemminger, 2012), intelligence (for criminal and fraud investigations) (McKeown, Maxwell, Azzopardi, & Glisson, 2014), healthcare information (Elliott et al., 2014; Russell-Rose & Chamberlain, 2016, 2017), legal research and eDiscovery (for litigation or regulatory purposes) (Cormack & Grossman, 2014), patent (validity, patentability, freedom to operate, etc.) (Joho, Azzopardi, & Vanderbauwhede, 2010) and recruitment (Russell-Rose & Chamberlain, 2016). In each of these domains, the search tasks meet most, if not all, of the criteria above; and depending on the domain, additional requirements may also be imposed.

A key distinction between professional search tasks and other kinds of search tasks, such as casual search (Elsweiler, Wilson, & Harvey, 2012) and web search (Broder, 2002) is that the latter:

- Are typically performed on a discretionary basis;
- Are not necessarily performed by an expert searcher or domain expert;
- And do not place at stake the professional reputation of the searcher.

In terms of behavior, professional search tasks have been characterized as highly interactive, requiring multiple iterations where many documents may be examined over an extended period of time (ranging from hours to weeks). Furthermore, such tasks are often recall-focused, particularly in cases where the omission of relevant information can have significant consequences (Tait, 2014). For example, if a patent attorney overlooks a relevant document in their prior art search, then their client could be exposed to the risk of an infringement litigation. Similarly, if a healthcare information professional overlooks a key research paper, then clinical policy could be formulated based on incomplete evidence. Consequently, professional search tasks

often need to be audited by other stakeholders to demonstrate due diligence and accountability (S. N. Kim, Martinez, Cavedon, & Yencken, 2011). As a result, many professions have a preference for Boolean search systems where the retrieval process is transparent and replicable (Joho et al., 2010; Y. Kim et al., 2011) and automated support technologies are often resisted in favor of manual approaches (Kruschwitz & Hull, C., 2017).

Professional search tasks are also characterized by the application of domain expertise. Liu & Wacholder, (2017) highlight the key role of domain expertise in adequately exploiting controlled indexing vocabularies such as MeSH. Similarly, Tamine & Chouquet (2017) demonstrate the role that domain expertise plays, not only in the lexical representation of information needs, but also in the perception of relevance. Likewise, Verberne et al. (2013) highlights the role of domain expertise and the diversity of information sources that need to be consulted. For example, a patent attorney may need to consider not only published patents but also technical material published online and in research databases.

List, (2013) describes the pressure placed on professional searchers, enumerating the demands placed upon them as follows:

- Confidentiality: the search process and its outcomes are stored securely and not disclosed to potential competitors;
- Timeliness: the evidence gathered is up to date and not superseded by more recent work;
- Repeatability: the search strategy and its outcome may be reproduced by colleagues;
- Transparency: the process is open to scrutiny by others who can see why certain results have been returned, and;
- Comprehensive: all relevant results are returned for a specific information need.

In contrast to the standard types of search tasks (Broder, 2002), i.e. navigational, informational or transactional, the nature of professional search tasks is decisional: that is, a decision needs to be made based on the evidence arising from the search. For

example, in recruitment search, the professional needs to select and decide between candidates, while in healthcare information, the professional needs to provide a recommendation to support evidence-based decision making. As previously mentioned, the ramifications of the decisions made often have significant consequences.

In this paper, we investigate four of the six professional search contexts discussed above that share a need to formulate complex search strategies using proprietary databases and tools: legal research, recruitment search, healthcare information search, and patent search. We briefly describe each of these in the following subsections.

2.1 Legal research

Legal research is the process of identifying and retrieving information necessary to support legal decision-making (Mersky & Dunn, 2002). It is typically performed by lawyers (otherwise known as attorneys), law librarians and paralegals, with the goal of gathering evidence to provide an answer to a legal question or to provide evidence to support a particular legal position or argument. It involves consultation of a range of resources, including primary sources (such as cases, statutes and regulations), secondary materials (such as treatises, practice guides and reviews) and also non-legal sources (Barkan, Bintliff, & Whisner, 2015).

While some law firms offer generalist services, many specialize in a particular practice area, e.g. employment, insurance, corporate, etc. In addition, their practice may be focused on litigation (i.e. dispute resolution) or transactional law (e.g. contracts, deals and doing business). The need to perform extensive research on a legal issue is usually greater in litigation practice as this is more closely associated with finding evidence to support a position and provide the basis for a legal argument.

Figure 1: An example Boolean query used to conduct a legal database search.

```
express! or explicit! or specific! or directly w/25
third w/5 beneficiary w/25 contract or agreement or
clause or terms or provision w/25 "not" or
inappropriat! or unnecessar! or redundan! or no or
never w/15 third party w/5 beneficiar! w/5 standard
or test or factor or element or criteria
```

The databases they use include WestLaw Next[2], Lexis Advance[3], as well as other sources including subscription products specific to their practice area, freely available resources such as web search engines and government-run websites. Searching is typically performed by combining keywords and operators to create a single, complex Boolean string (an example from our survey data is shown in Figure 1).

Various studies have been performed investigating legal information seeking behavior. Vollaro & Hawkins (1986) conducted interviews with patent attorneys at the AT&T Bell Laboratories, finding that they had difficulty in choosing appropriate search terms, remembering the special features of each resource, not knowing when all possible avenues had been pursued and forgetting commands. Similarly, Yuan (1998) monitored the LexisNexis Quicklaw searches of a group of law students over a year and found that search experience affected several aspects of end-user behavior, including the increase of participants' command and feature repertoires, increase of search speeds, and change of learning approaches. However, experience did not result in searchers making fewer errors or being helped to recover from errors.

A number of more recent studies have focused on analyzing legal information seeking in order to inform the design of legal information systems. For example, Kuhlthau & Tama (2001) conducted structured interviews with eight practicing lawyers to understand how they acquire and use information and how the stages of their information-seeking tasks fit together. The authors noted that the lawyers followed a process similar to that of the Kuhlthau's Information Search Process model (Kuhlthau, 1999), and a key requirement they identified was the need for a tool to aid the organization of files and the tracking of cases, as well as facilitating the storage (and potentially re-use and sharing) of information on individual practice areas.

[2] https://next.westlaw.com, accessed December 2017.
[3] https://advance.lexis.com, accessed December 2017.

Similarly, Jones (Jones, 2008) analyzed transcripts and videotapes of lawyers working in an academic Legal Aid clinic and examined their LexisNexis and Westlaw search logs and documents produced. Jones suggested that future systems designed to support such lawyers should focus on the social nature of legal information-seeking by acting as online repositories to facilitate the sharing, annotation and tagging of documents so they can be located more easily for re-use. Makri, Blandford & Cox (2008) investigated the application of Ellis's model (Ellis, 1993) to legal information seeking and found similar behaviors to those found by Ellis (e.g. chaining, browsing, differentiating, etc.) , along with several that were not identified in previous studies such as 'updating' which the authors argue is particularly pertinent to legal information-seeking.

2.2 Recruitment search

Recruitment is the process of finding and attracting capable applicants for employment. While there has been considerable research examining how individuals search for jobs and the search behavior of such individuals (Andrews, Bradley, Stott, & Upward, 2008; Bretz, Boudreau, & Judge, 1994; Jansen, Jansen, & Spink, 2005) there has been little research investigating the needs and requirements of the professionals in retainer and search firms.[4] Such professionals are proactive, performing outbound activities to facilitate hiring (which is often referred to as sourcing), as opposed to being reactive i.e. managing inbound responses to specific job postings (Sherman, Stone, & Thornton, 2006). In this study, we focus on search professionals that perform sourcing, where the recruiters are looking to find the best available candidate, often with unusual skills or the candidate that has the "right chemistry" for the organization (Dingman, 1993).

When performing sourcing, recruiters will typically create and execute queries by adding keywords and clauses to a single, complex Boolean string (Russell-Rose &

[4] Retainer and search firms who perform specialized services to source high skilled and high-level candidates (proactive) as opposed to employment agencies which tend to manage and match candidates to job postings (reactive).

Chamberlain, 2016). Figure 2 provides an example from our survey data of a query for individuals that have specialist expertise in Java software development.

Figure 2: An example recruitment search query.

```
Java AND (Design OR develop OR code OR Program) AND
("* Engineer" OR MTS OR "* Develop*" OR Scientist
OR technologist)
AND (J2EE OR Struts OR Spring) AND (Algorithm OR
"Data Structure" OR PS OR "Problem Solving")
```

Given a potential candidate, the recruiter also needs to take into account contextual variables such as availability, previous experience, remuneration, etc. The primary data sources for recruiters tend to be job boards such as Monster[5], CareerBuilder[6] and Indeed[7], although social networks such as LinkedIn, Twitter and Facebook are also commonly used (Russell-Rose & Chamberlain, 2016). The professional recruiter must also qualify and disambiguate the returned results (Balog, Fang, Rijke, Serdyukov, & Si, 2012), and then apply additional factors to select a smaller group of qualified candidates.

