An evaluation of a visual interface for supporting query formulation in scholarly searching

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Performing an effective literature review is a fundamental academic skill. Whether writing up a final project, preparing a research proposal, or simply finding answers to complex questions, students need to be able to systematically gather and analyze evidence from a variety of sources. However, many students have difficulty formulating effective search queries and understanding how to optimize their search strategy. This paper evaluates a novel approach to query formulation based on an alternative, visual interface. The approach is evaluated alongside a conventional, form-based interface in a comparative, controlled setting. The study finds that overall, participants considered the visual interface to be more complex and difficult to use. However, at the same time they used significantly more terms, facets and reformulations in the visual interface, and gave more attention to creating and refining more complex queries. In addition, the majority considered the visual interface to have greater transparency, with a clearer overview of the search tasks that encouraged them to invest greater effort in completing them successfully. The results demonstrate that visual approaches can offer tangible benefits in developing and improving students' competence in exploratory search tasks.

1. Introduction

Information literacy and search skills are vital for academic success. In today's information-rich world, students are faced with an overwhelming amount of academic information from multiple sources, making it challenging to locate and evaluate accurate and credible information. They need to learn how to navigate and critically analyze information sources to make informed decisions, solve problems, and engage in meaningful research. This problem becomes particularly acute when they undertake systematic searches such as those required for a literature review.

However, many students find systematic search tasks to be challenging (Catalano, 2013; Reisoğlu et al., 2020). Adjusting queries, selecting search terms, and adjusting the number of results can prove problematic, and knowledge of advanced search strategies and Boolean operators is often limited (Catalano, 2010; Hoffmann et al., 2008; Zlatkin-Troitschanskaia et al., 2021). Previous studies have investigated student use of discovery systems and literature databases (Dahlen et al., 2020). For example, Bloom and Deyrup (2015) studied students' research behaviours and emotive responses in conducting online research for their undergraduate courses and found their behavior to be characterized by simplistic keyword searches, frequent mistakes and failure to properly evaluate sources. Further, researchers have found that students tend to rely on a single search strategy rather than refining their searches or employing advanced search techniques (Holman, 2011). Boolean searching is poorly understood and ineffectively used (Dempsey and Valenti, 2016). Instead, students tend to rely on the relevance ranking provided by literature databases as a proxy for authority and accuracy (Asher et al., 2013; Cross and Gullikson, 2020). Facets, designed to augment

keyword search and provide a way for students to focus their searching, are often underutilized (Dempsey and Valenti, 2016).

A possible mitigation for this can be found through the use of alternative approaches such as visualization. The application of visualization to search query formulation can offer significant benefits, such as fewer zero-hit queries, improved query comprehension and better support for exploration of an unfamiliar database (Goldberg and Gajendar, 2008). In this paper, we investigate an alternative visual interface which represents queries as objects on a two-dimensional canvas (Russell-Rose, Chamberlain, and Shokraneh, 2019). Users can combine keywords and controlled vocabulary terms with Boolean and other operators to form higher-level groups and then iteratively nest them to create complex expressions (Russell-Rose and Shokraneh, 2020). We investigate how this interface influences how students formulate search queries by comparing it to a conventional form-based query builder in a controlled test setting. Further, we investigate how this interface affects the overall user experience of completing systematic search tasks through a series of pre- and post-task surveys, search log analysis, and post-test interviews.

2. Related work

2.1 Students' searching and interaction with information

Research into students' scholarly searching behaviour has highlighted various preferences and usage patterns. Ramdeen & Hemminger (2012) made a comparative study of two versions of a university library catalogue search interface with undergraduate students. The baseline interface was based on keyword search, while the comparative interface provided filtering with facets in the search results. They found that students preferred the support in searching offered by the facets. This was reflected in their manipulation of the search results and in their conceptual understanding of them. In particular, during exploratory searches, students used facets to narrow down search results, confirm the relevance of their queries, and manage less precise initial search terms (Ramdeen and Hemminger, 2012). Haggerty & Scott (2019) also studied the usability of a university library catalogue, focusing on the use and value of specialised search functions. The study showed that in a catalogue with heterogeneous content, test participants tended to prefer simple keyword search rather than explore different tabs leading to different content. Unless prompted otherwise, all participants chose simple search. Similar findings were made by Chase et al. (2016), who investigated university students' use of three different search functionalities in a library interface and found the quick search functionality to be preferred over both a database search functionality and a journal title search option. The authors concluded that the participants had difficulty using the database and journal name functionality but were able to locate relevant information using simpler search functionality. The studies suggest that keyword search is the default, but if presented in a useful manner, more advanced functions like facets can be of benefit.

