

# Query Reformulation in Accessing Library OPAC: A Comparative Study on Different Devices

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## Abstract

This paper discusses the differences in query reformulation for mobile phone, tablet and desktop devices by mining the transaction log data of a library OPAC. We aimed to analyze the impacts of different devices on user search behavior and provide constructive suggestions for the development of library OPACs on different devices. Based on transaction logs which are 9GB in size and contain 16,140,509 records of a university library OPAC, statistics is used to analyze the differences in query reformulation on different devices in terms of two aspects: query reformulation tactics and query reformulation complexity. The results found that as reformulation times increased, the differences between query reformulation among different devices decreased. Mobile-side libraries need to optimize user interfaces, for example by setting web page labels and improving input capabilities. Desk-side libraries can add more suggestive content on the interface.

**Keywords:** Query reformulation; Library OPAC; Mobile phone search; Tablet search; Desktop search

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## 1 Introduction

With the rapid development of mobile internet, increasing numbers of people are using mobile devices such as mobile phones, tablets, and wearables to access the web. The library OPAC, as the entrance for accessing library resources, is also searched by users with different devices. In addition to searching directly on the OPAC web site, there are many other ways to access the library OPAC, especially for mobile devices. For instance, some libraries have a library application (app) for mobile devices, and in China some libraries use a popular instant messaging app called WeChat to provide access to the OPAC. The differences between the diverse devices and access methods, such as the screen size, the input method, and the user interface, may affect user information-seeking behaviors and search results. Therefore, it is necessary to explore whether differences exist when searching a library OPAC using different devices in order to improve search efficiency, especially for mobile devices.

Some comparative studies of mobile search and desktop search on the web have found differences between different devices, such as the time spent, the number of inputs, the number of clicks, and the query length. Kim and Albers (2002) found that searching using a mobile device took longer than using a desktop to complete the same task. Kamvar et al. (2009) found that desktop users had more queries per search session than mobile users. The average input time and average character length were longer on mobile devices than desktops, while the number of inputs was lower (Wu and Bi, 2016). Compared with web searches on all kinds of information, library OPAC search, on a small range of academic information resources with high credibility, is more specific. Furthermore, search engines provide a full-text search strategy, especially keywords search, while a library OPAC uses a field search strategy, especially the

combination of search fields. Thus, web search is different from library OPAC search. However, it is not known whether the differences in impact that different devices have on library OPAC search are the same as those for web search, and it is this issue that this paper explores.

Query reformulation is essential information-seeking behavior, which reflects the process of constantly adjusting the search tactics and clarifying information demands. Query reformulation may be influenced by the use of different devices, given the different device sizes, user interfaces, search functions, users' habits, etc. Identifying the differences in query reformulation on various devices can help libraries to improve the search function on different devices and provide more accurate search services, especially for the mobile-side library. This research explores the differences between query reformulations on different devices in OPAC search and compare the results with web search. Two research questions are put forward.

RQ1: What differences are there in query reformulation tactics between different devices searching on a library OPAC?

RQ2: How different are devices in accessing a library OPAC in query reformulation complexity?

The two research questions were explored utilizing large-scale transaction logs of a library OPAC. The study required search session data containing durations and queries performed by OPAC users. Log data is more objective and appropriate for quantitative analysis than small-scale experiments or questionnaire investigations. Of course, there are some limitations in using log data. For instance, the situation in which users search and the emotions of users cannot be obtained from the log data, but the information is essential for cause analysis.

## 2 Related Work

### 2.1 Search Behaviors on Library OPAC

Studies have been conducted on patterns of query reformulation in library OPAC search. Huang et al. (2015) defined six kinds of reformulation pattern (narrowing search, expansion search, translation, format adjustment, dynamic pattern, repeat). Willson and Given (2010) identified two common patterns (narrowing search, expansion search).

