Known-item searches and search tactics in library search systems: Results from four transaction log analysis studies

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Abstract:
A better understanding of users' search interactions in library search systems is key to improving the result ranking. By focusing on known-item searches (search for an item already known) and search tactics, vast improvement can be made. To better understand user behaviour, we conducted four transaction-log studies, comprising more than 4.2 million search sessions from two German library search systems. Results show that most sessions are rather short; users tend to make short queries and usually do not go beyond the first Search Engine Result Page (SERP). The most frequently used search tactic was the extension of a query ('exhaust'). Looking at the known-item searches, it becomes clear that this query type is of great importance. Between 38%-57% of all queries are known-item queries. Titles or title parts were the most frequent elements of these queries, either alone or in combination with the author's name. Unsuccessful known-item searches were often caused by items not available in the system. Results can be applied by libraries and library system vendors to improve their systems, as well as when designing new systems. Future research, in addition to log data, should also include background information on the usage, for example, through user surveys.

Keywords:
library search system, transaction log analysis, TLA, search tactic, known item

Introduction

Transaction log analysis is a means to understanding user behaviour through actual interactions between users and information systems. It allows for a large-scale insight into users' information needs, their queries and their interactions with search systems. Many transaction log studies have examined Web searching behaviour (e.g., Jansen & Spink, 2006; Silverstein, Marais, Henzinger, & Moricz, 1999) and search behaviour in digital library systems (see Agosti, Crivellari, & Di Nunzio, 2012). However, two important topics were under-researched so far: known-item searches and the identification of search tactics in library search systems. Thus, our research focuses on these two topics in particular.
Known-item searches represent concrete information needs (Frants, Shapiro, & Voiskunskii, 1997, p. 38) in that a user aims to find an item already known (see Kantor, 1976). While in Web search, a distinction between query types, usually between informational, navigational and transactional searches (see Broder, 2002) is well established and is used to evaluate the effectiveness of these retrieval systems (Lewandowski et al., 2012), in the evaluation of library search systems, all queries are usually treated the same. However, focusing on known items may be key to considerably improving these systems, as this can be done with relative ease, compared to improving the performance on informational queries.

Search tactics have been the subject of research since the analysis by Bates (1979). Bates defined a search tactic as a move made to further a search. An example is the tactic called 'Exhaust', where one element (e.g., term) is added to an already-prepared query. The counterpart of 'Exhaust' is 'Reduce'. Smith (2012) updated the list to a new set of tactics for the age of web search engines. Various investigations were carried out on search tactics. They found that users are more likely to use 'Exhaust' than 'Reduce' (Jansen, Zhang, et al., 2007) and that both their research skills (Xie & Joo, 2012) and their discipline-specific expertise (Vakkari, 2001; Wang et al., 2011; Wildemuth, 2004) have an impact on the choice of tactics and the success of their searches.

The four studies we present in this article all have been conducted at the Hamburg University of Applied Sciences, Germany, using two different library search systems. In total, we analysed 4,309 queries in Studies I and II and 4.2 million sessions in Studies III and IV. Taken together, the studies help to gain a deeper understanding of user behaviour in library search systems. Results can be applied by libraries and commercial library system vendors to improve their existing systems, as well as when designing new systems or system components.

The rest of this article is structured as follows: The next section presents a literature review on transaction log studies in the area of library search systems. Then, we give an overview of the research focus and the data sets used in our research, where we briefly describe the four studies conducted. In the first part of the results section, we present descriptive statistics. In the second part, we focus on search tactics in general, and in the context of known-item searches, in particular. We discuss our results in terms of their relevance for improving library search systems and in terms of how further research can build on our results.

Literature review

While using a system such as a search engine, users perform several actions like entering a new query or clicking on a result. All these interactions are recorded in a so-called transaction log file. A transaction log is, therefore, an electronic record of the communication between a system and its users (Jansen, 2006, p. 408). The method of analysing these logs is called transaction log analysis (TLA) and has strengths such as inexpensively collecting data of a great number of users, but also has weaknesses. For instance, transaction logs do not provide reasons for the search, the searcher's motivations or other aspects of use (Jansen, 2006, p. 424-425). For a detailed description of the method, the reader is referred to (Jansen et al., 2008).

To distinguish between users when analysing transaction logs, *sessions* must be defined. A session is a series of interactions (e.g., entering a query or selecting a result) by the user toward addressing a single information need (Jansen, Spink, et al., 2007; Silverstein et al., 1999). There are different methods to identify a session: Using the searcher's IP address and the browser cookie, using IP, cookie, and a temporal cut-off (for instance, a 30-min period between interactions as the session boundary), or using IP, cookie, and content changes (Jansen, Spink, et al., 2007).

The method of TLA has widely been applied to the investigation of search behaviour in library search systems (Agosti et al., 2012), i.e., Online Public Access Catalogues (OPACs) and discovery services. In order to perform effective searches, the user must have knowledge of the functionality of an OPAC, such as Boolean expressions (Poo & Khoo, 2009). In contrast to the 'exact match' approach of OPACs, discovery services follow the 'best match' approach. For queries entered in a single search box, the service provides results that best match the query. The results are ranked according to what is most probably relevant to the query defined by an algorithm and can be narrowed by using the faceted navigation. To guide