Students' query building and reformulation behaviour has been another a topic of attention in the literature. Dahlen et al. (2020) compared search features across three different search systems, two versions of a discovery system (Summon) and one traditional database (Social Science abstracts). They found that only around 25% of their student study participants used advanced search functions

for building complex queries with Boolean operators. In general, the advanced search received positive feedback in the study, although some discovered it too late or preferred the keyword search. Tonyan & Piper (2019) also studied Summon in a usability study with students, focusing on intuitiveness and the need for library instructions. The study showed that the participants performed well in searching for known items but were challenged when the tasks were more open and exploratory and required the identification of relevant keywords. Some students could locate information effectively with suitable keywords using simple search, while others struggled to identify relevant search terms, which affected their search time.

Monchaux et al. (2015) studied the impact of domain knowledge on searching. Presenting psychology and non-psychology students with a variety of search tasks, they studied differences between the two groups in searching a university website either via a navigable taxonomy or a search engine. The study found that the participants with greater domain knowledge had an advantage in identifying relevant keywords. However, both groups tended to make minor reformulations in their queries, resulting in only minor changes to the results. Neither group made extensive use of the controlled vocabulary available to them. These results suggest that domain knowledge can be beneficial during searching, but students make limited use of search aids and query formulation continues to be dominated by simple keyword queries.

2.2 Visual search interfaces

Most information retrieval (IR) systems present search results as a list of documents, sorted by relevance. However, some utilize graphical interfaces to present search results visually. Visualization interfaces can provide more flexibility and control for end-users resulting in progressively greater use by untrained users (Liu et al., 2021). For example, FeatureLens (Don et al., 2007), TileBars (Hearst, 1995), and Jigsaw (Stasko et al., 2008) use visualization to offer searchers insights into the underlying structure of large documents, aiding them in extracting meaningful and understandable content. In related work, Ahn and Brusilovsky (2013) integrated interactive visualization into their Adaptive Vibe system to improve the precision and productivity of a personalized search system.

Similarly, Gale online databases offer the Topic Finder feature, allowing users to view retrieved results' titles in either tile or wheel format. Dörk et al. (2012) presented PivotPath, an interactive visualization tool that allows people to explore highly faceted information. To optimize the presentation of hierarchical relationships within bibliographic records in IR systems, Merčun et al. (2017) conducted a comparison of four layouts. They found that their indented tree and sunburst layouts were most successful in terms of search performance while the hierarchical layouts were useful exploratory tasks. Recently, Li et al. (2023) evaluated a novel approach to search assistance that allows users to organize items of interest into boxes that can be created, labeled and rearranged on a visual canvas. They conducted a controlled user study involving students and university staff and found that it offered support for cognitive and metacognitive activities in exploratory search.

In addition to work on visualization of search results, attempts have been made to apply visualization to search queries. An early example is that of Anick et al. (1989), who developed a two-dimensional graphical representation of a user’s natural language query that supported

reformulation via direct manipulation. Jones (1998) developed a query interface to the New Zealand Digital Library which uses Venn diagrams and query result previews. Likewise, Nitsche and Nürnberger (2013) developed a system based on a radial user interface that supports interactive visual refinement of vague queries. An example of a web-based visualization prototype is Boolify (www.boolify.com), which provides a drag and drop interface to Google. In a similar manner, de Vries et al. (2010) developed a system which utilizes a visual canvas and building blocks to allow users to graphically configure a search engine. Likewise, Scells and Zuccon (2018) developed a platform to edit and explore Boolean queries using a tree visualization, based on a common representation.

