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Study of User Search Activities With Two Discovery Tools at an Academic Library

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The goal of this study was to **investigate and compare user search activities of 2 discovery tools at an academic library. The implementation of a new discovery tool (Primo by Ex Libris) to replace an existing system (VuFind) provided a unique opportunity to collect transaction logs of both systems and examine user search behavior in an empirical test.** Results from a transaction log analysis and a **user study of this study** have contributed to the understanding of users' search behavior and their preferences and perceptions of the two systems. We find both commonalities and differences between VuFind and Primo for users' interactions. The combination use of the transaction log analysis and user study could be applied to other similar search systems assessments.

1. INTRODUCTION

In recent years, as more library collections are available electronically, libraries began to adopt discovery tools that are designed to be "one-stop" search platform for a wide range of library collections and resources. Discovery tools are web-based applications that search in a unified index of metadata from article databases, library catalogs, digital repositories, digital collections, and other scholarly information resources (Fagan, Mandernach, Nelson, Paulo, & Saunders, 2012; Williams & Foster, 2011). The unified metadata consist of facets, which Wynar and Taylor (1992) defined as mutually exclusive and collectively exhaustive properties of information items (e.g., books, journals, articles, etc.). With the utilization of faceted browsing and searching, users can achieve higher task accuracy and satisfaction than traditional direct search (Yeh & Liu, 2011). Because of these potential advantages of discovery tools over traditional library catalogs, the number of libraries in a sample of 260 academic libraries in the United States and Canada employing discovery tools has doubled from 2010 to 2012, increasing from 16% to 29% (Hofmann & Yang, 2012). Following the implementation of discovery tools, there

has been a growing interest of research among libraries on user search activities and task performance changes for assessing the effectiveness of discovery tools.

Purdue University Libraries (the Libraries hereafter) implemented VuFind (Figure 1) to replace the traditional OPAC (online public access catalog) in 2009. VuFind allows users to search and browse records in the library catalog and institutional repositories. In October 2012, the Libraries made a move to replace VuFind with a new discovery tool, Ex Libris Primo^TM (Figure 1; Primo hereafter), aiming at providing additional coverage of libraries' subscribed databases and online journals. The decision to implement Primo was largely due to its seamless integration with the existing library management system. During the testing period from October to December 2012, both VuFind and Primo interfaces were presented on the library's home page in order to make the transition easier for users. Note that the "Articles" search tab shown in Figure 1 was based on a legacy search tool that is not part of VuFind or Primo. The testing period provided a unique opportunity to contrast user activities of both systems. Primo provides a single entry point for the majority of library resources, including catalog records, institutional repositories, databases, and online subscribed journals/magazines (some electronic resources are not available in Primo search), whereas VuFind is mainly for the library catalog and institutional repositories (Figure 2). There are also differences of user interface between these two systems due to the coverage difference.

The goal of this study was to understand user search activities with both VuFind and Primo in a unique time window where both tools were available for the library searchers. We combined transaction log analysis and user testing, which has been rarely used in combination in studies on evaluating search systems, especially for discovery tools. Basic search activities such as search field selections, facet usage were examined. We also conducted a search query analysis and investigated the query formulation and reformulation strategies to further understand searchers' behavior and to provide guidance for future discovery tool design and implementation efforts.