Some scholars have studied the use of search fields in library OPACs. With regard to the study of the frequency of search fields, Kumar and Vohra (2013) used a questionnaire survey to compare the frequencies and causes of the use of different search fields in three Indian universities. The study found that author and title were the most frequently used search fields, and that subject, keyword, and combination search were the fields searched less frequently. Madhusudhan and Aggarwal (2013) evaluated the frequency of access to six Indian Institute of Technology Library search fields through form collection and found that author, title, subject, and publisher were the most frequently used fields, while barcode number was not being used. Alia and Farzana (1983) also found title, author, and subject to be the most frequently used search fields through a questionnaire. Regarding the relationship between search field and retrieval failure, Peters (1988) found that the highest percentage of failure retrieval was on keyword search (49.6%), followed by title search (43.8%), and author search (30.2%). However, Thorne and Whitlatch (1993) and Hildreth (1997) found the highest rate of failure retrieval was on subject search.

The relationship between information-retrieval system and search failure has been explored. A study on the effects of OPAC screen changes on search behavior and searcher success (Blecic et al., 1999) revealed that although screen changes initially had a positive impact on search behavior, in some cases the initial improvements in searching success were not sustained over time. Through transaction log analysis, Lau and Goh (2006) found that search options, typographical errors, query length, and Boolean operators had a relationship with search failure, and that some defects in the information-retrieval system might lead to

search failure. Given a longer query length, the probability of matching the query string against these records would be reduced.

Some scholars discussed the impact of web search engines on OPAC users. Kumar (2012), through questionnaire analysis, concluded that OPAC users were influenced by the ease of use, simple searching, convenient access, and relevance ranking of web search engines. As a result, web search has increased the expectations of OPAC users, and users have a more casual attitude towards OPACs. Yu and Young (2004) studied the effects of implementing a web-based OPAC along with interface changes and suggested that meta-searching, relevance-ranked results, and relevance feedback were expected in user searching and should be integrated into online catalogs as search options.

## 2.2 Comparison of Web Search Behavior on Different Devices

Studies in this area have mainly explored information category, query feature, query reformulation, and interaction behavior.

Through log analysis, Kamvar et al. (2009) compared search behaviors on computer, iPhone, and conventional mobile phone. They found that the percentages of local searches on iPhone and computer were lower than on conventional mobile phone, while more users searched for local content within an app on iPhone than on conventional mobile phone. The percentage of adult queries was vastly larger on desktop than on mobile phone (Kamvar et al., 2009; Kamvar and Baluja, 2006).

Studies on the query feature explored query length and query diversity. Kamvar et al. (2009) concluded that query length was very similar for computer and iPhone search, but was significantly shorter for mobile phone search. Both computer and iPhone queries had a much higher percentage of unique queries. It was found that computer users had the greatest number of queries per session, followed by iPhone, and then conventional mobile phone; this was in line with the findings of Kamvar and Baluja (2006).

According to Wu and Bi (2016), in general, the frequency of query reformulation in desktop search was greater than that in mobile search, as was the specified reformulation and parallel reformulation. They found that the input times and click times in desktop search were longer than in mobile search, while screenshot times were shorter than in mobile search when completing the same search task.

In summary, most studies have focused on the impacts of the screen, the function, or the features of library OPACs on search behaviors. All of these factors have been shown to affect users' search behaviors. Searching library OPACs on different devices highlights big differences in screen size, interface, search approach, and possibly other aspects. Furthermore, previous studies suggested that web search behavior differs on different devices. Therefore, research about the effect of different devices on library OPACs search is essential.

## 3 Methodology

### 3.1 Data Collection Methods

The OPAC logs of XXX Library were collected from April to October in 2015, a total of 16,140,509 records. Each record includes login and logout time, user identification code, device identification code, retrieval method, search field, and query request.

The different devices accessing the library OPAC were identified by User-Agent code. An example of User-Agent code is shown in Figure 1.