2.3 Healthcare information search

Healthcare information professionals perform a variety of search tasks (Collins, Coughlin, Miller, Kirk, & Joint Water Evidence Group, 2015; Hersh, 2003). These include:

- Literature reviews: have been the traditional response to enquiries where the aim is to provide an overview of a subject or answer specific questions.
- Scoping reviews: are performed to assess how much information exists about a particular topic (e.g. the size and type of evidence available) and to provide insights into the nature of that information. Often this is an

[5] www.monster.com/, accessed December 2017.
[6] www.careerbuilder.co.uk/, accessed December 2017.
[7] www.indeed.co.uk/, accessed December 2017.

antecedent to a more comprehensive search, to understand the state of the art or identify future trends.

- Rapid evidence reviews: extend a scoping review by additionally providing a critical appraisal of the evidence returned prior to answering the questions posed.
- Systematic reviews: serve as the definitive search task, by synthesizing the complex, incomplete and at times conflicting findings of biomedical research into a form that can readily inform healthcare decision making (Elliott et al., 2014). They are conducted through a robust but resource-intensive process (Tsafnat et al., 2014), which requires painstaking and meticulous searching of multiple literature sources.

The databases they use include MEDLINE[8], Cochrane Library[9] and Embase[10] and various other sources such as the open web and 'grey literature' (information that is created outside of commercial or academic publishing and distribution channels). Searching is typically performed using complex multi-line expressions that can consist of hundreds of keywords, operators and ontology terms, such as the example shown in Figure 3 (Karimi, Pohl, Scholer, Cavedon, & Zobel, 2010).

Figure 3: An example healthcare information search strategy.

```
1. Attention Deficit Disorder with Hyperactivity
2. adhd
3. addh
4. adhs
5. hyperactiv$
6. hyperkin$
7. attention deficit$
8. brain dysfunction
9. OR/1-8
10. Child/
11. Adolescent/
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[8] https://www.nlm.nih.gov/bsd/pmresources.html, accessed December 2017.
[9] http://www.cochranelibrary.com, accessed December 2017.
[10] https://www.elsevier.com/solutions/embase-biomedical-research, accessed December 2017.

```
12. child$ or boy$ or girl$ or schoolchild$ or
    adolescen$ or teen$ or "young person$" or
    "young people$" or youth$
13. OR/10-12
14. acupuncture therapy/or acupuncture, ear/or
    electroacupuncture/
15. accupunct$
16. OR/14-15
17. 9 AND 13 AND 16
```

These multi-line expressions, known as search strategies, are one of the fundamental building blocks of the systematic review process. Their sequential structure reflects the line-by-line, form-filling nature of the query builders offered by the majority of proprietary databases.

Numerous studies have been performed to investigate the healthcare information search process and to better understand the challenges involved. For example, Grant (2004) used a combination of a semi-structured questionnaire and interviews to study researchers' experiences of literature searching, with particular reference to the use of optimal search strategies (OSS). They found that the rigor and availability of OSS was a concern for 30% of respondents, with reservations expressed about their ability to facilitate a comprehensive search, and a belief that OSS can reduce the sensitivity of a search and might limit the breadth of coverage required. McGowan et al. (2016) used a combination of a web-based survey and peer review forums to investigate what elements of the search process have the most impact on the overall quality of the resulting evidence base and to develop guidelines for Peer Review of Electronic Search Strategies (PRESS). The results suggested that structured PRESS could identify search errors and improve the selection of search terms, and that the guidelines should focus on six key aspects: translation of the research question; Boolean and proximity operators; subject headings; text word search; spelling, syntax and line numbers; and limits and filters.

Other studies have focused on healthcare information seeking as part of a broader literature review process. For example, Gillies et al. (2009) used an online survey to investigate the systematic review process, with a view to identifying problems and

barriers and to improve the overall process for healthcare information professionals. They found that problems were identified through all stages of the review process, with reviewers relying on support from local colleagues particularly for advice on statistics and analysis. More recently, Ciapponi & Glujovsky (2012) used an online survey to study the early stages of systematic review, focusing on the time spent on tasks and the support provided by software applications. They found that the efforts of most review authors are fragmented across generic word processing, spreadsheet, email, reference management, and statistical analysis tools.

2.4 Patent search

The work of patent professionals can be divided into three main categories (Bonino, Ciaramella, & Corno, 2010): search; analysis; and monitoring. Within the first category, there are a variety of different search tasks (Joho et al., 2010), for example:

- State of the art: identify patents for the purposes of a general review;
- Novelty: identify literature which may affect the patentability of an idea/invention;
- Patentability: to ensure novelty of a given patent application;
- Infringement: identify patents, which cover the proposed product or process and are still in force;
- Opposition: identify literature to show lack of novelty or inventive step of a granted patent;
- Freedom to operate: like infringement, but also includes non-patent literature;
- Due Diligence: analyze strengths, weaknesses and scope of IP rights.

Some of the tasks require searching of patent databases while others require a more general search of patent and non-patent literature (see (Hansen & Järvelin, 2005) and (Salampasis & Hanbury, 2013) for details of the workflow). Examples of such databases include Thomson Innovation[11] and PatentScope.[12] Although these tasks are

[11] http://info.thomsoninnovation.com/, accessed December 2017.

undertaken with varying goals in mind, they are typically executed using complex, multi-line search strategies consisting of keywords, operators and ontology terms, such as the example shown in Figure 4 (from the survey data).

Figure 4: An example patent search strategy.

```
1. A01N0025-004/CPC
2. RODENT OR RAT OR RATS OR MOUSE OR MICE
3. BAIT OR POISON
4. 2 AND 3
5. 1 OR 4
6. AVERSIVE OR ADVERSIVE OR DETER? OR REPEL?
7. NONTARGET OR (NON WITH TARGET) OR HUMAN OR
   DOMESTIC OR PET OR DOG OR CAT
8. 6 AND 7
9. 8 AND 5
10.    BITREX OR DENATONIUM OR BITREXENE OR
   BITTERANT OR BITTER
11.    10 AND 5
12.    9 OR 11
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A number of studies have investigated patent information retrieval tasks. Joho et al. (Joho et al., 2010; Azzopardi, Vanderbauwhede, & Joho, 2010) conducted a survey of the information retrieval practices of patent search professionals to better understand the context of the patent search. They found that patent searching is highly interactive and iterative and requires support for the combination, organization and management of the query and the results sets. In addition, patent analysts preferred search functionality which provided control over how the query is formulated in order to return sets of results rather than fuzzy ranking / weighting-based approaches which return a ranked list. Hansen & Järvelin (2005) further detailed the workflow of patent professionals with a survey that focused on the collaborative nature of the work. They

[12] https://patentscope.wipo.int/search/en/search.jsf, accessed December 2017.

also highlight the importance of the need to store and manage queries and searches so that they can be used, shared and refined among collaborators.

3. Research questions

Despite a growing interest in developing tools and techniques for professional search, most previous studies have focused on a single profession or domain (Hanbury & Lupu, 2013). As a result, there has been very little work that investigates multiple professions (Salampasis & Hanbury, 2013), and it remains unclear whether insights and approaches from one domain can be applied more broadly or whether each community is fundamentally different, requiring domain-specific, bespoke solutions (Hanbury & Lupu, 2013). The work in this paper attempts to bridge this gap by comparing the information retrieval practices of four different professions using a common survey instrument and methodology with the goal of better understanding how and where insights and innovations from one domain may be applied to another. Our specific research questions were:

1. To what extent do individuals working in different professions share common search practices and goals?
2. Where do those practices differ, and how?
3. How can we use these commonalities and differences to inform the design of next generation information retrieval systems?

4. Method

In this study, we apply a survey instrument derived from Joho et al. (Joho et al., 2010) and perform a purposive survey of legal, healthcare information, and recruitment professionals. The use of a survey methodology offers a way to obtain a broad, qualitative and quantitative overview of similarities and differences before committing to more in-depth studies with participants. In this respect, our focus is on what Järvelin & Ingwersen (2004) describe as the "*perceived search task dimension*"

of information seeking and retrieval research. We then compare our findings with those of Joho et al. (Joho et al., 2010).

Since some of survey questions in Joho et al. (Joho et al., 2010) were phrased with respect to the language in the patent domain (i.e. sector specific) and only applicable to the patent profession, where appropriate, these were re-phrased to address a comparable issue in each profession or were otherwise omitted. The final survey instrument[13] consisted of an online questionnaire of 40 questions divided into five sections:

- Demographics: The background and professional experience of the respondents, including age, gender, education, role, job title, and client type.
- Search tasks: The types of search task that respondents perform in their work, how often they perform them, and what resources they use.
- Query formulation: How respondents construct search queries and what types of functionality they find valuable.
- Results evaluation: How respondents assess and evaluate the results of their search tasks, and the challenges this entails.
- Ideal search engine: Respondents' views on any other features and functions additional to those described above.