the user toward the library materials, discovery services also provide recommendations ('Do you mean …?') based on the query (Breeding, 2014).
Studies on OPACs report usage statistics, such as the frequency of search fields used or the length of sessions (e.g., Krebs, 2013; Niu & Hemminger, 2010; Sridhar, 2004). TLA studies that also include failure analyses provide more in-depth knowledge. These studies consider the reasons behind search queries leading to zero results. Typical causes are incorrectly employed Boolean operators, inappropriately selected search fields, or typographical errors (Jones et al., 2000; Lau & Goh, 2006; Ndumbaro, 2018; Waller, 2010). For the latter, Ndumbaro (2018) concludes that a discovery service could address this problem in contrast to an OPAC by integrating a spell checking functionality.
Looking at TLA studies on discovery services, similar analyses to those on OPACs have been published. They consider the scope and actions of sessions (Dougan, 2018; Mayr & Kacem, 2017), the query scopes and the frequency of result clicks (Mischo et al., 2019), the number of abstract views and full-text downloads (Calvert, 2015; Greenberg & Bar-Ilan, 2017), or visualize the activity of the searchers (Joseph et al., 2019). However, compared to OPAC studies, analyses with discovery services are generally more diverse. This is because of the larger functional scopes of the systems and thus the more diverse evaluation possibilities of the log data. Spiteri, Tarulli, & Graybeal (2010) investigated the use of enhanced features such as user-contributed content and Michaels & Cohen (2018) analysed whether users made use of the interlibrary loan when they had zero hits on a known-item search. A study by Barifah & Landoni (2019) identified different usage patterns in the library's log data that are able to contribute to a better user experience.
To gain more in-depth knowledge of user behaviour, mixed-method approaches were also applied. In addition to a TLA, Wells (2016) conducted a survey to determine the usefulness of the discovery service's features. Wakeling, Clough, Silipigni Connaway, Sen, & Tomás (2017) combined the results of a TLA with focus group interviews and an online survey to gain background knowledge on participants' usage of information. Such background information is missing in regular TLA studies, which is why triangulations with other methods provide additional value.
Given the importance of mobile devices in web search, two other studies provide insights into cross-device search behaviour. In discovery services, users tend to search with several different devices within 24 hours (Wu et al., 2018). Furthermore, Wu & Bi (2017) found that reformulation tactics used on the smartphone were less diverse than when searching on a desktop computer or tablet.
Looking at the literature, it becomes clear that little research has been done so far on search tactics and known-item queries and their success evaluation in the library context.

Research focus and data sources

We describe four TLA studies using data from discovery services, namely *beluga* and *EconBiz*. *beluga*[1] is a search platform of currently 13 academic libraries in Hamburg, Germany. It is hosted by the Hamburg State and University Library[2]. *beluga* is based on VuFind[3], which is an open source software for library discovery services. Based on the VuFind software, two indexes are integrated into *beluga*. These are GBV Discovery[4] for the search for 'books & more' (containing the participating libraries' holdings, e.g., books,

[1] https://beluga.sub.uni-hamburg.de/vufind/
[2] http://www.sub.uni-hamburg.de/startseite.html
[3] https://vufind.org/vufind/
[4] https://www.gbv.de/Verbundzentrale/serviceangebote/discovery-service-der-vzg

magazines, music, and films) and Primo Central[5] for electronic scientific articles[6]. *EconBiz*[7] is a search platform for economics and business studies, also based on VuFind, hosted by the German National Library for Economics (ZBW – Zentralbibliothek für Wirtschaftswissenschaften)[8].

As shown in Table 1, the first two studies (Studies I and II) focus on searching for objects already known to the user, so-called known items (Kantor, 1976). Their main research objective is to investigate how the retrieval effectiveness for known-item queries can be improved. Study III investigates log data for search tactics done by the users. It also examines how successful the users are when applying those different tactics. Studies I, II, and III all focus on known-item searches, whereas Study IV is similar to Study III in that it also looks at log data to determine search tactics, and to examine how successful users are when applying them. However, Study IV used a different approach for success evaluation. In all studies, different data sets with different numbers of queries were used, which are provided in Table 1.

Table 1

Overview of studies reported in this paper

	Working paper / previous publication	Focus	Data source	Size of dataset
Study I	Behnert & Lewandowski (2017)	Known-item searches	EconBiz	1,981 queries
Study II	Rulik (2014), working paper	Known-item searches	beluga	1,174 queries (set 1) 1,154 queries (set 2)
Study III	Linhart (2015), working paper	Search tactics when searching for known items	EconBiz	3,463,823 sessions (set 1) 1,825 sessions (set 2)
Study IV	Schultheiß (2018), working paper	Search tactics	beluga	717,092 sessions (set 1) 2,700 sessions (set 2)

While Study I has been published previously and is reported in this article mainly for comparison purposes (Behnert & Lewandowski, 2017), Studies II-IV have so far only been published as German-language working papers (Linhart, 2015; Rulik, 2014; Schultheiß, 2018). In the working papers the studies are reported in much more detail. All studies were conducted in Hamburg, Germany.

Study I: Known-item queries resulting in zero hits

The purpose of this study (Behnert & Lewandowski, 2017) was to understand the reasons behind known-item search queries returning zero hits, and to provide solutions to the zero-hits problem. The study was based on a manual inspection of log data using a random sample of 1,981 queries from the discovery service *EconBiz*, entered in July 2014. Before the reasons behind zero hits could be identified, queries were categorized as known-item queries if the search terms could be identified as one of the following:

- Author name in combination with title or title keywords,
- Author name in combination with a year of publication,
- Author name in combination with title or title keywords and year of publication,
- Author name in combination with title or title keywords and an edition information,
- Full title or title keywords,

[5] https://www.exlibrisgroup.com/products/primo-library-discovery/content-index/
[6] The search function for digital scientific articles is no longer available in *beluga* since 1 February 2020 (see: https://www.sub.uni-hamburg.de/index.php?id=2284)
[7] https://www.econbiz.de/
[8] https://www.zbw.eu/en/

- Title or title keywords in combination with a year of publication,
- Journal title, or
- Journal title in combination with a paper's title or title keywords.