**User-Agent<Mozilla/5.0 (Macintosh Intel Mac OS X 10\_11\_1)**

Figure 1. An example of User-Agent code

“Macintosh” stands for Mac computer. “Intel Mac OS X 10\_11\_1” indicates that the system is OS system, and the system edition is 10\_11\_1. The number of desktop records is 3,989,216, of tablet records 51,667, and of mobile phone records 895,841.

The search session is classified by user identification code, and the search duration is calculated by login and logout time. If the gap between two adjacent actions is more than 30 minutes, the search session is divided into two. Finally, the total number of desktop search sessions is 651,082, the number of tablet sessions 8,264, and the number of mobile phone sessions 150,727.

Query requests in the log are mostly Chinese. First, the UTF-8 code was converted to GB2312, and the word segmentation was then processed using the segmentation tool IKAnalyzer.

### 3.2 Data Analysis Methods

To allow for quantitative study, a taxonomy was constructed by combining the types of query reformulation identified in previous work (Liu et al., 2010). A matching rule was implemented for each tactic (Table 1), and the query reformulation pattern was defined as the combination of the query reformulation tactics in a search session. For example, in a search session, the query reformulation pattern may be firstly “New,” changing to “Specialization,” that is, “New→Specialization.”

Tactic	Definition
New (N)	$Q_i$ is the first query or does not share any common terms with $Q_{i-1}$
Generalization (Ge)	$Q_i$ shares common terms with $Q_{i-1}$ ; and $Q_i$ contains fewer terms than $Q_{i-1}$
Specialization (Sp)	$Q_i$ shares common terms with $Q_{i-1}$ ; and $Q_i$ contains more terms than $Q_{i-1}$
Reconstruction (Rc)	$Q_i$ shares common terms with $Q_{i-1}$ ; and $Q_i$ has the same length as $Q_{i-1}$
Repeat (Re)	$Q_i$ is the same query as $Q_{i-1}$

Table 1. Taxonomy of query reformulation tactics

The changes in query length, the edit times from one query to the next query, and the query vocabulary richness in each search session reflect the complexity of performance in query reformulation. Therefore, the query reformulation complexity of different devices by the three indicators was compared. Inspired by Shah and González-Ibáñez (2011), the average Levenshtein distance was computed as a metric of each reformulation tactic. Given two strings, A and B, the minimum number of editing operations needed to turn A into B is the Levenshtein distance. The editing operation allows replacement, insertion, and deletion of a character. This research calculated the average value of Levenshtein distance on query reformulation, including the New, Specialization, Generalization, and Reconstruction tactics. Borrowing an idea from Zhen et al. (2013), the average value of query vocabulary richness (QVR) was calculated for each type of query reformulation tactic. QVR refers to the average number of unique words each query contains in a search, and is calculated as:

$$\text{QVR} = \frac{\text{Error!}}{\text{Error!}} \quad (1)$$

## 4 Results Analysis

### 4.1 Query Reformulation Tactics

As shown in Figure 2, the proportion differs for each query reformulation tactic on different devices, but the rankings of the five types of reformulation are the same on each device. The proportions of the reformulation tactic for the tablet and the desktop are similar. The reason for this may be the similarity of the user experience on the tablet and the desktop, since the screen size and search options of the two devices are more comparable. There are more “Repeat” tactics for the mobile phone than for the tablet and desktop, but the other reformulation tactics are less frequent. The reason for the high probability of “Repeat” may be that the users repeatedly submit their query request when met with a slow response on the web page, especially on a mobile phone. Of course, ease of entry also influences the probability of “Repeat” on the three devices.