Color versions of one or more of the figures in the article can be found online at www.tandfonline.com/hihc.
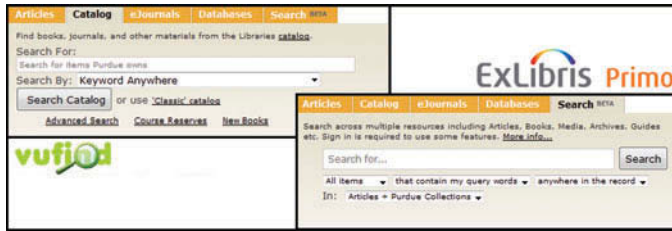
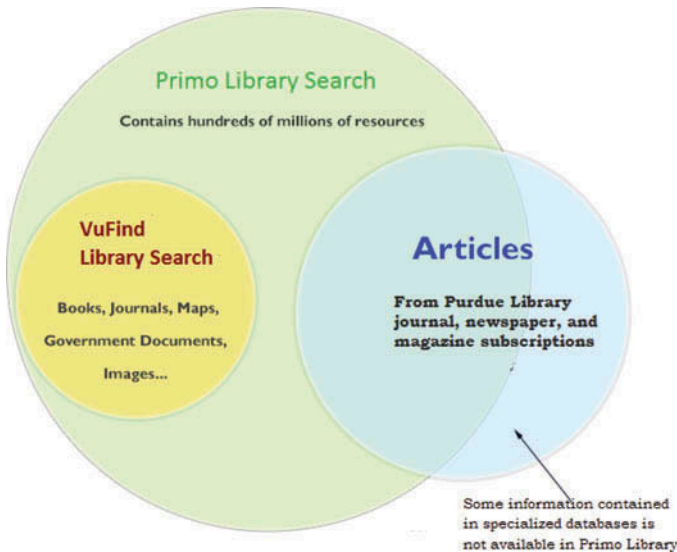FIG. 1. VuFind and Primo entry points on the Libraries' home page.

FIG. 2. The search scope of Primo and VuFind.

2. RELATED WORK

2.1. User Studies on Library Discovery Tools

Recent literature on discovery tools have been focused on usability and user acceptance (Comeaux, 2012; Denton & Coysh, 2011; Emmanuel, 2011; Williams & Foster, 2011), discussions on system design and implementation (Daniels & Roth, 2012; Wrosch, Rogers-Collins, Barnes, & Marino, 2012), information literacy and instruction (Buck & Mellinger, 2011; Fawley & Krysak, 2012), and impact on library collection usage (Way, 2010). Recent literature on discovery tools has covered a number of academic libraries and discovery tools. Hofmann and Yang (2012) provided many up-to-date facts about discovery tools used in academic libraries. In addition to the increased number of implementations from 2010 to 2012, they also found that among the libraries that used discovery tools, 96% also used their traditional catalog system at the same time and 92% featured their discovery tools first on their home pages. Hofmann and Yang (2012) found that the top three popular discovery tools were WorldCat Local by OCLC, Summon by Serials Solutions, and VuFind. About 66% of institutions with a discovery tool provided some degree of article search. Very few (five of 72) libraries were using more than one discovery tools in conjunction with their traditional catalog systems.

We have summarized recent user tests of existing discovery tools in Table 1. These studies showed that discovery tools deliver generally better search results including both books and articles to users than previous generation of library catalogs, although instruction and documentation will be needed for users to understand the scope of search results and access options for different materials. Users like the single search box interface that discovery tools usually use, and they tend to examine the first page of search results like when they use general search engines (e.g., Google). Several studies (Becher & Schmidt, 2011; Denton & Coysh, 2011; Williams & Foster, 2011) reported that users prefer facets for refining search results and distinguish between types of materials, but it is not clear to what extent users use facets in their search process. Furthermore, as Thomsett-Scott and Reese (2012) pointed out, these user studies of discovery tools were mainly for system testing and validation purposes. It is thus more important to assess and observe users search behavior in action, in order to obtain further valuable information regarding the impact of discovery tools.

2.2. Transaction Log Analysis

Transaction log analysis generally refers to the study of interactions recorded electronically between online systems of information retrieval and users who search for information contained in these systems (Villén-Rueda, Senso, & de Moya-Anegón, 2007). Most transaction logs contain information elements such as the particular page requested by the user, the identity of the requesting user (e.g., IP address), the date and time of the request, and whether the request was successful (e.g., the HTTP status 200 means the request is OK and the status 404 means page not found; Jansen, 2006). The format of transaction logs may vary depending on specific server settings, but they all capture users' behavior in natural settings and can accumulate a large amount of data over time.