Study II: Retrieval effectiveness for known-item queries

The second study we describe here is a transaction log analysis with a focus on known-item queries entered into the *beluga* discovery system. Due to the dissatisfaction of some employees with the performance of the *beluga* system regarding known-item search queries, the study aimed at answering the following research questions:
RQ1: How effective is *beluga* when searching for known items?
RQ2: How can the retrieval effectiveness for known-item queries be improved?
To answer these questions, we used two data sets from April 2014: 1,174 queries in set 1 (from three consecutive days) and 1,154 queries in set 2 (from three consecutive days one week after set 1), both from *beluga*. A session was defined using IP, cookie, and a temporal cut-off (see *Literature review*). Non-human actions were filtered out. In order to answer RQ1, a classification to determine the proportion of known-item queries had to be developed first. For this purpose, data set 1 was used. The criteria were:

- Query is a shelf mark, ISBN, or ISSN
- Query is a combination of several metadata
- Query contains two author names
- Query contains keyword (e.g., 'journal') or journal abbreviation of at least three letters
- Keyword search: full/partial match with title

A requirement for the classification as a known-item query was that a specific known item could be found, which was subsequently checked by re-entering the query, along with the item's position. Another study goal was to implement an algorithm that automatically identifies known-item queries. As a result, an alternative relevance ranking would take effect for this query type only and prefer the known item in the ranking. Lastly, data set 2 was used to evaluate the algorithm. For data analysis the Piwik software[9] was used.

Study III: Search tactics and their effectiveness when searching for known items

The aim of this study was to understand how users search in *EconBiz* when looking for known items. Thus, search tactics were determined, and their effectiveness examined.
The central research questions were:
RQ1: What is the proportion of known-item queries in *EconBiz*?
RQ2: Which elements are part of users' searches for known items?
RQ3: Which search tactics do users apply when searching for known items?
RQ4: How successful are users when searching for known items?
We conducted a transaction log analysis using two samples of 3,463,823 (set 1) and 1,825 (set 2) sessions from the discovery service *EconBiz* from the period November 2013 to November 2014. Set 1, which contained all sessions from the aforementioned period, was used for descriptive statistics. Set 2 is a random sample of those sessions from set 1 in which at least two pages, of which at least one is a search result page, had been visited. Set 2 was required to manually classify known-item queries and search tactics (see *Introduction*). We defined a session as we did in Study II. Non-human actions and reading room/employee access were filtered out.

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[9] Piwik is now Matomo: https://matomo.org/

To determine the proportion of known-item queries, two conditions had to be met for a query to be identified as such. First, the query must be entered by a human user. Second, the query contains bibliographic information, such as title keywords, names, ISBNs, etc. Regarding RQ3 and the detection of search tactics, we classified the search tactics into two different areas. These are 'formulation tactics' (How do the users modify their queries?) and 'search function tactics' (Which features of the search system do they use?). We studied the effectiveness of search tactics (RQ4) using clicks and ranks. A search for a known item was judged as successful if one of two conditions was met: (1) User clicked on known item, (2) User did not click on known item, but known item was ranked at position 1 (the position was determined by re-entering the query).

Study IV: Search tactics and their effectiveness

As well as Study III, this study has its focus on search tactics as defined by Bates (1979) and Smith (2012) and their effectiveness, but is not focusing on known items.

The research questions were:
RQ1: Which search tactics can be identified from the *beluga* log data?
RQ2: How successful are users in utilizing the search tactics?
RQ3: Which recommendations for action can be derived?

We conducted a log analysis using two samples of 717,092 (set 1) and 2,700 (set 2) sessions from *beluga*, held from April to September 2017. Set 1, which contained all sessions from the aforementioned period, was used for descriptive statistics. Set 2 is a random sample of those sessions from set 1 where at least one query was performed, and that consisted of between 2 and 100 actions. With this restriction, sessions considered too short (1 action) or unnaturally long (more than 100 actions) could be removed for the in-depth analysis regarding search tactics (see *Introduction*). Again, we defined a session as we did in Studies II and III (IP, cookie, temporal cut-off). Non-human actions and reading room/employee access were filtered out.
We grouped the identified search tactics according to Linhart's classification developed in Study III into 'formulation tactics' and 'search function tactics'. The effectiveness of formulation tactics was studied using click patterns (Huang & Efthimiadis, 2009). For each query, a user can decide to click or not click (skip) a result, creating 2×2=4 possible click patterns, as presented in Table 2.

Table 2

Click patterns (Huang & Efthimiadis, 2009, p. 83)

	Searcher Actions on Results			
Initial Query	Click		Skip	
Reformulation	Click	Skip	Click	Skip

To give an example for the click pattern SkipClick: A user enters a query containing one term, is dissatisfied with the search results and subsequently does not click a result. Then, the user adds one term to the previous query (tactic 'Exhaust') and clicks on a result. SkipClick indicates that the user found the applied search tactic to be effective. The effectiveness of search function tactics was studied by comparing their click-through rates.

Descriptive Statistics

First, Studies III and IV are considered. They describe the user behaviour at session and query levels and thus provide a first insight into the data.

Session duration

Due to some very long sessions, both studies come to average session lengths between 11 minutes (Study IV) and 2 hours (Study III). To disregard unnaturally long sessions, Study IV uses a cut-off value of 5 minutes. According to the log data, such sessions were usually caused by non-human access, but could not be identified and filtered out as search engine bots in the first place. Taking the cut-off value into account, a mean value of 01:18 minutes per session was determined in Study IV.

Session scope

The fact that most sessions are rather short is also reflected in the number of actions per session. Study IV shows that about every second session consist of only one action. Such sessions occur, for example, when a user performs a search without selecting a result afterwards. 2 actions were found in 12%, 3 actions in 6% of the sessions. Nevertheless, according to Study IV, there is also a proportion (13%) of very long sessions with 10 actions or more, which are attributed to extensive searches.

Selection behaviour on SERPs

Studies III and IV indicate that users do not go beyond the first search engine results page (SERP) in most cases. At session level, Study III shows that in only 17% of the sessions a SERP other than the first was viewed. At the SERP level, Study IV results show that (depending on the index) 87% (GBV Discovery) to 90% (Primo Central) of all visited SERPs are the first, 5-6% the second, and 2-3% the third SERP. The fourth and all following SERPs represent 1% or less of all SERPs viewed. With regard to selection behaviour, Study IV shows the typical user preference of the first-placed result. Depending on the index, the first result received 33-35% of all clicks. Rank 2 follows with 11-13%, rank 3 with 7-8%.