The online survey took participants 15-20 minutes to complete. Each version of the survey began with a qualifying question to screen out non-members of each target audience. Prior to administering the surveys, a series of qualitative interviews with representatives from each profession was conducted to refine and validate each version.

For legal researchers, the survey was distributed using the LexTalk[14] community, an open forum managed by LexisNexis "for those serving in the legal profession". The invitation described the eligibility criteria, expected time to complete the survey, and its purpose. Data were collected from April to May 2017. 108 responses were received, of which all were complete.

[13] https://www.surveymonkey.com/r/LitRevBlo, accessed December 2017.
[14] https://www.lextalk.com, accessed December 2017.

For recruitment professionals, a link was posted to the survey on social media (e.g. on LinkedIn) and additionally we engaged the services of SurveyMonkey Audience[15], who administered it to their panel of HR professionals. Data were collected from June to August 2016. 416 responses were received, of which 69 were complete. The majority of incomplete responses were due to participants failing the qualifying question. Five other responses were eliminated due to nonsensical answers, which left 64 complete responses.

For healthcare information professionals, an invitation was sent to five mailing lists that are frequently used within that community: Lis-Medical[16]; Clinical librarians[17]; Evidence-based health[18]; Expert searching[19]; and the Cochrane IRMG.[20] It was also sent to the Healthcare Libraries group of the Chartered Institute of Library and Information Professionals (CILIP).[21] The invitation described the eligibility criteria, expected time to complete the survey, its purpose, and funding source. Data were collected from July to September 2016. 218 responses were received, of which 107 were complete.

The patent survey responses were provided by Joho et al. (Joho et al., 2010), which was sourced by emailing two patent user group mailing lists: the Confederacy of European Patent Information User Groups (CEPIUG) and the International Patent Information Users Group (PIUG).[22] In total, these lists have over 700 members from over 27 different countries, and of these members, approximately 300 are patent information specialists. They received 81 responses in total to the survey.

Only complete surveys were examined. Text responses corresponding to numerical questions were cleaned as follows:

[15] https://www.surveymonkey.com/mp/audience, accessed December 2017.
[16] https://www.jiscmail.ac.uk/cgi-bin/webadmin?A0=lis-medical, accessed December 2017.
[17] https://www.jiscmail.ac.uk/cgi-bin/webadmin?A0=CLIN-LIB, accessed December 2017.
[18] https://www.jiscmail.ac.uk/cgi-bin/webadmin?A0=EVIDENCE-BASED-HEALTH, accessed December 2017.
[19] http://pss.mlanet.org/mailman/listinfo/expertsearching_pss.mlanet.org, accessed December 2017.
[20] http://methods.cochrane.org/irmg/welcome, accessed December 2017.
[21] http://www.cilip.org.uk/about/special-interest-groups/health-libraries-group, accessed December 2017.
[22] https://www.piug.org, accessed December 2017.

- When the respondent specified a range (e.g. 10-20 hours), the midpoint was entered (e.g. 15 hours);
- When the respondent indicated a minimum (e.g. 10+ years), the minimum was entered (e.g. 10 years);
- When the respondent entered an approximate number (e.g. about 20), that number was entered (e.g. 20).

5. Results and analysis

5.1 Demographics

The conflated ages of the participants were: healthcare information (M=45.9 SD=10.9), patent (M=45.1 SD=11.3), legal (M=40.3 SD=8.8) and recruitment (M=40.1 SD=12.9). In terms of gender, 86.4% of healthcare information participants were female, more than participants in recruitment (68.8%), legal (48.6%) and patent (41.9%). All four sectors were similar in that respondents mostly worked full time (legal 92%, recruitment 91%, patent 91%, healthcare information 86%). However, the clients that they worked for varied considerably: healthcare information and patent professionals mainly worked for internal clients, i.e. within the same organization (72.9% and 67.9% respectively) compared to legal researchers and recruitment professionals (22.2% and 34.4% respectively) who worked more for external clients.

Table 1 shows the most common job titles in each of the four groups, along with their counts, sorted in descending order. This provides some insight into the roles performed by the individuals completing each survey. The job titles for patent and recruitment showed particularly high variation (forming a 'long tail' distribution).

Table 1: Most frequent job titles for respondents in each group.

Legal	*Recruitment*	*Healthcare Info*	*Patent*
47.2% (51/108)	15.3% (9/59):	21.4% (23/107)	16.0% (13/81)
Associate	Recruiter	Librarian	Patent Information

			Specialist
25.0% (27/108) Partner	8.5% (5/59): HR Manager	13.1% (14/107) Information Specialist	6.1% (5/81) Patent Analyst
14.8% (16/108) Librarian	6.8% (4/59): HR Generalist	6.5% (7/107) Medical librarian	4.9% (4/81) Patent Engineer; Patent Information Analyst; Research Engineer

Professionals all had a similar average (mean) years' experience in their current role: legal (M=13.9 SD=7.8); recruitment (M=11.3 SD=8.5); healthcare information (M=12.0 SD=9.1); and patent (M=10.2 SD=8.7). Their experience within industry was more varied: healthcare information (M=16.6 SD=10.0); legal (M=12.8 SD=8.5); recruiters (M=12.1 SD=8.7); and patent professionals (M=10.9 SD=9.0). More revealing is the difference between experience in the role and in their industry, with healthcare information professionals having (on average) worked in this sector much longer than they have in their current role.

5.2 Search tasks

In this section we asked respondents to indicate the amount of time they spent completing their most frequent search task and the number of queries they used. We considered a search task in this context to be the creation of one or more queries or strategy lines to search a specific collection of documents or database, with task completion resulting in a set of search results that will be subject to further analysis. It was expected that this interpretation would also be shared by participants in the context of their professional role (see (Vakkari, 2005)) but some misinterpretation may have been evident (as discussed later).

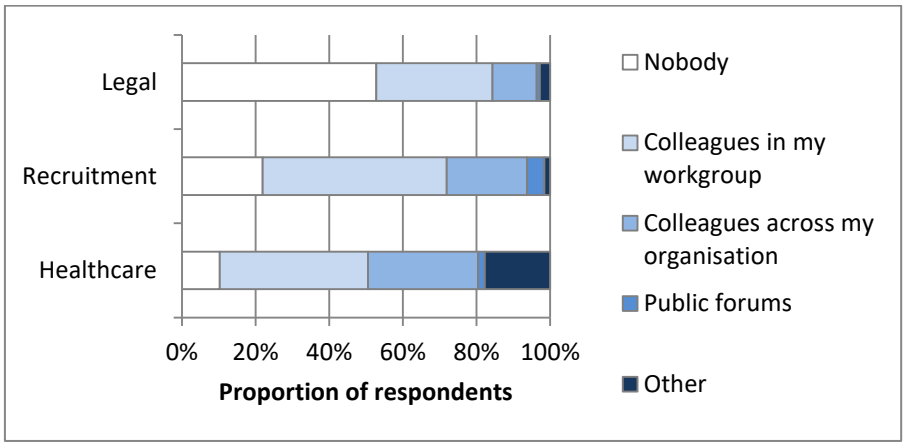
Table 2: Average (median) search effort, with inter-quartile range in parentheses, of respondents in legal, recruitment, healthcare information and patent domains.

	Legal	*Recruitment*	*Healthcare Info*	*Patent*
Search task completion time (hours)	0.3 (0.1-0.5)	3.0 (1.5-5.0)	4.0 (2.0-6.5)	12.0 (6.0-24.0)
Number of queries	3.0 (2.0-3.5)	5.0 (3.3-10.0)	15.0 (9.1-30.0)	15.0 (6.5-25.0)

The median task completion times vary from 15 minutes (legal) to 12 hours (patent), reflecting the iterative search paradigm of searching in these professions, with successive phases of document search combined with other activities such as analyzing results, exporting documents, collecting citations, etc. (see Table 2). The time to complete search tasks varied by profession ($F(3,345)=21.398$, $p<0.01$, one-way ANOVA), with the average time for patent professionals (Mdn=12.0, M=17.4, SD=17.6) being significantly longer than legal, (Mdn=0.3, M=0.6, SD=1.6), recruitment (Mdn=3.0, M=5.0, SD=6.5) and healthcare information professionals (Mdn=3.5, M=8.0, SD=20.6).

The number of queries used also varied by profession ($F(3,345)=16.951$, $p<0.01$, one-way ANOVA), with the average for legal (Mdn=3.0, M=4.1, SD=26.5) and recruitment (Mdn=5.0, M=9.9, SD=11.4) being much lower ($p<0.01$, unpaired t-test) than both healthcare information (Mdn=15.0, M=23.5, SD=22.4) and patent (Mdn=15.0, M=26.4, SD=42.5) professionals. There was no difference between the number of queries used in healthcare information and patent searches ($p=0.553$, unpaired t-test). This difference between sectors is likely to be influenced by the methodology employed: in healthcare information and patent search, independent strategy lines are combined to create an overall composite search strategy. However, for legal and recruitment, queries are generally expressed as a single, complex Boolean string, and in this context, the count represents successive iterations on a given query string.