However, less is known about the effect of query visualization on student searching behaviour. Schlötterer (2020) present a formative evaluation with non-expert users of QueryCrumbs, a compact visualization for navigating the search query history. Gaona-Garcia et al. (2017) offer a review of visual search interfaces, focusing on information visualisation, knowledge organisation systems and metadata quality. Likewise, Barifah (2021) evaluates a visual digital library interface, showing that visualization of search results can be of benefit to users. However, neither of these studies addresses the application of visualization to the specific task of query formulation. More recently, Svarre and Russell-Rose explored the use of visualisation applied to query formulation, but this work focused solely on the behaviour of expert searchers (Svarre and Russell-Rose, 2022).

In summary, the use of visual approaches may, in principle at least, allow students to take more initiative for undertaking and completing their own systematic searches without additional support. It is this proposition that this study aims to investigate.

2.3 Research questions

In this paper, we investigate the use of query visualization in the context of student information seeking. We employ qualitative and quantitative methods to address the following research questions:

1. How does the use of a visual interface influence the structure of students' search queries?

2. How does the use of a visual interface impact students' user experience of systematic searching?

We investigate RQ1 by measures of prior search experience (confidence and use of Boolean operators) and query analysis (search terms, facets, number of reformulations and task completion). We investigate RQ2 by measures of clarity, interest, domain knowledge, simplicity, pleasantness, ease of use and effort. We elaborate on the details of the methodical approach in the next section.

3. Research methods

This study investigates the differences between a visual interface and a conventional form-based interface in searching the Medline database. The methodology of comparing an experimental system against a conventional baseline has been established in previous studies (e.g, Ahn & Brusilovsky,

2013; Merčun, Žumer, and, Aalberg, 2017). The conventional interface was represented by PubMed's query builder, while the visual interface was represented by 2Dsearch[1].

At the heart of 2Dsearch is a graphical editor which allows the user to formulate search strategies as objects on a visual canvas (Russell-Rose, Chamberlain, and Shokraneh, 2019). These objects can be simple keywords or attribute:value pairs representing controlled vocabulary terms (e.g. MeSH terms) or database-specific search operators (e.g. field codes and other commands). Users can combine them using Boolean—and other—operators to form higher-level groups and then iteratively nest them to create complex expressions (Russell-Rose and Shokraneh, 2020).
This approach embodies many of the design principles identified in the prior art:

- Users can formulate and manipulate Boolean expressions as objects on a visual canvas
- Users can create complex queries by combining objects to create composite structures
- Query elements can be individually interrogated to facilitate exploration
- Interaction and animation can be used convey meaning and structure
- Real-time feedback can be used to facilitate query optimization

Visualizing queries in this way offers a more intuitive user experience (UX) that eliminates many sources of error, makes the query semantics more transparent, and offers new ways to collaborate, share, and optimize search strategies.

The two interfaces are illustrated in Figures 1 and 2. Note that although the conventional interface includes a visual component (the histogram), this refers only to the search results and offers no support for the task of query formulation. We compare the two approaches using four search tasks performed by 15 students of a Master's program in IT. We evaluate the performance of each approach and report our findings using a variety of quantitative and qualitative metrics (see Section 3.3). In the remainder of this paper, we will refer to these two systems as the conventional and visual interfaces respectively.