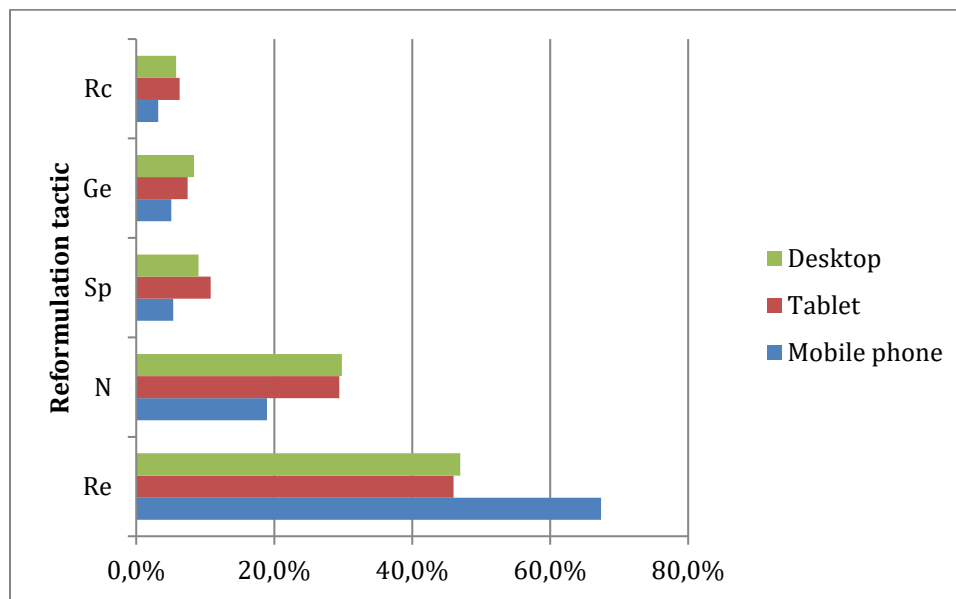


Figure 2. The proportion of different reformulation tactics on the three devices

The reformulation patterns were obtained by identifying the number of characters and the query terms. The reformulation patterns can be divided into two categories. One is the pattern with only one kind of reformulation tactic, for example, “computer science→computer science” or “computer science→computer science→computer science,” both of which use only one kind of tactic, “Repeat,” and the reformulation patterns are “Repeat,” “Repeat→Repeat.” The other category is the pattern with more than one kind of reformulation tactic, for example, the query reformulation “information retrieval→information retrieval→digital library” uses two kinds of tactic, “Repeat” and “New,” and the reformulation pattern is “Repeat→New.” In the log data, there are 2,823 kinds of reformulation pattern on the mobile phone, 530 kinds on the tablet, and 25,414 kinds on the desktop. The patterns whose proportions are within the top 10 on different devices are listed in Figure 3.

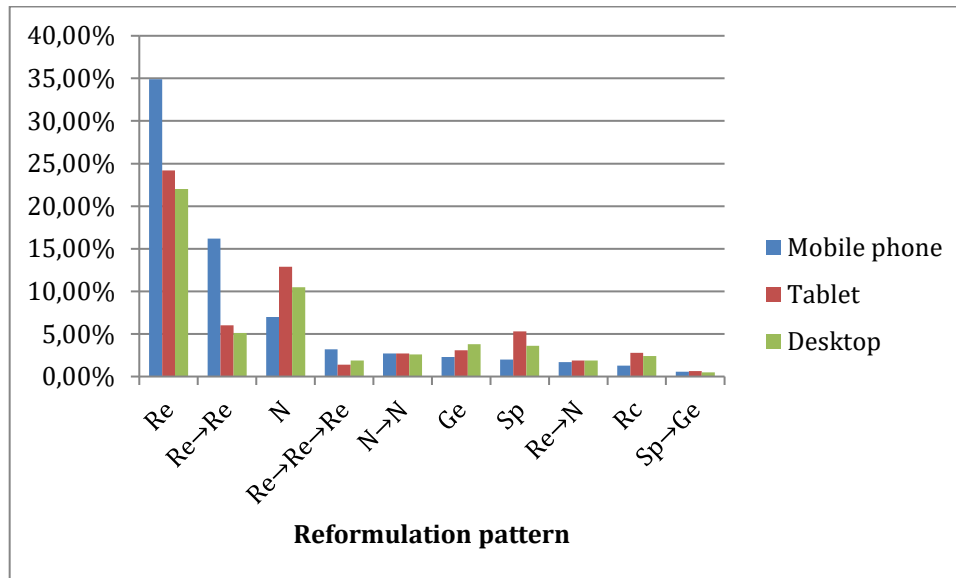


Figure 3. The proportion of different reformulation patterns on the three devices