Figure 8: Proportion of respondents who share their search strategies in different ways. This question was not asked in the patent survey.



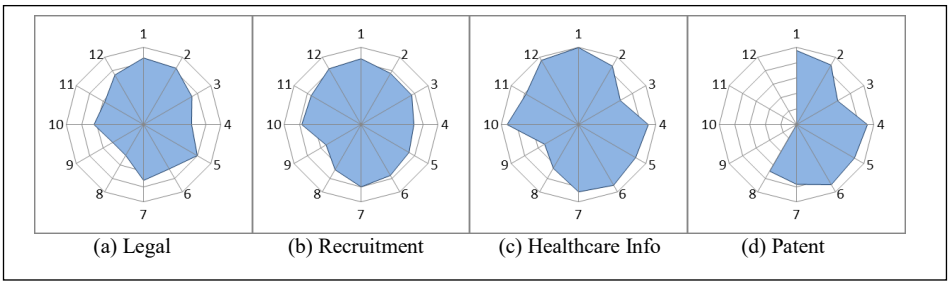
There is also a significant difference in the degree of collaboration within sectors, with healthcare information and recruitment sharing their search strategies more readily than legal professionals ($\chi^2(15, N = 279)=68.179$, $p<0.01$), see Figure 8 (this question was not asked in the patent survey). This reflects the high value placed on client confidentiality for legal professionals, and the fact that search strategies are often published as part of the output of a healthcare information search.

5.3 Query formulation

In this section we explore the importance of various functions employed in formulating a query. We asked respondents to indicate their level of agreement to statements using a 5-point Likert scale ranging from strong disagreement (1) to strong agreement (5). The questions were typically phrased as "use of <X> is important to formulate effective queries". Summary results are shown in Figure 9 as a radar diagram using a weighted average across responses (full results are presented in Appendix I).

Firstly, with the exception of query translation, the average of all features is above 3 (neutral) on the Likert scale, suggesting that all professions value a wide range of search functionality to complete their tasks.

Figure 9: Radar diagrams for (a) legal, (b) recruitment, (c) healthcare information and (d) patent sectors showing the value placed on search functionality during query formulation, including Boolean logic (1), proximity operators (2), relevance ranking (3), truncation (4), wildcards (5), field operators (6), query expansion (7), query translation (8), case sensitivity (9), abbreviations (10), misspellings (11) and synonyms (12). The patent survey did not include 9-12.



Secondly, the use of Boolean logic was the number one criterion for formulating effective queries across all professions. It is particularly high for patent and healthcare information professionals, which reflects a need for transparent and repeatable search behavior, and an associated requirement to demonstrate due diligence and accountability for their search practices. Recruiters and legal researchers, by contrast, are not subject to the same degree of regulatory constraint surrounding their search practices, although they do share a need to articulate complex queries that are portable across different databases.

This need is also reflected in a number of other syntactic features, notably proximity operators, truncation and wildcarding. All of these scored highly for both patent and healthcare information search, underlining their shared need for fine control over their search strategies and an advanced level of sophistication offered by the databases they consult.

Field operators were also found to be highly important to patent and healthcare information professionals. This most likely reflects the use of controlled indexing vocabularies (such as IPC codes and MeSH terms respectively) and the structured metadata of the documents with which they are associated. Recruiters also employ fielded lookups, although this is usually to restrict searches to specific elements

within a webpage or to exploit advanced search operators offered by social networks and other proprietary websites (e.g. LinkedIn's search operators include current company, past company, title, school, industry, etc.). Query expansion was scored most highly by the healthcare information professionals, perhaps reflecting the common availability of taxonomic metadata within this profession.

In contrast to the typical behavior of web searchers (Yin et al., 2016), relevance ranking was seen as least important by both patent and healthcare information professionals, and is the only feature which was scored higher by legal researchers and recruiters. This suggests that the benefit of sorting results by relevance may be outweighed by a potential lack of transparency and repeatability in the ranking algorithm. However, for recruiters and legal researchers, these criteria are less problematic, and weighting may offer greater value in prioritizing the heterogeneous results returned from multiple sources with varying metadata and degrees of curation.

Query translation was considered least important overall, particularly to legal researchers who typically work within a given jurisdiction and one language.

5.4 Search results evaluation

In this section we examined respondents' behavior when evaluating search, by asking them to indicate the number of results they examine and the amount of time they spend evaluating each result, see Table 3. Despite the variance in number of results examined the difference was not significant ($F(3,340)=1.464$, $p=0.224$, one-way ANOVA). However, the number of results examined by healthcare information professionals (Mdn=175, M=723.9, SD=1,555.2) was significantly higher than for legal (Mdn=21, Mean=43.4, SD=81.9) and recruitment professionals (Mdn=30, M=1,911.9, SD=12,738.9). This difference reflects a high value placed on recall and an obligation to ensure that the search process is comprehensive and not biased by easily accessible documents (Tsafnat et al., 2014). Conversely, legal researchers and recruiters are more interested in precision, evaluating only as many results as are required to create a shortlist of suitable candidate documents. One reason the average for patent (100) is lower than for healthcare information search may be that for certain

types of patent search task (e.g. an invalidity or freedom-to-operate search), finding a single 'knock out' document may be all that is required.

Table 3: Average (median) search results evaluation, with inter-quartile range in parentheses, of respondents in legal, recruitment, healthcare information and patent domains.

	Legal	*Recruitment*	*Healthcare*	*Patent*
Number of results examined	21 (10-50)	30 (10-100)	175 (75-500)	100 (30-300)
Time examining each result (mins)	5 (3-15)	5 (2-23)	3 (1-5)	5 (1-10)

The time taken to assess the relevance of a single result varied by profession ($F(3,342)=5.144$, $p<0.01$, one-way ANOVA), with healthcare information professionals taking less time (Mdn=3, M=6.0, SD=10.1) on average. One explanation for this may be that with greater numbers of documents to examine, there is simply less time available to scrutinize each one. However, for healthcare information professionals the search task is often part of a longer process in which the retrieved documents are exposed to further phases of analysis and evaluation involving other colleagues and reviewers. In this context, the time to assess relevance may reflect the dynamics of the initial sift, rather than the overall attention given to a document.

5.5 The ideal search engine

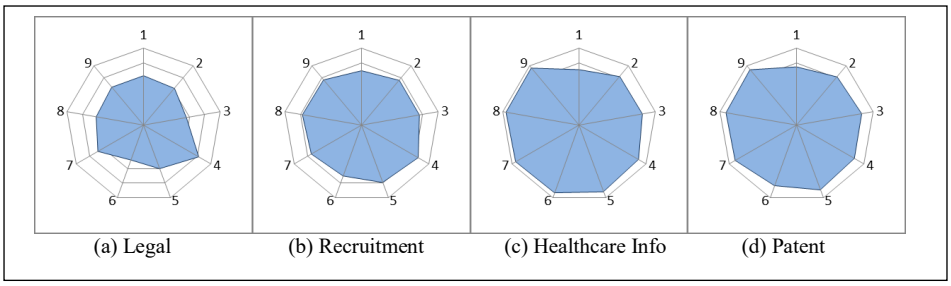
In this section we examine other features that respondents found important in helping them complete their search tasks. As before, we asked them to indicate a level of agreement to statements using a 5-point Likert scale. Summary results are shown in Figure 10 as a radar diagram with a weighted average across responses (full results are presented in Appendix II).

The average of almost all features is above 3 (neutral) on the Likert scale, suggesting that the respondents value a wide range of functionality from search systems. The patent and healthcare information professionals agreed on the three most important features and ranked them in the same order: combining search queries, combining search results, and recording search histories. This reflects the line-by-line strategy building approach offered by most proprietary databases and its status as the dominant query formulation paradigm within both professions.

The healthcare information professionals rated the ability to export search queries (histories) higher than the other professions, possibly reflecting their need to publish completed search strategies as part of their professional practice.

The aspect that legal researchers and recruiters both ranked as most important was recency of retrieved results, reflecting their need to have confidence that the resources they are retrieving are up to date. Conversely, the feature which they both ranked as least important was exporting search queries, suggesting that their value is more ephemeral, with fewer opportunities for re-use.

Figure 10: Radar diagrams for (a) legal, (b) recruitment, (c) healthcare information and (d) patent sectors showing the value placed on features of search systems, including storing search results with an expiry date (1), alerting functions (2), saving custom lists from search results (3), recency of retrieved results (4), organizing search queries (5), exporting search queries (6), search history (7), combining multiple search results (8) and combining search queries (9).



With the exception of the two time-oriented features (recency of retrieved results and storing search results with an expiry date) the scores for the legal researchers are

lower than those of all the other professions. This suggests that although their search tasks and queries are both complex, they find less value in advanced search features and options.

6. Discussion

In this section we return to our original research questions and the broader implications of the study. We also include verbatim comments from the survey (shown in italics) to provide examples of how a thematic analysis of the qualitative data might inform the next generation of information retrieval systems.