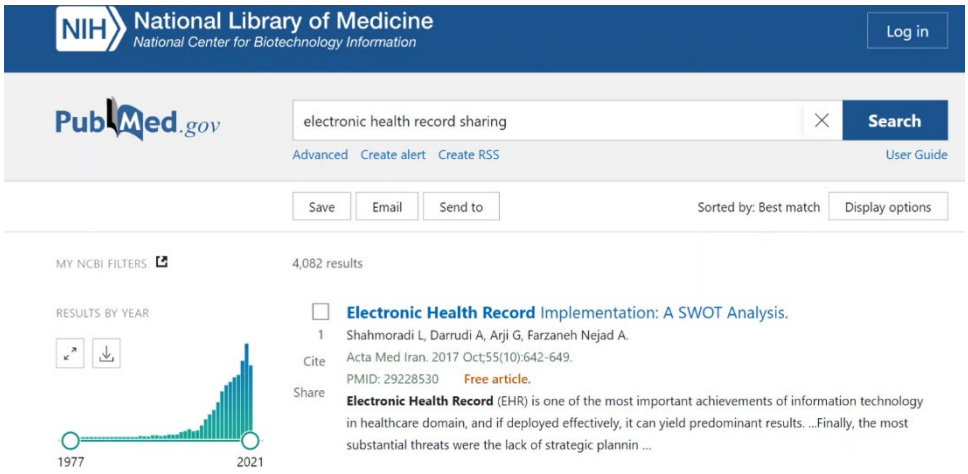

Figure 1: Example query in the conventional interface

[1] https://www.2dsearch.com/

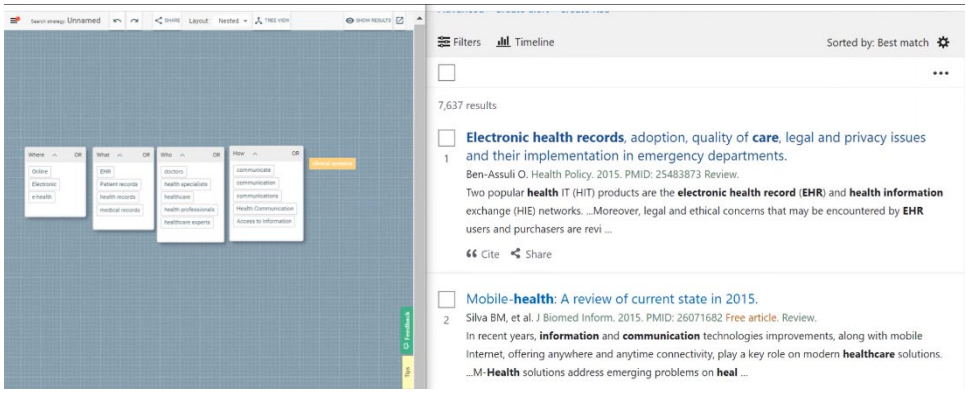

Figure 2 Example query in the visual interface

3.1 Study design

The study used a within-subjects design with one independent variable: the type of interface. Its effects were measured in terms of a number of dependent variables (see Table 1). Before the study, each participant completed a pre-test survey to elicit demographic data, their prior experience with advanced search and their search preferences. This data facilitated consideration of their background as a contextual factor in their evaluation of the two interfaces.

Type	Data collected	Method	Corresponding research question (RQ)
Independent	Type of interface: conventional or visual	Query formulation tasks	
Contextual	Prior search experience and preferences (confidence, use of Boolean operators)	Pre-test survey	RQ1
Dependent	Query analysis (search terms, facets, reformulations, task completion)	Search log	RQ1
Dependent	Self-assessment of each task (in terms of clarity, interest and domain knowledge) and overall search experience (in terms of simplicity, pleasantness, ease of use and effort)	Post-task survey	RQ2
Dependent	Reflections and comparisons of the two interfaces	Post-test interview	RQ2

Table 1 Overview of experimental variables

A post-task survey was used to collect self-reported evaluation measures after completing each task (Liu, Liu, Liu & Bierig, 2021). Three areas were covered in the survey; domain knowledge, task assessment, and search experience. Domain knowledge has been shown to be a crucial factor in

completing complex search tasks (Dosso et al., 2023; Monchaux et al., 2015), so it is important to control its influence. Task assessment is included to capture the participants' motivation for engaging with the task (Ingwersen & Järvelin, 2005). Lastly, the survey included questions to evaluate the overall search experience to identify the participants' subjective opinion towards the two interfaces (Shapira, Taieb-Maimon & Nemeth, 2005).

During the test, participant queries were logged to enable a quantitative analysis of the number of terms, facets and reformulations, and whether participants were able to successfully complete each task. Each session was concluded with a post-test interview to capture participant reflections and comparisons on the two interfaces in terms of 1) support for complex search tasks, 2) support for query formulation, 3) feedback on query construction and 4) transparency. Transparency has been identified as an important criterion in previous work on search interface design (e.g. Russell-Rose and MacFarlane, 2020).