Terms per query

According to Studies III and IV, most queries are between 2-3 terms long. Study III showed that 28% of all queries contained 2 terms, followed by 19% with 3 and 15% with 1 term. Study IV came to similar results with a median of 3 terms per query.

Search Tactics

In the following, Study IV is considered for the description of the search tactics.

Formulation Tactics

In Study IV, we analysed the data with regard to the formulation tactics presented in Table 3. Most of the tactics were derived from the work of Smith (2012), such as ‘Exhaust’ and ‘Reduce’. The other tactics were either deduced from the work of Huang & Efthimiadis (2009), e.g., ‘Reorder’, or are specific to the discovery service investigated, such as the fuzzy search.

Table 3

Formulation Tactics (Study IV)

Formulation Tactic	Description
Block	Exclusion of terms (NOT)
Change	Exchange of terms while retaining the other terms
Close	~: Proximity of words, for values > 1
Combine	Combination of terms (AND)
Contrary	Switch to term of opposite meaning

Correct_fail	Unsuccessful correction attempt of spelling errors
Correct_final	Successful correction of spelling errors
Exhaust	Adding one or more aspects to an existing query
Extend_abbreviation	Change from abbreviation to full form
Extend_acronym	Change from acronym to full form
Form_abbreviation	Change from full form to abbreviation
Form_acronym	Change from full form to acronym
Fuzzy	~: Fuzzy search, for values between 0-1
Parallel	Expand with terms of equal meaning using OR
Phrase	Phrase search
Range	Range search using { } or []
Reduce	Removal of one or more aspects from previous query
Relate	Switch to a term of similar meaning
Reorder	Rearrangement of terms without changing them
Respace	Change of punctuation or spaces
Respell	Switch to different spelling, e.g., foreign languages
Same	Repeating of a previous query
Sub	Switch to subtopic
Super	Switch to generic term
Truncate_asterisk	*: Placeholder for 0 or more characters
Truncate_questionmark	?: Placeholder for exactly 1 character
URL	URL or domain as query
Weight	^: Weighting of terms

As can be seen from Figure 1, queries were mostly modified by varying their lengths (Exhaust/Reduce). More than 50% of all formulation tactics are one of the two mentioned. In contrast, phrase search or truncation using an asterisk (Truncate_asterisk) were rarely used.

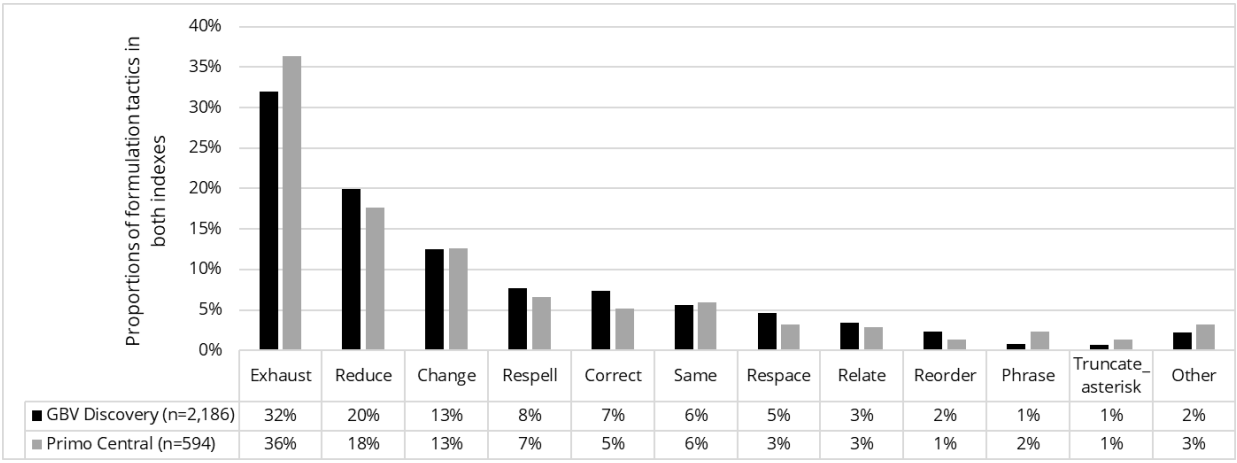

Figure 1: Proportions of formulation tactics (Study IV)

The effectiveness of the formulation tactics differs, as can be seen in Figure 2. A chi-squared analysis verifies that the formulation tactic has a statistically significant effect on the click patterns $\chi^2(27) = 181.429$, $p < .001$.