Although the four professions represent distinct, largely non-overlapping communities, we found several practices in common. All four professions undertook complex search tasks that were inherently interactive, with successive phases of document search combined with other activities such as analyzing results, exporting documents, collecting references etc. The duration of these tasks was substantially longer than typical web search (Broder, 2002), with median task completion times varying from 20 minutes to 12 hours. With the exception of query translation, all professions valued a wide range of functionality for query formulation. This represents a marked contrast to the behavior of typical Web searchers who rarely, if ever, use any advanced search functionality (Spink, Wolfram, Jansen, & Saracevic, 2001) and is in line with previous studies of professional librarianship search (Jankowski, 2016). Evidently, this contrast may not be entirely unexpected given the nature of professional search tasks compared to web search, but it does further underline the difference between the two search contexts.

The use of Boolean logic was the number one criterion for formulating effective queries across all professions, and all professions found value in a wide range of search system functionality. In addition, the patent and healthcare information professionals agreed on the three most important features and ranked them in the same order: combining search queries, combining search results, and recording search histories.

In addition to the above commonalities, we also found significant differences. For example, patent and healthcare information professionals develop composite search strategies to complete search tasks that take longer than those of recruitment and legal research, and also examine a greater number of results. Patent professionals also spend more time completing search tasks than the other professions. Patent and healthcare information professionals also use more queries per task than legal researchers and recruiters, which reflects their shared practice of combining independent queries to create a composite search strategy.

The query formulation features that patent and healthcare information professionals valued most highly were proximity operators, truncation, wildcarding and field operators. The feature they valued least was relevance ranking. This suggests that the benefit of sorting results by relevance may be outweighed by a potential lack of transparency and repeatability in the ranking algorithm, and further underlines the recall-oriented nature of their search tasks. Conversely, for recruiters and legal researchers, their search behavior is more precision-oriented, and ranking may offer greater value in prioritizing the heterogeneous results returned from multiple sources with varying metadata and degrees of curation. The least valued feature for legal and recruitment professionals was query translation, which reflects the regional nature of these professions.

The healthcare information professionals rated the ability to export search queries (histories) higher than the other professions. By contrast, the feature that legal researchers and recruiters ranked as most important was recency of retrieved results. This highlights the reassurance that legal researchers seek that their argumentation is based on current law, and for recruiters that their candidate profiles are as up to date as possible.

We now reflect on the implications of these results for the design of next generation information retrieval systems, using verbatim responses as illustrative examples. Despite the increasing sophistication of relevance ranking algorithms, Boolean search remains the primary means for completing the majority of professional search tasks. The qualities of transparency, repeatability and auditability remain dominant, and support for recall-oriented, incremental strategy development remains critical, particularly for patent and healthcare information professionals. This

creates opportunities for improved support for the management and sharing of search strategies: *"...being able to download, share, remix, transfer and translate search strategies"*. It also suggests opportunities for better query formulation support:

- Syntax checking: *"...automate checking of parentheses, operators and field codes..."*;
- Truncation: *"Wildcards at beginning of words; wildcard within a word (to replace a single or multiple letters e.g. $sthetic or wom$n"*;
- Misspellings: *"...account for misspellings..."* and *"UK/American spelling..."*;
- Proximity: *"...interpreting proximity within sentence rather than crossing punctuation limits."*

The numerous strategies for expanding or restricting queries to return a comprehensive results set are often not available to the searcher for a particular database causing frustration (Jankowski, 2016) and more support for query formulation has been previously proposed (Wacholder, 2011).

Patent and healthcare information professionals commonly work across multiple databases, so there is a need for greater standardization and consistency between suppliers: *"A service that could map search strategy between databases would save a lot of time"*, and a need for support when translating strategies between terminologies, ideally with *"one universal thesaurus of medical terminology for all databases"*. The re-use of search strategies also suggests an opportunity for community sharing (Hansen & Järvelin, 2005) and the use of search filters or templates to promote best practice (Glanville et al., 2008). However, a key concern for patent searchers is privacy, and the reassurance that their searches are secure using *"a secure connection and uncompromised privacy"*.

Patent searchers also expressed a need to be able to search for images, drawings, chemical structures, and mathematical expressions within patents. Organization and management of search results were also identified as being vital, suggesting features such as *"a way to quickly sort the search results into keep or discard"* or *"being able to apply your own custom classification to a number of documents"*.

In contrast with patent and healthcare information searchers, recruitment and legal research is characterized by more precision-oriented, satisficing strategies. For recruiters, the objective is to identify a sufficient number of candidate documents in the shortest possible time *"Generally speaking, it's a trade-off between time and quality of results"*. Recruiters would also benefit from improved support for term selection: *"The specific job is so new I cannot find terms used on resumes to match"*.

For legal researchers, however, the challenge is knowing that their results are both recent and trustworthy: *"The most important is trustworthiness… Reviewing the status of a search result, as in if it has been overruled, repealed, etc."*

6.1 Limitations

The approach used in this study was motivated by the observation that it is more productive to investigate the relationships between characteristics of the users and their queries, rather than the effectiveness of queries themselves (Wacholder, 2011). Hence one of the main limitations of this study is the use of the survey methodology, in that self-reported behavior may not always correspond with actual observed behavior. A further limitation is the overall size of each sample, and the variation in sample sizes between groups, both of which may affect the validity and generalizability of the results. Although the total number of respondents compares favorably with previous studies, the individual sample sizes are insufficient to allow reliable further stratification, e.g. by educational background. This would allow us to separate the influence of formal academic training (e.g. in information science or librarianship) on the observed search behavior and preferences. This is suggested as an item for future work.

A further challenge is the difficulty in administering a common survey instrument across different professions. Sector-specific differences mean that a given question may be interpreted in different ways by those professions, and so care must be taken to ensure that the interpretation remains as consistent as possible across groups. For example, recruiters and legal researchers refer to the product of the query formulation process as "search strings", whereas patent and healthcare information professionals

refer to “search strategies” consisting of “strategy lines”. In the design of this study, we paid particular attention to these sector specific differences, which meant that only a subset of the questions in the original study could be used (Joho et al., 2010). While this precluded us from probing more deeply into the other three professions, it did enable us to meaningfully compare results across all four professions.

There are also differences of interpretation due to the context. The search practices of legal researchers, for example, bear the closest resemblance to the classic notions of web search: individual query strings that are iteratively refined in pursuit of an increasingly precise set of results obtained from a variety of sources, within the context of a task that is considered complete when certain satisficing conditions are met. By contrast, patent and healthcare information professionals employ line-by-line query builders to exhaustively search curated resources, within the context of a task that is considered complete when the strategy is deemed sufficiently comprehensive, transparent and repeatable. Despite this and the above limitations, we believe we put in place sufficient mitigation strategies to allow the findings from each survey to remain broadly comparable across professions.

Finally, our original aim with this study was to investigate a fifth profession: that of media monitoring professionals. These individuals provide clients with copies of media content that is of specific interest to them, by creating and executing complex Boolean search strategies applied to proprietary databases and tools. We followed a similar methodology, distributing a version of the survey via social media interest groups and through SurveyMonkey Audience. However, reaching suitably qualified individuals in this profession proved to be significantly more difficult, and the data we obtained was of much lower quality with many incomplete and contradictory responses. It was therefore excluded from further analysis in this study.

7. Conclusions

This paper describes the results of a study of the information retrieval practices of four different professions. As such, it is the first study of its type, applying a common survey instrument and methodology to allow their search practices to be directly

compared. The results reveal that these professions share many fundamental needs and face similar challenges; in particular a continuing preference to formulate queries as Boolean expressions, the need to manage, organize and re-use search strategies and results and an ambivalence toward the use of relevance ranking. However, they differ in the priority that they give to certain features and functions given the domain and task. For example, legal and recruitment professionals tend to be more precision-oriented, whereas health and patent search professionals tend to be more recall-oriented.

Much of the research effort in the information retrieval community continues to assume that searches are formulated using natural language (Tait, 2014). However, our results provide evidence that many professional searchers continue to prefer to formulate queries as Boolean expressions. Moreover, even relevance ranking, so often seen as the '*core problem of a commercial search engine*' and the focus for '*thousands of researchers from both academia and industry*' (Yin et al., 2016), is seen by many professionals as least important among a range of features.

Previous studies have reviewed the scope and focus of the information retrieval research community. Jarvelin and Ingwersen (Järvelin & Ingwersen, 2004) argue that '*The real issue in information retrieval systems design is … whether it helps the actor solve the search task more effectively or efficiently. To achieve this it is necessary to learn how the actors can be helped.*' Our results support this general conclusion and further identify significant aspects of information retrieval practice that unite and divide professional searchers.