3.2 Search tasks

Marchionini (2006) distinguishes between 'look-up' and 'exploratory' search activities, where the former are more basic and the latter are more investigative. This study is based on four exploratory tasks. Exploratory search tasks have been shown to be general, dynamic, multi-faceted, open-ended, have multiple items as their target, and involve uncertainty (Wildemuth & Freund, 2012). They are commonly used in studies of interfaces that support complex queries (Kules et al., 2009) and can be completed in number of different ways (Ramdeen and Hemminger, 2012). Exploratory search tasks represent scholarly searching by simulating the process researchers often follow when investigating new or unfamiliar domains. These tasks involve navigating large volumes of information, refining queries, and discovering unexpected insights, much like the iterative and evolving nature of academic research. By using exploratory tasks, we aim to mirror the challenges and dynamics typical of scholarly inquiries. We therefore follow the recommendations of Kules & Capra (2008) that each task should initiate discovery, have a general character, address a situation that participants can relate to and consider topically appealing, and provide sufficient context for the participants to act upon.

Our study consisted of four controlled tasks preceded by one training task. Tasks were chosen to align with the domain of the participants' studies and pilot tested with the target group for quality assurance. Evidently, some degree of variation in participant domain knowledge is inevitable, but controlling the tasks in this way allows us to minimise its effect and focus instead on participants technical (i.e. query formulation) performance. Further, tasks that are oriented towards investigation, are open-ended and multi-facetted, are more likely to trigger exploratory search activities (Wildemuth & Freund, 2012). We have aimed to incorporate these characteristics into the tasks guiding the current study. Table 2 illustrates the structure of the tasks with title, description, and narrative.

Task A: Patient information seeking
Description: Find studies of how patients look for online information on their cancer diagnosis

Narrative: Relevant documents will contain a description of purposes, information sources, approaches or the like.
Task B: Mobile apps for self-management Description: Find studies of how mobile apps are used for self-management of chronic diseases Narrative: Relevant documents contain a description of the disease, the patient group, and their use. Documents on the development of apps are not relevant.
Task C: Electronic health records in professional communication Description: Find studies on how health professionals are using electronic health records for communication with their colleagues, both within and across professions Narrative: Relevant documents mention EHR mediated communication about patients between one or more professions at the hospital or in the clinic. Documents on communication by means of other clinical systems are not relevant.
Task D: Knowledge sharing among health professionals Description: Find studies on the characteristics and practice of knowledge sharing among health professionals for the purposes of education or professional development. Narrative: Relevant documents concern sharing of health knowledge and the benefits and challenges in this regard. Documents relating to knowledge sharing for operational reasons (e.g. treatment, diagnosis) are not relevant.

Table 2 Tasks used in the experiment

3.3 Study protocol

The test took place in a lab environment. Before the test began, participants signed a written consent form. Each participant carried out two tasks in each of the two interfaces. Prior to using the visual interface, they were presented with a short video introducing the core functionalities of the interface. This was followed by a training task for them to try the system before recording took place.

The order of interfaces and tasks was rotated to avoid systematic bias. Thus, one half of the participants used the form-based interface first and then the visual interface. The other half used the two interfaces in reverse order. Tasks were rotated using the dcode permutation generator[2]. Relevance was considered to be subjective (Borlund, 2003), so a task was considered complete when participants believed they had found relevant results. No limits were set for the time spent on searching in each task. When a task was completed, the participant completed the post-task survey before moving on to the next task.

[2] https://www.dcode.fr/permutations-generator

4. Results

4.1 The structure of student search queries

Research Question 1 was investigated using a pre-test survey and a process of search log analysis.

4.1.1 Pre-test survey

15 master's students participated in the study, 8 male and 7 female with a mean age of 25.5 years. When asked about their search preferences, 14 out of 15 responded that they preferred simple over advanced search as perceived by the participants. When asked about their confidence in using Boolean operators, just 4 out of 15 felt confident (see Table 3).

	Very low	Low	Moderate	High	Very high
Confidence in using Boolean operators	1	4	6	4	0

Table 3 How confident do the participants feel using Boolean operators? N=15.

Table 4 shows participants prior experience with advanced search. The most used functionality was phrase search, which 6 out of 15 used on a weekly basis or more. Boolean operators such as AND, OR, NOT, and parentheses were used relatively rarely (on a monthly basis or less by most participants). This observation is also reflected in the post-test interviews (see Section 4.4).

Search operator	**On a weekly basis or more**	**On a monthly basis or less**
Phrases	6	9
Parentheses	4	11
Boolean AND	4	11
Boolean OR	2	13
Boolean NOT	2	13

Table 4 Participants' prior experience with advanced search operators and general preference for search approach. N=15.