Analysis of transaction logs leads to an understanding of detailed user behavior and interaction with the system in a large scale. Agosti, Crivellari, and Di Nunzio (2011) reviewed research on log analysis over the past decade and identified two main areas: web search engine log analysis and digital library systems log analysis. The goal of web search engine log analysis is to characterize users' information need: how users make requests by submitting queries to the search engine, how users interact with the search engine to retrieve search results, and how the search engine organizes and presents search results. Digital library system log analysis is based on transaction logs of well-organized and explicitly described library collections (i.e., objects with much higher quality metadata than normal web pages) and the goal is to study how users interact with the search interface in order to improve the effectiveness and efficiency of the search process.

Researchers have used transaction log analysis to assess the scope and distribution of search queries, the use of search

TABLE 1
Summary of Recent User Studies on Discovery Tools

Article	Discovery Tool Studied	Major Findings
Gross and Sheridan (2011)	Summon by Serials Solutions	• Participants preferred a single search box. • The discovery tool met the participants' search tasks. • The participants were able to evaluate the search results.
Becher and Schmidt (2011)	WorldCat Local by OCLC and Aquabrowser	• A list of discovery tool features preferred by participants were: links to full text articles using a link resolver, results incorporating both articles and books, and facets such as date, format and subject.
Williams and Foster (2011)	EBSCO Discovery Service by EBSCO	• Participants mainly examined the first page of search results and relied heavily on the facets to distinguish between different types of materials. • Instruction and documentation will be needed for users to better utilize the discovery tool.
Fagan et al. (2012)	EBSCO Discovery Service by EBSCO	• Improvement is needed to assist users understand the scope and purpose of the discovery tool to choose between the discovery tool and subject-specific databases, • Integration is needed for users to navigate between the discovery tool and other library services and resources.
Comeaux (2012)	Primo by Ex Libris	• Participants rated the discovery tool highly in both usability and quality of search results. • Minor usability issues were unclear location labels, difficulty requesting items through interlibrary loan, and confusion regarding hold and recall features.
Zhang (2013)	Primo by Ex Libris	• Search results had comparable relevancy ratings to Google Scholar. • Low interface usability and preference ratings. • System workflow involving a link resolver affected its usability. • The Primo interface had some consistency issues such as display inconsistency between books and journals, format inconsistency between different versions of the same book
Majors (2012)	Encore Synergy, Summon, WorldCat Local, Primo Central, EBSCO Discovery Service	• Participants reported jargon issues the discovery tool interfaces. • Most participants conducted Google-like searches. • Discovery tools should help users evaluate resources, provide context so it is clear what has been searched or not included in search results, and provide easy-to-access user help.
Emmanuel (2011)	VuFind	• VuFind provided a more intuitive interface than the former WebVoyage catalog. • Usability issues were the lack of integration of Refworks (a bibliography management tool), simplicity of favorites listing, difficulty of linking to holdings from other libraries in Illinois, and difficulties in using the facets.
Denton and Coysh (2011)	VuFind	• Participants liked the facets and richness of search results. • There were issues of known journal title search and terms used in the interface.

options, and query construction and refinement. Lown, Sierra, and Boyer (2012) examined how users search a large public university library from a prominent, single search box on the library's website. They analyzed two semesters' transaction logs data and found that catalog and article searches were dominant among all searches. But they also learned that about 23% of searches were outside the catalog and articles, suggesting that users attempted to access all types of information from the single search box. In addition, they reported that a small number of the most popular search queries accounts for a disproportionate amount of the overall queries. Jones, Cunningham, McNab, and Boddie (2000) conducted a transaction log analysis on users' search activity in the Computer Science Technical Reports Collection of the New Zealand Digital Library. They examined user acceptance of search settings, query complexity, search sessions, query refinement, and results viewing. The results showed that most users used the default search settings, user sessions were very short, few queries were submitted in those sessions, and the queries themselves were very simple. Jones et al. concluded that users tended to spend minimum effort and time when specifying their search needs.