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References

Andrews, M. J., Bradley, S., Stott, D., & Upward, R. (2008). Successful Employer Search? An Empirical Analysis of Vacancy Duration Using Micro Data. *Economica*, *75*(299), 455–480. https://doi.org/10.1111/j.1468-0335.2007.00619.x

Azzopardi, L., Vanderbauwhede, W., & Joho, H. (2010). Search system requirements of patent analysts. In *SIGIR 2010 Proceedings - 33rd Annual International ACM SIGIR Conference on Research and Development in Information Retrieval*. https://doi.org/10.1145/1835449.1835610

Balog, K., Fang, Y., Rijke, M. de, Serdyukov, P., & Si, L. (2012). Expertise Retrieval. *Foundations and Trends in Information Retrieval*, *6*(2–3), 127–256.

Barkan, S. M., Bintliff, B., & Whisner, M. (2015). *Fundamentals of Legal Research* (10th ed.). Foundation Press.

Bonino, D., Ciaramella, A., & Corno, F. (2010). Review of the state-of-the-art in patent information and forthcoming evolutions in intelligent patent informatics. *World Patent Information*, *32*(1), 30–38. Retrieved from http://www.sciencedirect.com/science/article/pii/S0172219009000465

Bourne, C. P., & Hahn, T. B. (2003). *A History of Online Information Services*. The MIT Press.

Bretz, R. D., Boudreau, J. W., & Judge, T. A. (1994). Job Search Behaviours of Employed Managers. *Personnel Psychology*, *47*(2), 275–301. Retrieved from http://dx.doi.org/10.1111/j.1744-6570.1994.tb01725.x

Broder, A. (2002). A taxonomy of web search. *SIGIR Forum*, *36*(2), 3–10.

Ciapponi, A., & Glujovsky, D. (2012). Survey among Cochrane authors about early stages of systematic reviews. In *Proceedings of the 20th Cochrane Colloquium*. Auckland.

Collins, A., Coughlin, D., Miller, J., Kirk, S., & Joint Water Evidence Group. (2015). *The production of quick scoping reviews and rapid evidence assessments: a how to guide*. Retrieved from http://nora.nerc.ac.uk/512448/

Cormack, G. V, & Grossman, M. R. (2014). Evaluation of machine-learning protocols for technology-assisted review in electronic discovery. *Proceedings of the 37th*

International ACM SIGIR Conference on Research & Development in Information Retrieval. Gold Coast, Queensland, Australia: ACM. https://doi.org/10.1145/2600428.2609601

Dingman, H. B. (1993). The right fit: Executive search by retained recruiters. *The Cornell Hotel and Restaurant Administration Quarterly*, *34*(6), 26–31. Retrieved from http://www.sciencedirect.com/science/article/pii/0010880493901367

Elliott, J. H., Turner, T., Clavisi, O., Thomas, J., Higgins, J. P. T., Mavergames, C., & Gruen, R. L. (2014). Living Systematic Reviews: An Emerging Opportunity to Narrow the Evidence-Practice Gap. *PLoS Medicine*, *11*(2), e1001603. Retrieved from http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3928029/

Ellis, D. (1993). Modeling the Information-Seeking Patterns of Academic Researchers: A Grounded Theory Approach. *The Library Quarterly*, *63*(4), 469–486. https://doi.org/10.1086/602622

Elsweiler, D., Wilson, M. L., & Harvey, M. (2012). Searching for fun: Casual-leisure search. In *ECIR 2012 Workshop Proposals*.

Gillies, D., Maxwell, H., New, K., Pennick, V., van der Wouden, H., Fedorowicz, Z., … Ciapponi, A. (2009). A collaboration-wide survey of Cochrane authors. *URL Accessed On*, *5*(12), 2014.

Glanville, J., Bayliss, S., Booth, A., Dundar, Y., Fernandes, H., Fleeman, N. D., … Welch, K. (2008). So many filters, so little time: the development of a search filter appraisal checklist. *J Med Libr Assoc*, *96*.

Grant, M. J. (2004). How does your searching grow? A survey of search preferences and the use of optimal search strategies in the identification of qualitative research. *Health Information & Libraries Journal*, *21*(1), 21–32.

Hanbury, A., & Lupu, M. (2013). Toward a model of domain-specific search. *Proceedings of the 10th Conference on Open Research Areas in Information Retrieval*. Lisbon, Portugal: LE CENTRE DE HAUTES ETUDES INTERNATIONALES D'INFORMATIQUE DOCUMENTAIRE.

Hansen, P., & Järvelin, K. (2005). Collaborative Information Retrieval in an information-intensive domain. *Information Processing and Management*, *41*(5), 1101–1119.

Hawking, D. (2004). Challenges in enterprise search. *Proceedings of the 15th Australasian Database Conference - Volume 27*. Dunedin, New Zealand: Australian Computer Society, Inc.

Hersh, W. (2003). *Information Retrieval: A Health and Biomedical Perspective* (2nd ed.). Springer-Verlag New York.

Jankowski, T. A. (2016). *Expert Searching in the Google Age*. Lanham, MD: Rowman & Littlefield.

Jansen, B. J., Jansen, K. J., & Spink, A. (2005). Using the web to look for work: Implications for online job seeking and recruiting. *Internet Research*, *15*(1), 49–66. Retrieved from http://www.emeraldinsight.com/doi/abs/10.1108/10662240510577068

Järvelin, K., & Ingwersen, P. (2004). *Information seeking research needs extension toward tasks and technology*. *Inf. Res.* (Vol. 10).

Joho, H., Azzopardi, L., & Vanderbauwhede, W. (2010). A survey of patent users: An analysis of tasks, behavior, search functionality and system requirements. In *IIiX 2010 - Proceedings of the 2010 Information Interaction in Context Symposium*. https://doi.org/10.1145/1840784.1840789

Jones, Y. P. (2008). *"Just the facts Ma'am?" a contextual approach to the legal information use environment*. Drexel University.

Karimi, S., Pohl, S., Scholer, F., Cavedon, L., & Zobel, J. (2010). Boolean versus ranked querying for biomedical systematic reviews. *BMC Medical Informatics and Decision Making*, *10*(1), 58. Retrieved from http://dx.doi.org/10.1186/1472-6947-10-58

Kim, S. N., Martinez, D., Cavedon, L., & Yencken, L. (2011). Automatic classification of sentences to support Evidence Based Medicine. *BMC Bioinform*, *12*.

Kim, Y., Seo, J., & Croft, W. B. (2011). Automatic boolean query suggestion for professional search. *Proceedings of the 34th International ACM SIGIR Conference on Research and Development in Information Retrieval*. Beijing, China: ACM. https://doi.org/10.1145/2009916.2010026

Koster, C., Oostdijk, N., Verberne, S., & D'hondt, E. (2009). Challenges in Professional Search with PHASAR. *Proceedings of DIR 2009*, 101–102.

Kruschwitz & Hull, C., U. (2017). Searching the Enterprise. *Foundations and Trends in Information Retrieval*, *11*(1), 1–142.

Kuhlthau, C. C. (1999). Inside the search process: Information seeking from the user's perspective. *Journal of the American Society for Information Science*, *42*(5), 361–371. https://doi.org/10.1002/(SICI)1097-4571(199106)42:5<361::AID-ASI6>3.0.CO;2-#

Kuhlthau, C. C., & Tama, S. L. (2001). Information search process of lawyers: a call for 'just for me' information services. *Journal of Documentation*, *57*(1), 25–43. https://doi.org/10.1108/EUM0000000007076

Lancaster, F. W., & Fayen, E. G. (1973). *Information retrieval: on-line* (Informatio). Los Angeles, CA: Melville Publishers.

List, J. (2013). The name of the game: Information seeking in a professional context. In *Proceedings of the Integrating IR Technologies for Professional Search Workshop,* . Moscow, Russia.

Liu, Y. H., & Wacholder, N. (2017). Evaluating the impact of MeSH (Medical Subject Headings) terms on different types of searchers. *Information Processing & Management*, *53*(4), 851–870.

Makri, S., Blandford, A., & Cox, A. L. (2008). Investigating the information-seeking behaviour of academic lawyers: From Ellis's model to design. *Information Processing and Management*, *44*(2), 613—634.

McGowan, J., Sampson, M., Salzwedel, D. M., Cogo, E., Foerster, V., & Lefebvre, C. (2016). PRESS Peer Review of Electronic Search Strategies: 2015 Guideline Statement. *Journal of Clinical Epidemiology*, *75*, 40–46. Retrieved from http://www.sciencedirect.com/science/article/pii/S0895435616000585

McKeown, S., Maxwell, D., Azzopardi, L., & Glisson, W. B. (2014). Investigating people: A qualitative analysis of the search behaviours of open-source intelligence analysts. In *Proceedings of the 5th Information Interaction in Context Symposium, IIiX 2014*. https://doi.org/10.1145/2637002.2637023

Mersky, R. M., & Dunn, D. J. (2002). *Fundamentals of Legal Research* (8th ed.). Foundation Press.