4.1.2 Search log analysis

Table 5 summarizes the analysis of the 302 queries formulated by the test participants. This shows the differences between the two interfaces, with the visual interface eliciting a significantly higher number of terms, facets and reformulations. Task completion measures participants' ability to successfully complete each task. Tasks were considered incomplete when participants were unable to find documents relevant to the task description. Chi-squared tests for task completion showed no significant difference across the two interfaces.

	Conventional	Visual
Terms	2.80***	5.70***
Facets	2.34***	2.70***
Reformulations	3.28*	5.60*
Task completion	96.4%	93.3%

Table 5 Mean number of query terms and facets, along with mean number of reformulations and percentage of tasks completed for each interface. Significance based on Mann-Whitney test (***p < 0.001, *p < 0.1). N=302.

4.2 The user experience of structured searching

Research Question 2 was investigated using a post-task survey and post-test interview.

4.2.1 Post-task survey

Table 6 shows participants' assessment of the tasks in the search test. In aggregate, the tasks were found to be more clear than unclear and more interesting than boring. Minor variations were found between individual tasks, but none were significantly different. Likewise, there were minor variations in participants' self-assessment of domain knowledge between interfaces and tasks, but none were statistically significant.

Likert scales (1-5)	**Task A** mean (std dev)	**Task B** mean (std dev)	**Task C** mean (std dev)	**Task D** mean (std dev)
Clear vs. unclear	1.79 (0.975)	1.36 (0.633)	1.67 (0.900)	2.00 (0.845)
Interesting vs. boring	2.71 (0.726)	2.29 (0.825)	2.67 (0.976)	2.73 (0.594)
Domain knowledge	2.21 (1.626)	2.57 (1.828)	2.20 (1.612)	1.93 (1.223)

Table 6 Participants' assessment of the search tasks, including prior knowledge of the task. N=58.

Table 7 shows participants assessment of the search experience in the two interfaces. Participants judged the conventional interface to be simpler, more pleasant, easier, and slightly more relaxing. Mann-Whitney test was used to test for statistical significance, but no significant differences were identified.

Likert scales (1-5)	**Conventional, mean (std dev)**	**Visual, mean (std dev)**
Simple vs. complex	2.14 (1.239)	2.83 (1.053)

Pleasant vs. unpleasant	2.04 (0.962)	2.27 (0.785)
Easy vs. difficult	2.61 (1.197)	3.03 (0.999)
Relaxing vs. exhausting	2.61 (1.133)	2.67 (1.028)

Table 7 Participants' assessment of the search experience. N=58.

4.2.2 Post-test interview

The analysis of the post-test interviews elaborates on the differences identified above.

Several participants comment that their preferred and most common approach to searching is simple and Google-like. To illustrate: "*I usually tend to lean towards simple search*" (TP1). Another participant comments on the outcome of simple search: "*The [form based interface] was more like a google search, which I am used to, and it is simple, but it also provides more imprecise results*." (TP10). This is elaborated on by a third participant: "*Normally I don't use complex searches. I actually pretty much try to avoid them, because you only have this one line to work with. So I mostly just make simple searches, and if I don't get what I want, I change the terms instead of adding more terms*." (TP2). So the simplicity remains, and terms are changed if different search results are needed. These observations illustrate how simple search is the preference for most participants, with limited use of Boolean operators.

One theme that re-occurred was participants considering the conventional interface as a kind of Google search, where they simply enter some keywords and see what is returned. To illustrate: "*In the [conventional interface] I just started by typing the heading of the tasks, because then I figured I would be safe*." (TP10). Another participant follows up with: "*[The conventional interface] reminds me of something I have done a million times in Google or the like. So there I am not insecure about how to search. [...] It is how I am used to searching.*" (TP11). The Google association further underlines the limited use of Boolean operators mentioned above, and partly explains why fewer terms, facets and reformulations are used in this interface.

When presented with complex tasks like those used in this study, participants had contrasting reflections on the issue of transparency. Some felt more confident using the conventional approach. One participant comments: "*it was much faster to see in [the conventional interface], if you were on the right path, whereas in the [visual interface] you had to go back and forth… and I got a little confused sometimes, because I had an idea that this may not be the right direction, but I wasn't sure which term caused the trouble*." (TP2). Another participant elaborated on this viewpoint: "*There is an incredible transparency in the [conventional interface], because you are you, sitting and thinking about what search terms you want to use. I feel much more in control of what you are actually searching for and wanting to find*." (TP5).