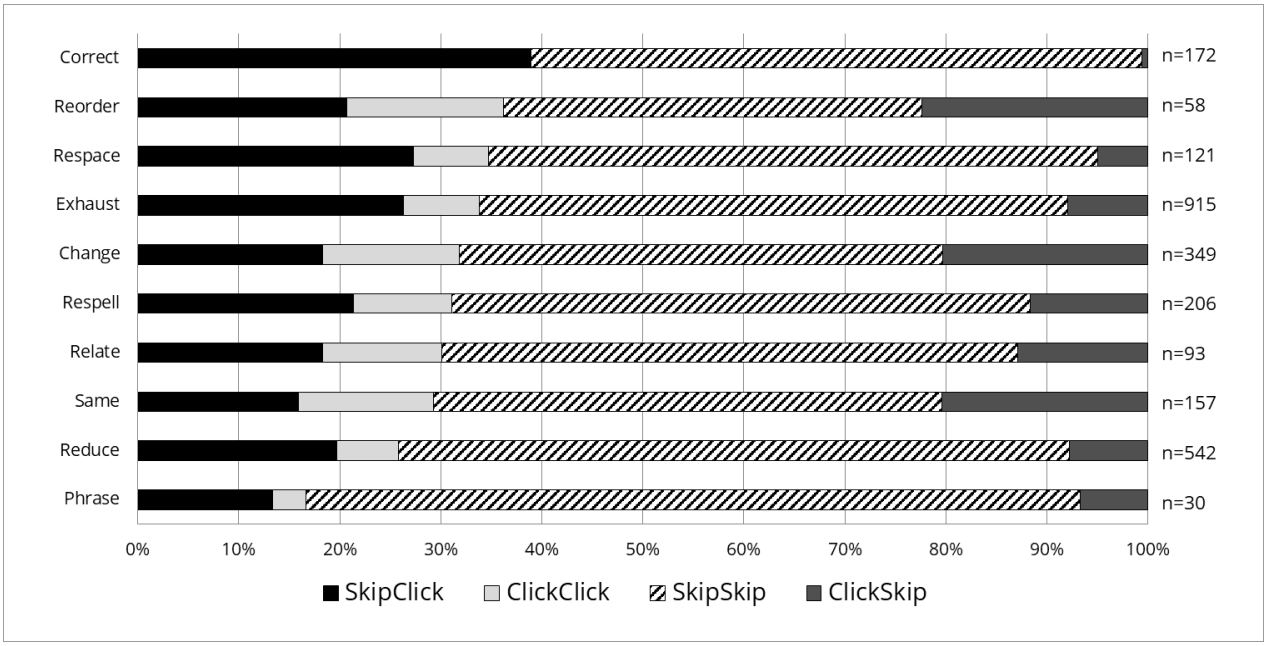

Figure 2: Proportions of click patterns for formulation tactics (Study IV)

The most effective formulation tactics can be identified by looking at the ratios of the click pattern SkipClick. Not surprisingly, the correction of a previously incorrect query (Correct) has the highest ratio of that pattern. The tactics Exhaust, Reduce, and Respace also have relatively high ratios of SkipClick. In contrast, tactics like Phrase search have low proportions, indicating they did not help the users during their search processes. No distinction by index (GBV Discovery/Primo Central) was made due to the small number of cases.

Search function tactics

With respect to search function tactics, Study IV distinguished between different forms of tactics: query submission, results selection, navigation on the results page, facet use, chaining, search fields, and results ranking. The tactic forms of chaining, search fields, and ranking were considered most differentiated in Study IV and thus allow most conclusions to be drawn about user behaviour. Therefore, they are given particular attention in the following.
Ellis (1989, p. 176) describes chaining as following up references discovered in a found document. In *beluga*, for example, chaining occurs when the author name is clicked on during the search for a document in order to receive further publications from the same author ('Chain_author'), as shown in Table 4.

Table 4

Search function tactics: chaining (Study IV)

Chaining	Description
Chain_author	Click on author (or other person), corporation, or conference
Chain_bk	Click on library classification 'Basisklassifikation' (BK)
Chain_class	Click on subject area
Chain_included	Click on source
Chain_issues	Click on existing issues/volumes
Chain_number	Click on ISBN/ISSN
Chain_other	Click on other editions
Chain_rvk	Click on library classification 'Regensburger Verbundklassifikation' (RVK)
Chain_series	Click on Journal/Series/Journal Title
Chain_similar	Click on suggestion at Similar entries
Chain_subject	Click on keyword
Chain_title2	Click on secondary title

Figure 3 shows the chaining actions for both indexes. When searching for electronic articles ('Primo Central'), the possibilities of chaining actions are limited to 'Author', 'Subject', and 'Series'. Therefore, the proportions of the chaining actions refer to all search actions in the respective index and not to the frequencies of chaining actions, in order to allow a comparison of the indexes.
Overall, it also becomes clear that chaining is performed considerably more often in GBV Discovery. Clicks on author names represent the most frequent chaining actions in both indexes. About 3% of all actions performed in GBV Discovery concern author clicks. This chaining form is the only one that can also be performed directly from a result page, since the author names can already be clicked there.

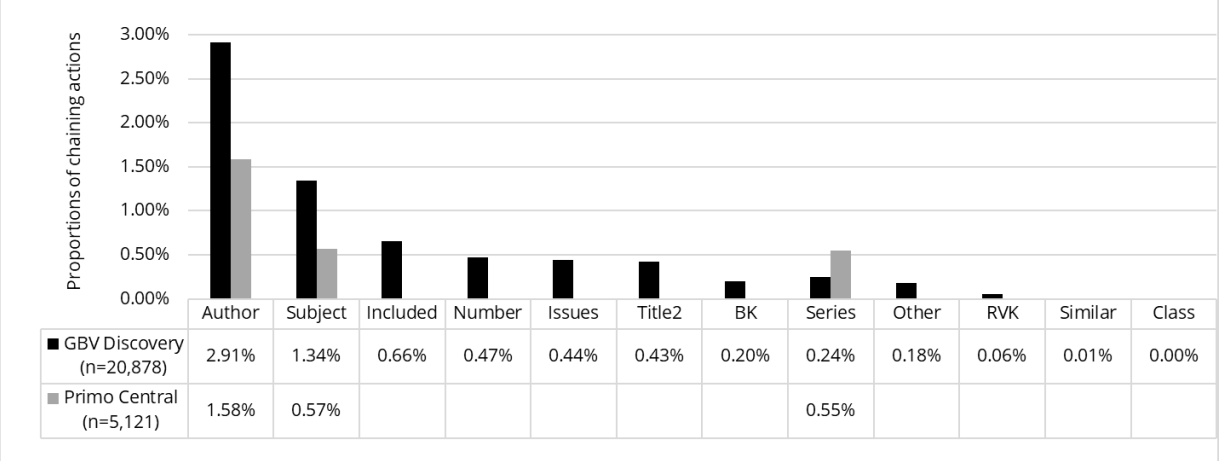

Figure 3: Proportions of chaining actions (Study IV)

Looking at the usage of search fields, the default setting 'All fields' was retained in most of the searches, as can be seen in Table 5. It shows how often a click and a skip (no click) occurred in both indexes as a result of an action with corresponding search field settings. A chi-square analysis verifies that the search field setting has a statistically significant effect on click behaviour for index 'GBV Discovery', $\chi 2\ (2) = 6.055$, $p < .05$. No effect was found for index 'Primo Central'. In other words, when searching for 'Books & more' (GBV Discovery), the search field 'Title' generated most result clicks.