Niu, X., & Hemminger, B. M. (2012). A study of factors that affect the information-seeking behavior of academic scientists. *Journal of the American Society for*

Information Science and Technology, *63*(2), 336–353. Retrieved from http://dx.doi.org/10.1002/asi.21669

Ortiz-Cordova, A., & Jansen, B. J. (2014). Linking external and internal search: investigating the site searching patterns of referred searchers. *Proceedings of the Extended Abstracts of the 32nd Annual ACM Conference on Human Factors in Computing Systems*. Toronto, Ontario, Canada: ACM. https://doi.org/10.1145/2559206.2581199

Russell-Rose, T., & Chamberlain, J. (2016). Real-World Expertise Retrieval: The Information Seeking Behaviour of Recruitment Professionals. In *European Conference on Information Retrieval* (pp. 669–674). Springer.

Russell-Rose, T., & Chamberlain, J. (2017). Expert Search Strategies: The Information Retrieval Practices of Healthcare Information Professionals. *JMIR Medical Informatics*, *5*(4), 33. https://doi.org/10.2196/medinform.7680

Salampasis, M., & Hanbury, A. (2013). A generalized framework for integrated professional search systems. In *Information Retrieval Facility Conference* (pp. 99–110). Springer.

Sherman, R., Stone, B., & Thornton, K. A. (2006). Why take the call? Working with executive search firms. *Nurse Leader*, *4*(2), 28–30. Retrieved from http://dx.doi.org/10.1016/j.mnl.2006.01.009

Spink, A., Wolfram, D., Jansen, M. B. J., & Saracevic, T. (2001). Searching the Web: the public and their queries. *Journal of the American Society of Information Science AndTechnology*, *52*(3), 226–234.

Tait, J. I. (2014). An Introduction to Professional Search. In G. Paltoglou, F. Loizides, & P. Hansen (Eds.), *Professional Search in the Modern World: COST Action IC1002 on Multilingual and Multifaceted Interactive Information Access* (pp. 1–5). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-12511-4_1

Tamine & Chouquet, C., L. (2017). On the impact of domain expertise on query formulation, relevance assessment and retrieval performance in clinical settings. *Information Processing & Management*, *53*(2), 332–350.

Tsafnat, G., Glasziou, P., Choong, M. K., Dunn, A., Galgani, F., & Coiera, E. (2014). Systematic review automation technologies. *Systematic Reviews*, *3*(1), 74.

Retrieved from http://dx.doi.org/10.1186/2046-4053-3-74

Vakkari, P. (2005). Task-based information searching. *Annual Review of Information Science and Technology*, *37*(1), 413–464.

Verberne, S., Sappelli, M., Sørensen, D. R., & Kraaij, W. (2013). *Personalization in professional academic search*. CEUR-WS.

Vollaro, A. J., & Hawkins, D. T. (1986). End-User Searching in a Large Library Network: A Case Study of Patent Attorneys. *Online*, *10*(4), 67–72.

Wacholder, N. (2011). Interactive query formulation. *Annual Review of Information Science and Technology*, *45*, 157–196.

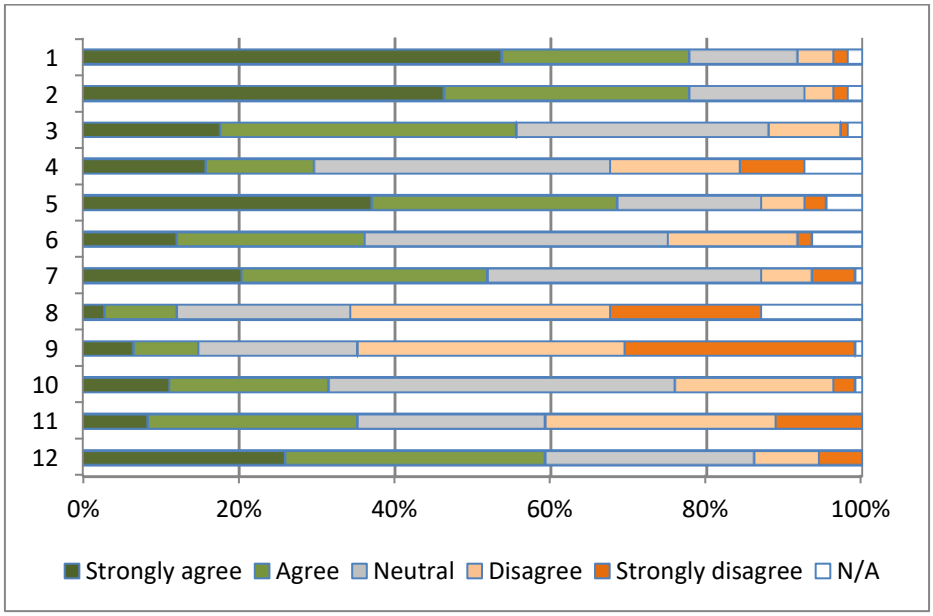
Yin, D., Nobata, C., Langlois, J.-M., Chang, Y., Hu, Y., Tang, J., … Deng, H. (2016). *Ranking Relevance in Yahoo Search*. https://doi.org/10.1145/2939672.2939677

Yuan, W. (1998). End-user searching behavior in information retrieval: A longitudinal study. *Journal of the American Society for Information Science*, *48*(3), 218–234. https://doi.org/10.1002/(SICI)1097-4571(199703)48:3<218::AID-ASI4>3.0.CO;2-#

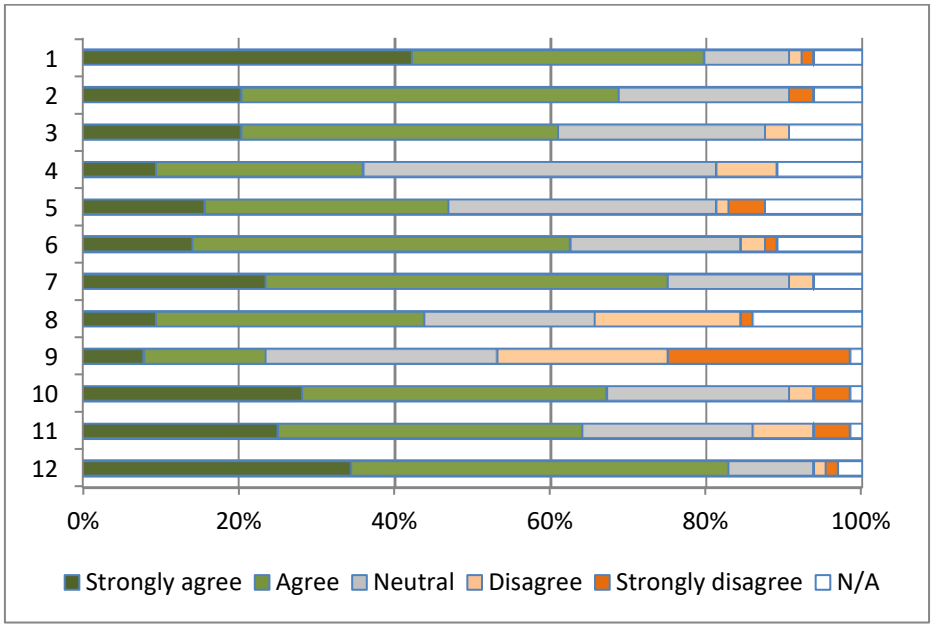
Appendix I

Likert diagrams for legal, recruitment, healthcare and patent sectors showing the value placed on search functionality during query formulation, including Boolean logic (1), proximity operators (2), relevance ranking (3), truncation (4), wildcards (5), field operators (6), query expansion (7), query translation (8), case sensitivity (9), abbreviations (10), misspellings (11) and synonyms (12). The patent survey did not include 9-12.