Although transaction log analysis is an unobtrusive and inexpensive way of collecting large amounts of data of users' searching behavior, it fails to capture any information about the context in which the search event occurs (Kurth, 1993; Sheble & Wildemuth, 2009), such as user demographics, motivations, information needs, and satisfaction. User tests complement the limitations inherent of logs by providing such missing contextual information. In addition to the common shortcomings, transaction log analysis may be descriptive in nature. The methodology is not standardized. For example, definitions of metrics and identification of individual search sessions are not consistent across studies (Kurth, 1993). This limitation is partly related to the specific research questions and contexts of different studies and partly related to the limited information in the transaction logs (Asunka, Chae, Hughes, & Natriello, 2009). Therefore, there is a need to integrate transaction log analysis with other empirical research methods in order to provide a comprehensive assessment of users' search activities.

3. RESEARCH QUESTIONS

The major difference between Primo and VuFind is that Primo includes coverage of electronic resources (e.g., library-subscribed databases and online journals) in addition to library cataloged items covered by VuFind. As the additional coverage of electronic resources introduced new search options, facets, and search results display, there is a need to investigate whether users alter their search tactics when they are searching for electronic resources compared to the traditional catalog items such as books and print materials. In addition, faceted search has become a standard approach for academic libraries to provide information access for users. Because both VuFind and Primo support faceted search and browsing as one of the key features,

it is important to examine and compare users' facet selections with the two discovery tools to see whether the coverage difference would lead to different facet usage. By analyzing the transaction logs and conducting user tests of VuFind and Primo, we expected to address the following specific questions: (a) How users were using the search fields and facets, and forming queries with VuFind and Primo, and (b) whether there was any user search activity difference at both the group and individual level between VuFind and Primo.

4. METHOD

4.1. Transaction Log Analysis

Transaction logs of VuFind were collected from the library's Apache web server (the logs were generated by Apache itself). The logs covered the 1-month period from November 8, 2012, to December 7, 2012. Similarly, transaction logs of Primo were collected from its JBoss (JavaBeans Open Source Software) for the same 1-month period. The VuFind logs contained 41,655 useful records with 15,291 sessions, and the Primo logs contained 10,946 useful records with 2,973 sessions. Data fields in the logs from both systems included IP address, date, time, URL, referrer URL, and user agent. Referrer URL is the page on which the user clicked a link that led to the current URL. User agent is a string that identifies the user's browser and provides certain system details to servers hosting the discovery tools. The logs were processed in a Perl script to extract the data fields, and the data fields were further analyzed in SAS 9.2.

4.2. The User Study

Eight student participants were recruited through the campus mailing list for the individual user test of VuFind and Primo in a usability lab of the Libraries. At the beginning of the user test, participants were briefed about the purpose of the study. They then read and signed a consent form and completed a demographic survey regarding their experience of the library website and scholarly search. Participants explored the library website with VuFind and Primo before they performed the six test tasks. During the test tasks, they were encouraged to talk aloud about their expectations, difficulties, and general comments about using VuFind and Primo. The researcher provided necessary assistance only when participants explicitly requested. After the tasks, participants completed the System Usability Scale (SUS; Brooke, 1996) questionnaire about their overall experience of VuFind and Primo. Each session lasted approximately 1 hr.

The literature on OPAC studies suggests that people primarily conduct two types of searches using OPACs (Hancock-Beaulieu, 1990). One is the known-item search where the user wants to find a specific item using information such as author, title, and publication year. In contrast, another type of search frequently conducted by users is the subject search, which is conducted on a topic using either a keyword or a subject heading. Known-item searches and subject searches can also

TABLE 2
Tasks for the User Study

Task Type	No.	Task Description
Close-ended task	1	Determine if the library has the book *The Machine that Changed the World: The Story of Lean Production* by *James Womack.*
	2	Find the book and video of *Wizard of Oz.*
	3	Find the call number and location of the book *Introduction to Algorithms* by Thomas H. Cormen.
Open-ended task	4	How would you find a journal article on soap operas?
	5	Find some recent journal articles on Supply Chain Management.
	6	Use *Advanced Search* to find some recent journal articles on Supply Chain Management.

be called close-ended and open-ended searches, respectively, because the former has a definite target document and the latter has more open-ended target documents. In this study, two types of search tasks were tested: close-ended and open-ended. Participants performed three close-ended tasks and three open-ended tasks using either VuFind or Primo based on their own preferences. Table 2 summarizes the six tasks used for the test. Response measures of the user study included (a) success in performing tasks, (b) participants' ratings of using VuFind and Primo based on the SUS ratings, and (c) comments made by the participants and observation notes recorded by the researcher.