However, the majority of the participants considered the visual interface to have greater transparency. One comments on the building blocks of the visual interface: "*in [the visual interface] I could split it into what I want to search for , and even split it into boxes, so I can see it. In the [conventional interface] it is one long thread, where I step by step start to enter terms*." (TP4). The

transparency issue also features in query reformulations: "*I thought it was very clear as soon as I deleted a term or a synonym in [the visual interface], then the results changed remarkably, just because of one term. In [the conventional interface] it was more like the same results, if i deleted an OR or an AND. So I was a bit uncertain where to change my query in the [conventional interface], because I couldn't really see where to adjust to get a different query. That, on the other hand, was very clear in the [visual interface].*" (TP10).

Transparency also featured in their understanding of the search process: "*In the [visual interface] there is a better overview. I always knew, what i had searched for. Contrary to [conventional interfaces] in general, as soon as you go down, then you can no longer see the search terms, you used earlier. And then, if you search long enough, you will likely have forgotten the specific terms, you used for searching*." (TP11). To some participants, the perception of transparency depends on the complexity of the query: "*In terms of formatting the search string I think that with a simple search string it is easier to to write it out myself with parentheses and operators. But when we move into these complex queries then [the visual interface] starts to make sense, because then it gets difficult to comprehend*." (TP12).

Idea generation and brainstorming was another theme reported by participants. One mentioned it as a natural extension of their training: "*We make a lot of brainstorms, so it is natural to us to have terms spread all over the place and then combining them. And it feels very natural to go: These terms are relevant. They can go in this box because they are synonyms… It was almost like a brainstorm in itself. Very different from if you had done it in the [conventional interface].*" (TP5). Another participant uses the analogy of a mindmap: "*You don't really have to think about the connection, you just type the terms that come to mind, like in a mindmap, and then the system puts them in for you*." (TP8). A third participant continues: "*It is a more creative way of searching. You can unfold more. But you need to get acquainted with the system first*." (TP11).

Several participants commented that the visual interface was more demanding, and that it encouraged them to formulate queries in a more precise manner than they were used to. One participant mentions that the structured way of searching in the visual interface "*can be a bit exhausting in the long run, but I can clearly see why you would use it for specific areas*" (TP4). Another participant agrees on the user challenges: "i*n [the visual interface] I took every term from the [task] heading and found synonyms for patient information and seeking and saw what the different terms should include, so it required more thinking to use the [visual interface]*". However, at the same time the participants reflect on the visual interface's ability to help them improve their queries: "*..it seems that [the visual interface] adjusts to the syntax where I could see that it was different from the [conventional interface], there were some things it didn't accept, and the way I was typing*." (TP9). One participant brings out the persuasion element: "*The [visual interface] supports advanced searching more, so it sort of nudged me towards trying something more advanced*." (TP1).

5. Discussion

We now discuss the outcomes of the study with respect to our specific research questions and related works and reflect on some of the broader implications.

5.1 Overall findings

In this section we return to our original research questions and attempt to provide answers to them. The first question concerned how visual interfaces influence the structure of students' search queries. Previous work has shown that students struggle with complex search tasks, especially when trying to identify concepts and related keywords. In our pre-test survey the majority of participants claimed to possess only modest search skills, preferring simple over advanced search, with infrequent use of Boolean operators. This is reflected in the post test interviews, where several participants equate the search box in the conventional interface with that of Google, indicating a larger familiarity and confidence with this type of interface. This aligns with previous studies (Bloom and Deyrup, 2015; Chase et al., 2016; Zlatkin-Troitschanskaia et al., 2021), in particular Haggerty & Scott (2019), who found that students preferred simple keyword search over more specialized alternatives.

These results suggests that participants in our study would exhibit a type of satisficing behaviour, in which they invest the minimal effort to achieve the task rather than exploring more specialized alternatives. However, in our query analysis we found that participants used significantly more terms, facets and reformulations when using the visual interface. This is not a reflection of the difficulty of the tasks, since that is a constant in both cases. It suggests instead that the visual interface encouraged students to give more attention to creating and refining their search and thus formulate more complex queries. Previous studies have found that effort expended in the search process may degrade precision but leads to better task outcomes (Vakkari and Huuskonen, 2012).