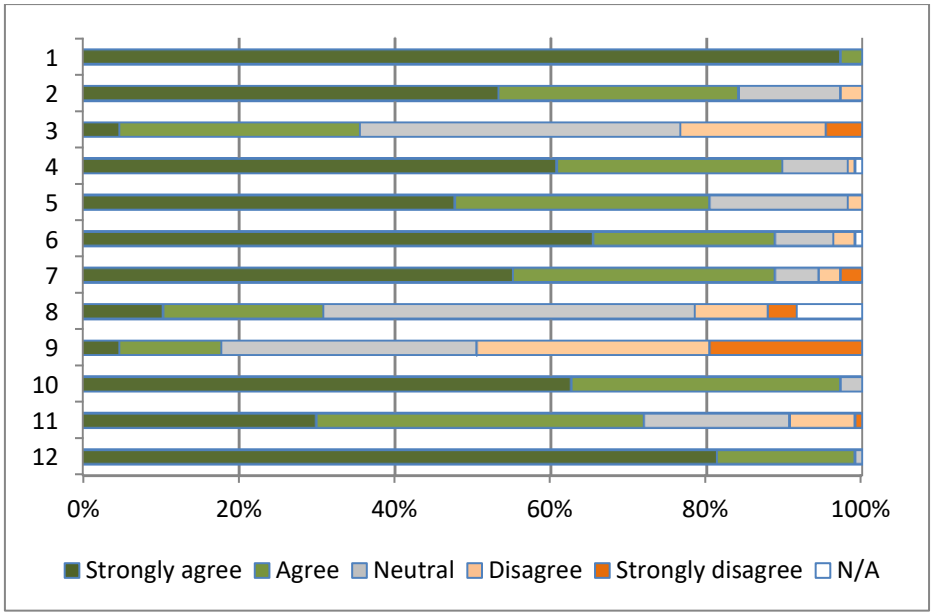
A1: Legal



A2: Recruitment

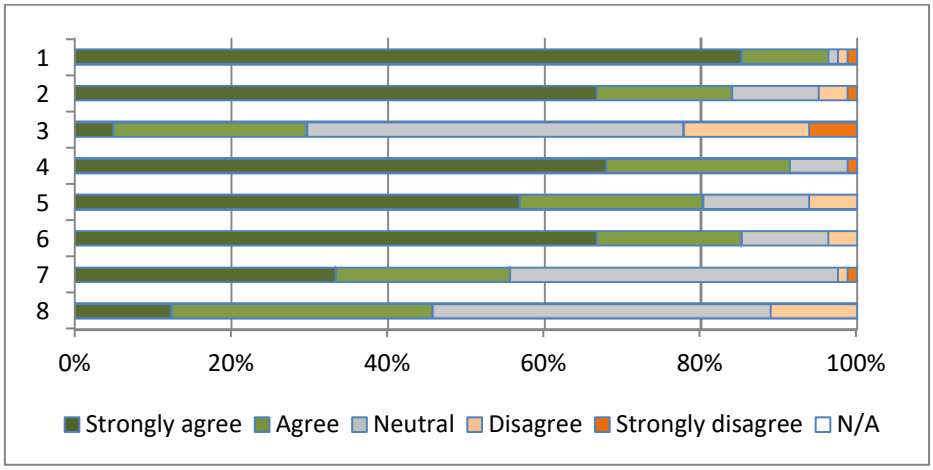


A3: Healthcare



1020

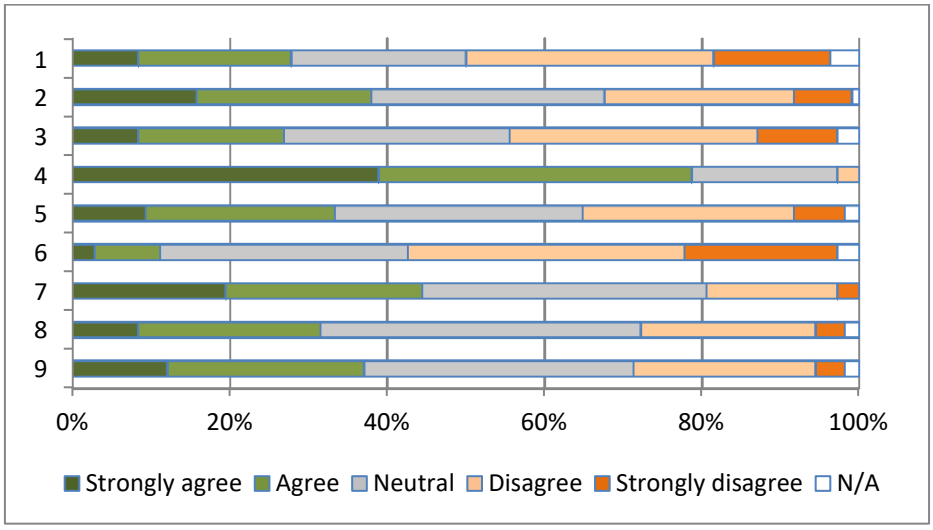
A4: Patent


1
2
3
4
5
6
7
8
0%
20%
40%
60%
80%
100%
Strongly agree
Agree
Neutral
Disagree
Strongly disagree
N/A

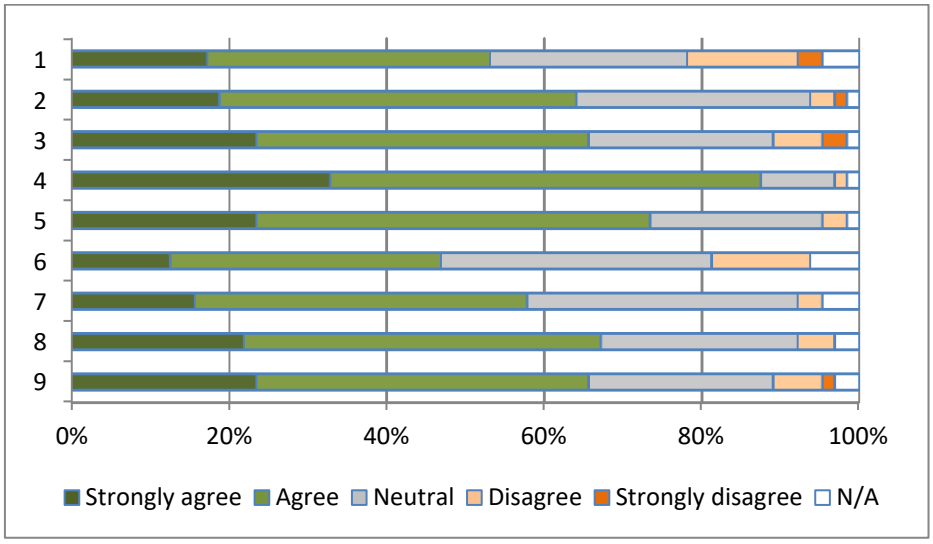
Appendix II

Likert diagrams for legal, recruitment, healthcare and patent sectors showing the value placed on features of search systems, including storing search results with an expiry date (1), alerting functions (2), saving custom lists from search results (3), recency of retrieved results (4), organizing search queries (5), exporting search queries (6), search history (7), combining multiple search results (8) and combining search queries (9).

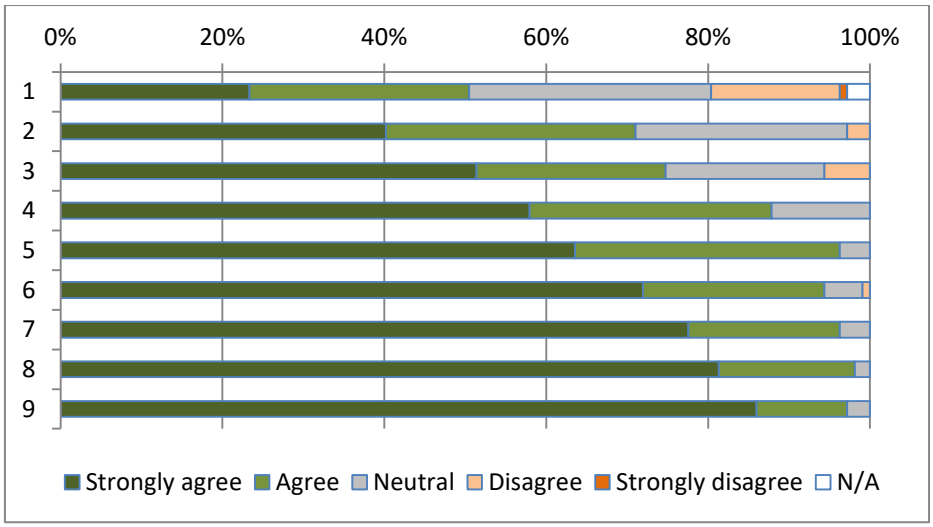
A1: Legal



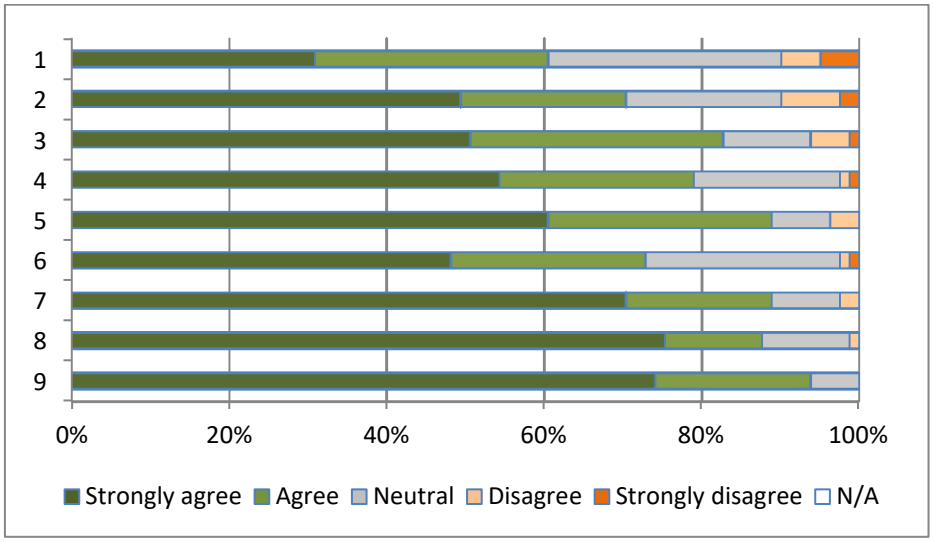
A2: Recruitment



1040 A3: Healthcare



A4: Patent



1045