5. RESULTS

5.1. Results From Transaction Log Analysis

Search fields. VuFind provides users with nine search fields, including *Keyword, Title, Author, Journal Title, Subject, Call Number, ISBN, Series,* and *OCLC number*. A dominant percentage (68.4%) of searches performed by users during this study was *keyword* search, the default search field option. On the other hand, *ISBN, Series*, and *OCLC Number* were rarely chosen (less than 1% of all searches). In contrast, Primo offers seven search fields: *Keyword, Title, Creator, Subject, Description, Create Date,* and *Call Number*. Similar to VuFind, the majority of searches (88.2%) in Primo were keyword searches. *Description, Create Date*, and *Call Number* were used less than 1%. The majority of searches with both VuFind and Primo were default keyword searches. This finding confirms conclusions published from previous studies that most people started with the broadest and default search, that is, keyword search (Lown, 2008; Niu & Hemminger, 2011; Pennell & Sexton, 2010). Compared to keyword searches, other fields were complementary and supplemental, and used only in a smaller number of search sessions. For Primo, it was assumed that users might use the description field frequently because it enables users to conduct free-text search against the free-text item description. However, only around 0.2% searches used this option. This result reflects that people might not know exactly

what information was included in the description and what was not. In addition, not all items include information in the description field, because they are from various sources including databases, journal publishers, and the library itself. This lack of metadata consistency might have contributed to users' hesitancy to use the item description as a search field.

VuFind and Primo have five common search fields: *Keyword, Title, Creator (Author), Subject,* and *Call Number*. By and large, the distribution of searches performed using the common search fields are fairly consistent for both Primo and VuFind, as shown in Figure 3. Primo users performed a higher percentage of keyword searches than VuFind (88.2% vs. 68.4%). One most likely reason for this higher percentage is that two drop-down menus (format and exact phrase search) next to the search box in the Primo interface might be distracting for users. When facing a possible choice overload in a search interface, users may respond by keeping every setting as default. Another possible reason might be that Primo is intended as a "one-stop" search for all library resources. Users like to apply minimum search effort with Primo as they would when using search engines like Google and Bing.

In addition to the search field options, Primo also provides two drop-down lists for specifying format and exact phase search in the interface. The format specification has eight
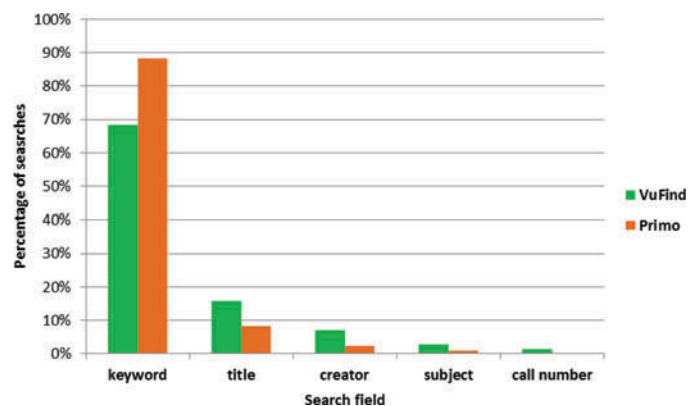

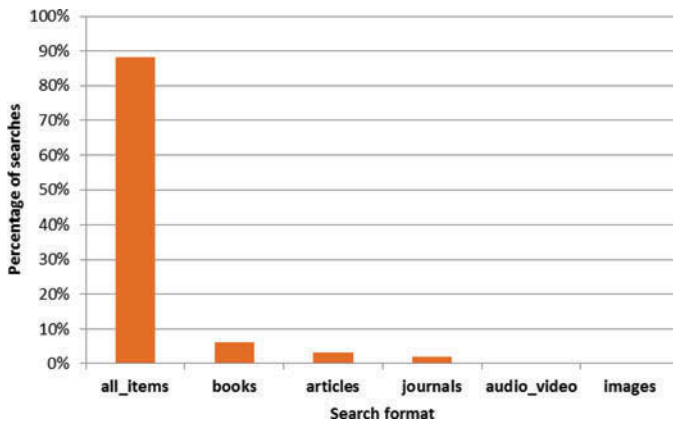FIG. 3.   Contrast of common search fields used in VuFind and Primo.