Table 5

Click behaviour according to search field setting (Study IV)

			GBV Discovery			Primo Central		
			Click behaviour			Click behaviour		
			Click	Skip	Sum	Click	Skip	Sum
Search field setting	**All fields**	Count	4537	7319	11856	933	2723	3656
		% within search field	38.3%	61.7%	100.0%	25.5%	74.5%	100,0%
	Title	Count	45	60	105	6	11	17
		% within search field	42.9%	57.1%	100.0%	35.3%	64.7%	100,0%
	Person	Count	24	66	90	5	27	32
		% within search field	26.7%	73.3%	100.0%	15.6%	84.4%	100,0%
Sum		Count	4606	7445	12051	944	2761	3705
		% within search field	38.2%	61.8%	100.0%	25.5%	74.5%	100.0%

Finally, we consider the results ranking. Table 6 shows how often a click and no click (skip) occurred in both indexes as a result of an action with the corresponding sort setting. Most users have maintained the default relevance sorting in both indexes. The sorting 'oldest first' (=Year (asc); not available for Primo Central) caused most of the clicks for GBV Discovery.

In the case of electronic articles ('Primo Central'), sorting by relevance led to relatively frequent clicks. No clicks were made when sorting by author or title for 'Primo Central'. Chi-squared analyses verify that the sort setting has a statistically significant effect on click behaviour for 'GBV Discovery', $\chi 2$ (4) = 15.353, $p < .01$ as well as for 'Primo Central', $\chi 2$ (3) = 17.092, $p < .01$.

Table 6

Click behaviour according to sort setting (Study IV)

			GBV Discovery			Primo Central		
			Click behaviour			Click behaviour		
			Click	Skip	Sum	Click	Skip	Sum
Sort setting	Relevance	Count	4759	7867	12626	944	2730	3674
		% within sort setting	37.7%	62.3%	100.0%	25.7%	74.3%	100,0%
	Year (desc)	Count	172	315	487	16	109	125
		% within sort setting	35.3%	64.7%	100.0%	12.8%	87.2%	100,0%
	Year (asc)	Count	30	43	73	/	/	/
		% within sort setting	41.1%	58.9%	100.0%	/	/	/
	Author	Count	3	13	16	0	8	8
		% within sort setting	18.8%	81.2%	100.0%	0.0%	100.0%	100,0%
	Title	Count	1	23	24	0	11	11
		% within sort setting	4.2%	95.8%	100.0%	0.0%	100.0%	100,0%
Sum		Count	4965	8261	13226	960	2858	3818
		% within sort setting	37.5%	62.5%	100.0%	25.1%	74.9%	100.0%

Known-item queries

Proportion of known-item queries

To identify the known-item queries, the three Studies (I-III), which address this query type separately, use different approaches (see *Research focus and data sources*). As a result, the results of the studies might differ not only due to the different data sets but also due to methodological differences.

In Study I, 38% (n=758) of the queries in the sample were classified as known-item queries. Of these, 7% (n=50) were excluded from the sample because they included a library internal record ID. These queries were assumed to be entered by library staff. In Study II, 600 of 1,174 queries could be classified as probable known-item queries (51%), of which 523 (45%) were unambiguous. In Study III, of the 862 queries initially entered by human users, 491 were identified as known-item queries (57%).

Elements of known-item queries

In Study I, the largest part of known-item queries (60%) contained only the title or title keywords. This was followed by an author name in combination with a title (16%), with year (6%), and with title and year (6%). Study II shows similar results: the largest part (39%) contained the title, the second largest part (27%) contained title and author. In Study III, the most common element of known-item queries was the author's surname (38%), followed by the full title (37%) and title parts (31%). However, if the full title and title parts are considered together, the title is also the most common element of known-item queries. Thus, all three studies have in common that titles or title parts are the most frequent elements of known-item queries, either alone or in combination with the author's name.

Formulation tactics when searching for known items

When searching for known items, users employed various tactics (see section *Formulation Tactics* for a description of the tactics). As Figure 4 shows for Study III, 'Exhaust' was the

most frequently used formulation tactic. In the case of known-item queries, this means adding further information from the bibliographic data of the searched item. For example, if the first query only contained the author's surname, this was supplemented by the title of the item.

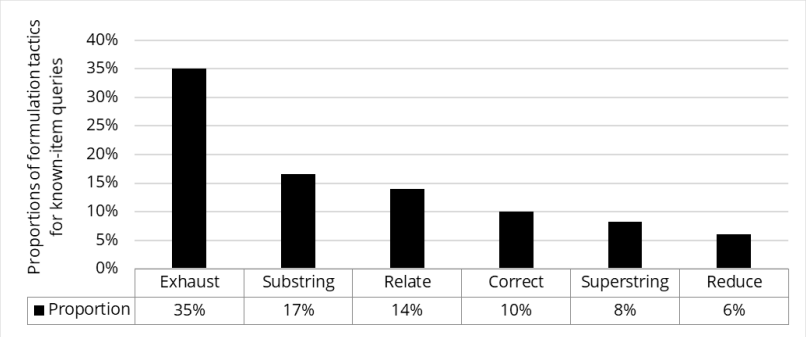

Figure 4: Formulation tactics of known-item queries (Study III)

Identification of known-item queries

In Study II, an algorithm that automatically identifies known-item queries was developed. Based on the classification carried out with data set 1, characteristics were derived that are detectable for the algorithm, e.g., number of terms, names of persons, ISBNs, etc. It was examined, which of the characteristics from the intellectual classification apply to most of the known-item queries. Only these were used for the algorithm. For some of the characteristics, lists (of personal names or other words) were used. See *Appendix 1* for the complete algorithm. Lastly, data set 2 was used to evaluate the algorithm. 498 of the 1,154 queries were classified by the algorithm as known-item queries. Of these, 82.8% were true positive and 17.2% false positive.