In all patterns, “Repeat” and “New” tactics appear the most times. The proportion of transition from “Repeat” to “New” is the highest; this is the same on the tablet as the desktop, while on the mobile phone it is lower. This result is in line with our experience: when no record returns or the web page responds slowly, we often repeat our query request. Besides, the OPAC users’ information demands are usually clear and they may obtain what they want through just one query and then search for the next one. Therefore, “Repeat” and “New” appear frequently. Due to input inconvenience, users may choose to use desktop search when they have more than one demand, and try to avoid creating a new query when they access the library OPAC on a mobile phone. Both lead to fewer occurrences of “Repeat→New” on mobile phones.

“Specialization→Generalization” also appears very frequently. Narrowing the search to make a demand clearer and then generalizing the search when demand is not met is very common.

#### 4.2 Query Reformulation Complexity

As the number of reformulations increases, the query length changes (Figure 4). Overall, the query lengths on the three devices decrease. The length of the first query on the desktop is the longest among the three devices. While the query length decreases with the number of reformulations, the query length on the mobile phone first increases and then decreases, and the third time is greater than that of the desktop. The query length on the tablet is relatively shorter compared with the other devices. As the number of reformulations increases, the query lengths on the three devices gradually become more similar.

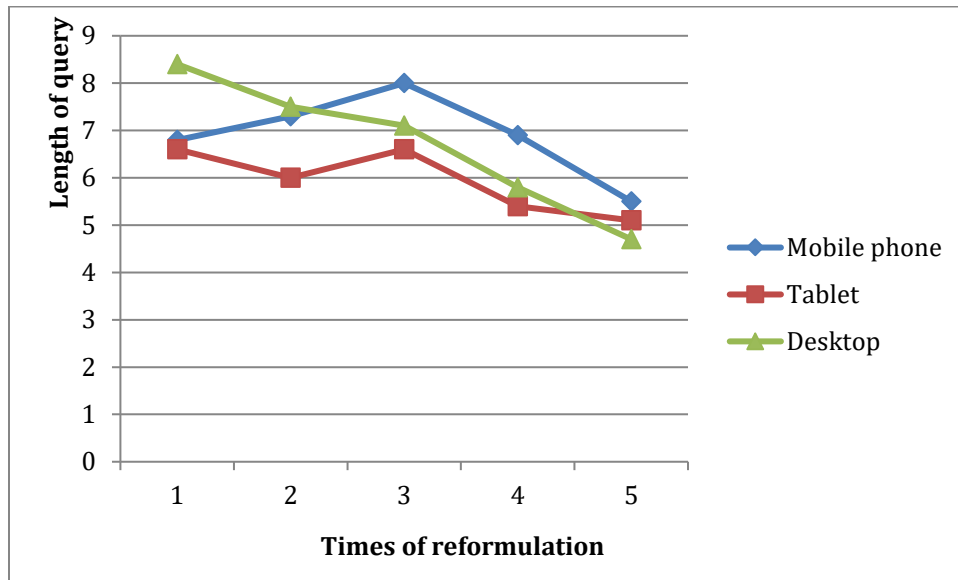


Figure 4. Change in length of reformulated queries on the three devices

The average Levenshtein distance of each query reformulation tactic on the three devices is shown in Table 2. Tested by one-way ANOVA in SPSS, only the “Generalization” tactic shows significant difference (Sig<0.05) between the three devices. For the “Generalization” tactic, the Levenshtein distance on the mobile phone is greater than on the tablet and desktop, which indicates that mobile phone queries require more operations when they are changed.