FIG. 4.   Distribution of search format options for Primo.

options: *All Items, Books, Journals, Articles, Images, Audio Visual, Scores,* and *Maps*. As shown in Figure 4, the majority of all searches in Primo (88.2%) were *All Items* search, which is also the default format option. Among the nondefault options, *Books* accounted for 6.2%, and *Articles* and *Journals*

combined accounted for 5.2% of all searches. No searches were performing using the *scores* and *maps field*. In the format drop-down list, *Books* refer to the physical books in the library, and most of the *Articles* and *Journals* in Primo are online resources. The combined percentage of searches with *Articles* or *Journals* selected is close to the percentage of searches with *Books* selected as the format. This result suggests a roughly balanced *explicit* interest between physical items (books) and online resources. From the relative proportions of *Books* and *Journals* and *Articles* selected in the format drop-down, it is likely that there were about equal percentages of physical item searches and online resources searches among the *All Items* searches.

Facet selections. Figure 5 presents the summary of facets available in VuFind and Primo. Overall, facet operations accounted for 8.4% of all search actions of VuFind and 9.7% of Primo. This suggests that faceted searches are still smaller in amount compared to text searches. The slight percentage difference between the two search tools suggests that the use of facets is about the same, despite the different search interfaces and the underlying collections.
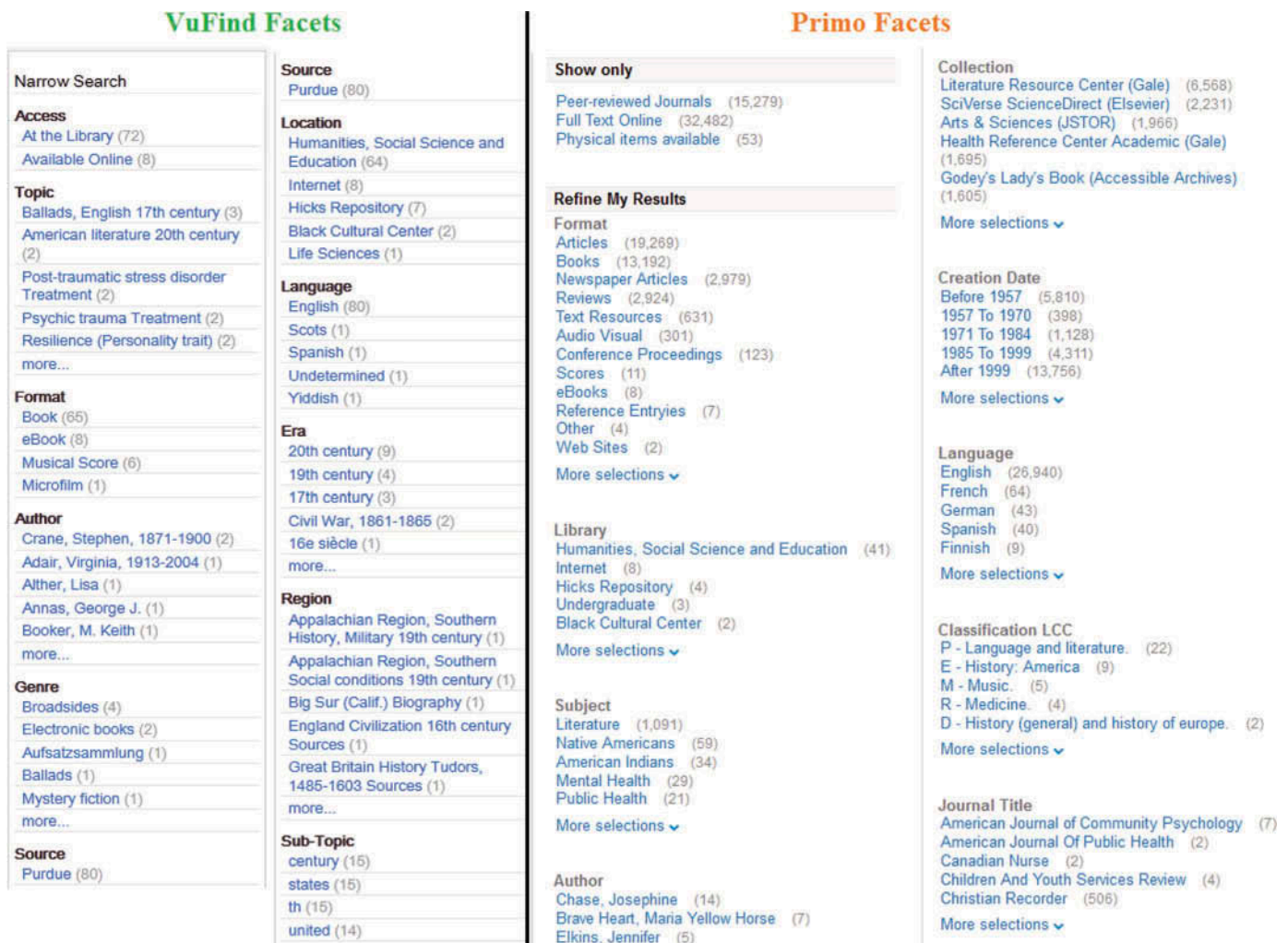