Retrieval effectiveness for known-item queries

In the following, we show the results from Studies I, II, and III concerning the retrieval effectiveness of the two library search systems for known-item queries.
After identifying known-item queries in Study I, we classified all queries that led to zero hits. First, all queries of the final sample (n=708) were re-entered. Then, we marked those queries that did not lead to at least one result or that did not place the correct result within the top 30 results. All marked queries were analysed regarding the reasons for no (correct) hits. 44% (n=314) of queries resulted in zero hits. Consequently, only 56% of all known-item searches in the final sample led to correct results. All zero-hits queries were searched for in additional information systems (for instance, library catalogues and academic search engines) to verify books, articles, and other documents. This allowed determining query errors and items not being in stock at the library investigated. Each query was assigned to one of four categories, with possible solutions provided, as presented in Table 7.

Table 7

Known-item queries resulting in zero hits and possible solutions (Study I)

Category	N=	Percentage of queries	Possible solution
Item in stock but query incorrect	95	30%	Implement functions like spell checking into the information retrieval system
Item not in stock	125	40%	Link to the local or national library network
Item in stock but incomplete or erroneous metadata	62	20%	Link to alternative bibliographic database or academic search engine; partial match approach
Query is ambiguous or not understandable	32	10%	Display search interface and link to help page

In Study II, referring to the positions of the known items in the SERP, success @n (94.7% @20, 93.5% @10, 74.1% @1) and mean reciprocal rank (0.78) were calculated for the known-item queries. In Study III, 51% of known-item queries initially entered by the users were rated as successful. In these cases, the known item was either clicked or ranked at position 1. Figure 5 shows the query components used in successful and unsuccessful searches in Study III, respectively.

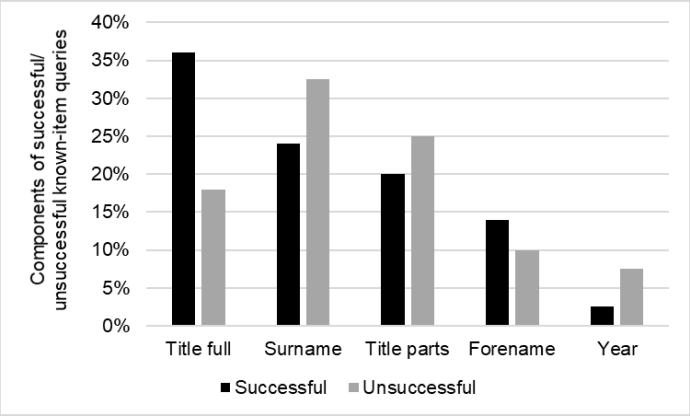

Figure 5: Components of known-item queries (Study III)

As expected, the full title is used much more frequently in successful known-item queries than in unsuccessful ones. The opposite is true for title parts. These can be found more frequently in unsuccessful queries. By re-entering the known-item search queries in Study III, we found that the reasons for unsuccessful searches were either that the known item was not in stock or that inappropriate field restrictions were being used.

Discussion

Our results show that most sessions are rather short, users tend to make short queries of 2-3 terms and usually do not go beyond the first SERP. When comparing the search tactics in the library search systems *beluga* and *EconBiz*, we found similarities. The most frequently used search tactic was the extension of a search query by adding one or several terms ('Exhaust'). This result could be determined both regarding all queries (*beluga*) and only regarding known-item queries (*EconBiz*). Looking at the proportion of known-item searches, it becomes clear that this query type is of great importance in both systems. Depending on the study and the different approaches for identification, 38%-57% of all queries are known-item queries. Titles or title parts were the most frequent elements of these queries, either alone or in combination with the author's name. Searches for known items, which were classified as unsuccessful, were often caused by a lack of indexing of the searched title.

The behaviour shown by users also corresponds to user behaviour in conventional web search engines. In a study using data from a meta-search engine, Dogpile, Jansen, Zhang, et al. (2007) found that most reformulations either served to generalize ('Reduce') or, even more frequently, to specify ('Exhaust') a search query.

One surprising result from Study IV relates to the sort setting. The sorting 'oldest first' caused the most result selections. A possible explanation for this is that a deliberate change of the sort setting could be related to a more specific search, e.g., by a user who deliberately searched for the oldest edition of a certain item.

A major limitation of transaction log analyses such as those described in this paper is the lack of information on the reasons for the search, the searchers' motivations, or other aspects of use. Therefore, it is recommended to combine the analyses with surveys, interviews, or similar methods. As the studies have shown, cleaning and parsing the data by filtering out requests from robots, sessions that are too long or too short, and actions from library staff is

crucial for a precise analysis of the data (Jansen, 2006, p. 415-416). However, it remains unclear whether all sessions that were intended to be filtered out have been detected. For example, sessions that exceed the maximum length, but come from a human user, may have been mistakenly filtered out, or requests by robots may have been overseen. Another limitation of the studies are their samples. They were formed in order to manually detect search tactics that could not or only with great difficultly have been determined automatically. As a result, the number of cases of individual tactics is small in some cases, which could have a negative impact on the significance of the results.

Practical implications

The findings of Study I indicate the importance of metadata quality. Of all queries resulting in zero hits, 20% could be attributed to incomplete or incorrect metadata. The results of Studies II and III showed that known-item queries are of great importance in searching library search systems with about 50% of all search queries. With the help of the algorithm for identifying known-item queries (Study II), considerable improvements in the retrieval effectiveness for this query type could be achieved by relatively simple means. One requirement for this would be the development of an alternative relevance ranking which favours the known items within the results list. In addition, a refinement of the algorithm would be necessary to reduce the proportions of false-positive assignments. Otherwise, negative effects on the ranking of non-known-item queries are to be expected. Since the algorithm as well as the other results come from working papers, it is to be understood as a concept that can serve as a starting point for further research and development.