Reformulation tactic	Mobile phone (number of times)	Tablet (number of times)	Desktop (number of times)	Significance
N	5.98	5.69	6.71	0.109
Sp	4.94	4.36	4.99	0.540
Ge	10.56	4.82	6.50	0.000*
Rc	2.71	2.96	2.47	0.125

Table 2. Average Levenshtein distance of different reformulation tactics on the three devices

The mean values of QVR for each reformulation pattern on the three devices are different. Due to technical limitations, only the QVR of patterns that include only one kind of reformulation tactic can be counted, and there are 147 kinds in total; only eight kinds of patterns’ QVR are in the normal distribution tested by Kolmogorov–Smirnov in SPSS (Table 3). Only the eight kinds of pattern are compared because the other data are so small that they are not suitable for analysis.

The reformulation patterns “New,” “New→New,” “Repeat,” “Repeat→Repeat,” and “Generalization” have significant differences (Sig<0.05) on the different devices tested by one-way ANOVA. There are differences between the mobile phone and the desktop, and between the tablet and the desktop; the mobile phone and the tablet do not have significant differences. Clearly, QVR values for the desktop are greater than those for the other devices. This suggests that accessing OPACs on different devices affects users’ entry behavior, and this may lead to different search results. In the initial reformulation, the QVR for the desktop is greater than that for the mobile phone and tablet, but the QVR values become closer as the number of reformulations increases. The reason for this may be the impact of the device and the OPAC interface on users’ impression and search habits.

Reformulation pattern	Mobile phone (QVR)	Tablet (QVR)	Desktop (QVR)	Significance
N	1.946	1.933	2.081	0.000*
N→N	1.591	1.663	1.765	0.000*
Re	1.279	1.211	1.337	0.000*
Re→Re	0.924	0.962	0.955	0.041*
Re→Re→Re	0.66	0.632	0.681	0.657
Ge	2.156	2.104	2.427	0.037*
Sp	1.876	1.775	1.89	0.454
Rc	1.809	1.245	1.885	0.115

Table 3. Mean QVR values of query reformulation patterns on the three devices

## 5 Discussion

### 5.1 Reasons and Implications of Query Reformulation Tactic and Complexity in Library OPAC Search on Different Devices

The obvious difference in the query reformulation tactics on different devices is the much higher proportion of “Repeat” on the mobile phone. The reason for this may be that users repeatedly submit their query request when met with a slow response to the web page. More frequent use of “Repeat” on mobile phones may also be the effect of the smaller screen size and the inconvenience of entry. On the tablet and desktop, owing to larger screen sizes and the clearer page labels, users may wait, refresh the page, or open another page for a similar search or additional search if the web page responds slowly following the submission of the request. However, the mobile phone screen is small and mainly shows the contents that users are searching, so the tolerance of users waiting for a response decreases, and users tend to repeat the query request.

The results of this study indicate that the length of reformulated query and QVR of reformulation patterns present a similar change regulation. In initial reformulation, the query length and QVR on the desktop are greater than they are on the other two devices, while they gradually become closer as the number of reformulations increases. Users may be influenced by the first impression of the OPAC interface on different devices; for example, users usually think that the desktop is easy to input and suitable for longer queries. If users cannot find what they need, they may take more care over the query content, regardless of the device they are searching on. Furthermore, a long query length is apt to produce a search failure (Lau and Goh, 2006). Thus, the query length and QVR on the desktop are greatly reduced, and are closer to those for the other devices.