The second question focused on how the use of a visual interface impacts students' user experience of systematic searching. We found that overall, participants considered the visual interface to be more complex and difficult to use when asked in the post-task surveys. Moreover, their task completion rate was lower for the visual interface (although this difference was not significant). In part this can be explained by a lack of familiarity with the visual interface combined with limited experience of conducting systematic searches. Both of these observations were reported in the post-test interviews. However, it could also reflect the fact that the visual interface requires participants to articulate explicit boundaries between terms and facets and therefore give greater consideration to the logical structure of their query, which results in a heavier cognitive load on participants.

Despite the difficulties identified in using the visual interface, the majority considered the visual interface to have greater transparency, with a clearer overview of the search strategy. Similar findings were made by Li et al. (2023), who found that visual cues helped participants in organizing information and completing search tasks. Indeed, several participants described their experience of the visual interface as a kind of 'mind map', providing a flexible structure for their exploration of the search task. This aligns with the findings of Ramdeen & Hemminger (2012), who found that features that facilitate conceptual understanding are positively received, and with those of Barifah (2021), who observed positive feedback toward visual library services. These results give the first indication that query visualisation can be of benefit to students working on query formulation tasks, analogous to the benefits of visualisations of search results (e.g., Barifah, 2021; Liu et al., 2021). At the same time, authors have emphasised the importance of promoting information literacy among students

(Chase et al., 2016; Haggerty & Scott, 2019). Query visualisation may thus constitute one of several initiatives towards supporting, encouraging and improving systematic searching among students.

5.2 Future work

The outcomes of this study suggest a number of avenues for future work. First, the study was carried out in a controlled lab setting, so further investigation would be needed to verify these findings within a naturalistic setting. Second, although a sample of 11-20 participants is common for studies of this nature (Kelly & Sugimoto, 2013), we would hope also to replicate this study with a larger sample. Third, although our results suggest that domain knowledge did not play a significant role in the outcome, we would like to confirm this by replicating the study with a cohort from a different domain. We would also like to engage in a more longitudinal study, to evaluate the extent to which familiarity (over a prolonged period of time) affects participants query formulation performance and overall search experience.

Our methodology elicited interaction data by means of surveys, search logs and post-test interviews. However, we have limited insight into where participants' attention was focused on the screen or how they perceived and understood what they saw. The use of alternative methods such as eye tracking could provide additional insights into the user interactions taking place.

Finally, this study focused on one instance each of a conventional and a visual interface, and further work is needed to determine the extent to which these findings would generalize to other examples and how different types of visual interface can influence on the search process. In addition, the analysis could be extended to follow the framing of Li et al. (2023) and explore the outcomes in terms of cognitive and metacognitive issues.

6. Summary and conclusions

In this paper, we have investigated and compared student usage of a conventional and visual interface for search query formulation. We compared them using a variety of quantitative and qualitative metrics on a number of search tasks in a controlled test setting. We now draw conclusions in relation to our original research questions.

First, we wanted to understand how the use of a visual query builder influences the process of query formulation. Our pre-survey results suggested that students would exhibit a type of satisficing behaviour, in which they invest the minimal effort to achieve the task, rather than taking the opportunity to develop their searching competence and skill. However, we found that students used significantly more terms, facets and reformulations using the visual interface, suggesting a deeper engagement with the tasks and the formulation of more advanced, complex queries.

Second, we wanted to understand how use of a visual interface impacts the overall user experience of students engaged in systematic search tasks. We found that most participants considered the visual interface to be more complex and difficult to use. This could be partly due to the lack of familiarity, but also a reflection of the fact that the visual interface requires participants to articulate explicit boundaries between terms and facets and therefore give greater consideration to the logical

structure of their query. Conversely, the majority considered the visual interface to have greater transparency, with a clearer overview of the search tasks that encouraged them to invest greater effort in completing them successfully. In summary, the fact that they formulated significantly more complex queries using the visual interface suggests that the potential remains for alternative interfaces to elicit more sophisticated search behaviours, and to support students in extending and developing their competence in query formulation and systematic searching.

7. References

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