Study III showed that unsuccessful known-item queries can be largely attributed to incorrect field restrictions. The field restriction changes with certain actions of the user, which some users, however, may not be aware of. In these cases, users continue their research without noticing the changed field restriction and, thus, do not find the item they are looking for. We therefore propose not to offer the possibility to change the field restriction in the simple search, since it is rarely consciously changed by users.

Study IV on search tactics revealed that about every second formulation tactic described the variation of the search query length (‘Exhaust’, ‘Reduce’). Both tactics were also among the most effective ones, i.e. those that were most beneficial for a subsequent result selection. Also, a frequent correction of erroneous queries was noted. This emphasizes the importance of catalogue functions such as an automatic spell check to assist users. Similar findings were also made in Study I regarding known items. Incorrect queries generated zero hits when searching for known items that would have been in stock.

Conclusion

In this article, we presented four studies with the aim to gain a deeper understanding of two underresearched topics, namely known-item searches and the identification of search tactics in library search systems. The studies have all been conducted at the Hamburg University of Applied Sciences, Germany. Apart from descriptive statistics on the use of the library search systems *beluga* and *EconBiz*, we have shown that users employ a variety of search tactics. Most frequently, they vary the length of their queries or change individual terms. We also detected frequent corrections of queries. A large proportion of queries are known-item queries. For their automatic identification we have developed an algorithm. In Study IV we used KNIME Analytics Platform[10] software for analysis, which has proven to be a highly effective tool for analysing log data. The results of the four studies can be used by libraries

[10] https://www.knime.com/knime-software/knime-analytics-platform

and commercial library system vendors to improve their systems and to develop new systems or system components. In particular, automatic spell checking should be looked at more closely. Further research should focus on analyses which, in addition to log data, also consider background information on the usage via user surveys or interviews. In addition, a revised version of the presented algorithm could identify known-item queries with sufficient certainty and enable an alternative relevance ranking for these queries, which prefers the known item in the ranking.

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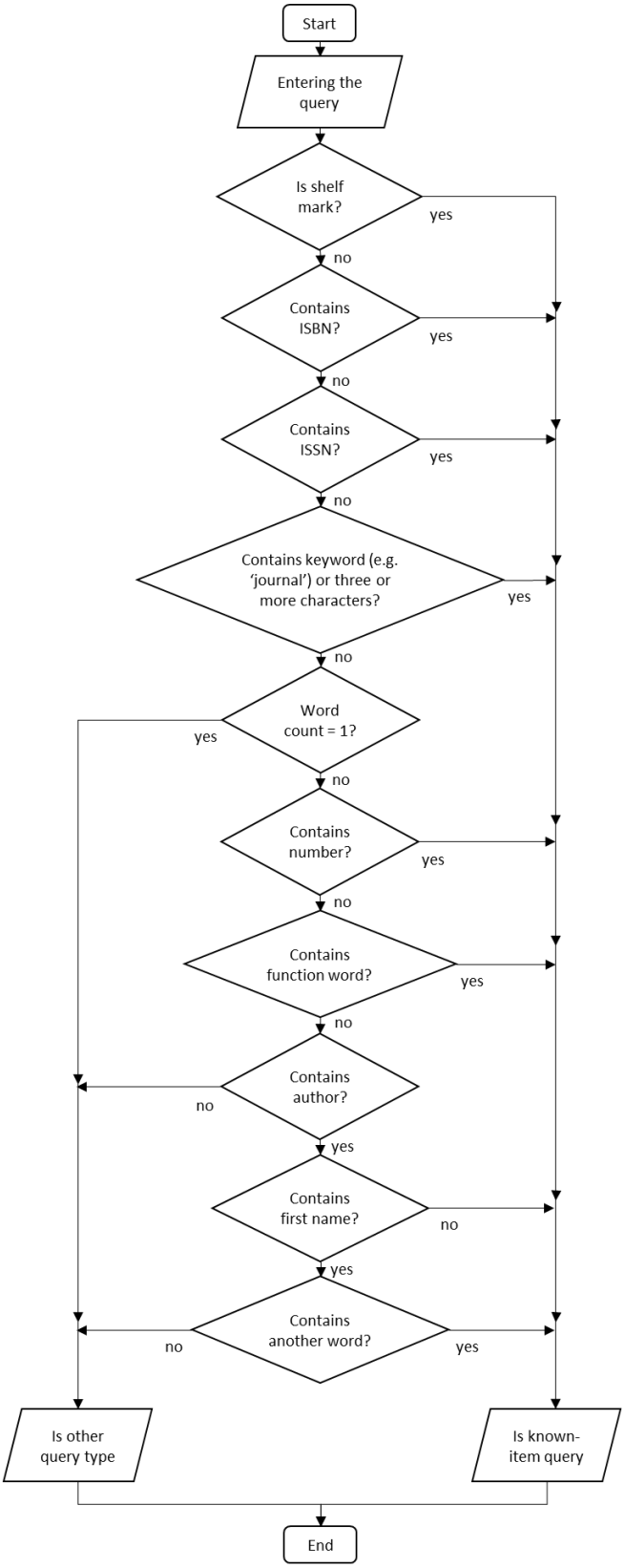
Appendix 1


Start
Entering the query
Is shelf mark?
yes
no
Contains ISBN?
yes
no
Contains ISSN?
yes
no
Contains keyword (e.g. 'journal') or three or more characters?
yes
no
Word count = 1?
yes
no
Contains number?
yes
no
Contains function word?
yes
no
Contains author?
no
yes
Contains first name?
no
yes
Contains another word?
no
yes
Is other query type
Is known-item query
End