### 5.2 The Comparison of Library OPAC Search and Web Search on Different Devices

A slight difference in this paper compared with previous research investigating web search is the inclusion of “New” and “Repeat” in the query reformulation tactics. If “New” and “Repeat” are excluded, the probability of transitions from “Specialization” to “Generalization” is the highest. This differs from the conclusion of previous studies that the probability of transition from general query reformulation to specific query reformulation is highest (Boldi et al., 2011). The current research is based on library OPAC search, while previous studies were based on web search, so the reasons for the different conclusions still need to be studied further. It could be that the function setting of the screen influences user behavior. A library OPAC has search fields, giving users the impression that they should select more specific terms to search, and should then turn to a general search if their first search fails. However, a web search does not necessarily provide search fields, and users may start from a more general search. In addition, the types of information



resources on the web and in the library are different, and this may also affect users' tactics. Controlled experiments, supplemented by questionnaires, would allow an exploration of the reasons, which cannot be found in the transaction logs.

"Repeat" appears most frequently on the three devices, and the conclusion of this research is the same as that of Huang et al. (2015), who also studied library OPAC search. However, Jansen et al. (2007) studied web search, and found that "New" appeared the most frequently, followed by "Reformulation." The reformulation tactics of library OPAC search and web search are different. The different types of information resources and users' needs might lead to these variations. Information on the web has many carrier formats, such as web pages, images, and videos. If users need diversified information resources, they will create new queries, thus increasing the frequency of "New." However, information resources in libraries are relatively simple, and users' needs are clearer, so they often repeat or modify their query.

### 5.3 Recommendations for Library OPAC Search on Different Devices

Mobile-side libraries need to optimize user interfaces. To avoid too many ineffective "Repeat" tactics, the mobile-side library can present web page labels allowing users to open multiple search pages. If there is more than one web page, in the transition of search fields, users need only click on the label to switch back to the home page and then start a new search, thus avoiding the loss of the initial search page and facilitating a secondary search. Moreover, with more than one web page, users can perform similar or other searches if the web page responds slowly. Improving the OPAC performance and web access speed is also important.

The input capabilities of mobile phones could also be improved. This study found that the Levenshtein distance on the mobile phone is greater than on the tablet or the desktop, indicating that mobile phone queries need more operations when they are changed. It might be that the input capabilities of mobile phone devices can be improve to make the operations more convenient, such as allowing the user to select and move a word.

The desk-side library can add more suggestive content to the interface. The findings on query length demonstrate that helping users to clarify their information demands and select appropriate terms before query input is essential for effective search. The desk-side library can add explanatory notes to the more specialized search fields, not only to improve the utilization rate of these search fields but also to help users to improve their search efficiency. The desk-side library should also increase the query input prompts, such as the appropriate word length, how to select query words, etc., in order to help users to clarify their information needs and select the appropriate query terms before entering the query, to avoid excessive query reformulation.

## 6 Conclusion

This paper studies the differences between three different devices in relation to query reformulation using transaction log data of a library OPAC. The differences are presented in Table 4.

Item	Mobile phone	Tablet	Desktop
Query reformulation tactics	More "Repeat" type, and the others are less frequent. The proportion of "Repeat→New" is the lowest.	The proportions of the five types are similar. The proportions of "Repeat→New" are the same.	
Complexity of query reformulation	The length first increases and then decreases, and is longer than that of the desktop as the number of reformulations increases.	The length first increases and then decreases.	The length shows a decreasing trend. The QVR is greater, but as the number of reformulations increases, the differences

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More operations are required to expand the scope of the search.	between QVR values gradually disappear.
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Table 4. Differences of query reformulation among the three devices

It can be seen that the tablet and desktop are similar in terms of the query reformulation tactics, while the mobile phone and tablet are more consistent for the complexity of query reformulation complexity. A great deal of the data show that the search function of the OPAC on the tablet is between that of the mobile phone and the desktop. The search function of OPAC on the mobile phone, tablet, and desktop is progressive. This effectively shows that devices have a great influence on search behavior. The latter scholars also need depth mining and research on the impacts of the devices on search behavior.

The limitation of this research is that it is conducted mainly through data analysis by logs, with no consideration of different scenarios, so it cannot explore in depth the reasons for the differences between the different devices. Thus, future research will utilize a survey of library users to explore the reasons and motivations of search pattern transitions using different devices.

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