FIG. 5.   Facets available in VuFind and Primo.

TABLE 3
Top 10 Facets by Frequency Used in VuFind and Primo

	VuFind			Primo		
Rank	Facet	Count	Popular Values	Facet	Count	Popular Values
1	Format	1171	eBook; Book	Show only	200	Online resources; Peer reviewed; Available
2	Access (availability)	906	Available Online; At the Library	Format	169	Articles; Books; eBook
3	Topic	706	Alchemy History, Operas, Design	Subject (Topic)	75	Blogs; Animal welfare; Biological; Evolution
4	Building	315	Humanities, Social Science and Education; Engineering; Veterinary Medical	Creation date	73	2004 to present; 2006 to present; 2009 to present
5	Author	234	Mann, Thomas, 1875–1955; Sharma, Rohit; Arnauld, Antoine, 1612–1694	Library	43	Humanities, Social Science and Education; Internet; Earth and Atmospheric Sciences
6	Language	95	English; German; Chinese	Author	21	Sparsely distributed. No popular values.
7	Genre	71	Electronic books; Documentary films; Electronic journals	Collection	20	INFORMS Journals
8	Sublocation	61	HSSE; Engineering; Life Science	Language	19	English
9	Subtopic	35	History; Management; Criticism	Title	5	Sparsely distributed. No popular values.
10	Era	28	20th century; 2009 –; 18th century	Sublocation	4	Sparsely distributed. No popular values.

Table 3 summarizes the top-10 frequently used facets and their popular values for VuFind and Primo. *Format, Location* (*Building* in VuFind and *Library* in Primo), and *Availability* (*Access* in VuFind and *Show only* in Primo) are in the top-10 frequently selected facets for both discovery tools. These facets contain metadata without content-related information but important for users to locate or access the actual physical or online item. For example, through the *Format* facet, users could quickly refine the search results to only eBooks, which is an effective way to address the challenge of searching for eBooks that libraries have been facing recently. For example, through the format facet, users could quickly refine the search results to only eBooks, which is an effective way to address the challenge of searching for eBooks that libraries have been facing recently (Walters, 2013). The increasing importance of format and location facets has been recognized by general search engines like Google on their search results pages.

Topic (or *Subject*) is another frequently used facet in both VuFind and Primo. *Topic* is content related and based on the Library of Congress Subject Headings, which may be difficult to understand for users without some training or knowledge. The relatively high usage of *Topic* (or *Subject*) facet suggests that the patrons were able to take advantage of the authority data to access the library's collections. Although some facets are frequently used, it is difficult to find a highly used value under that particular facet. Users used a variety of facet values with each value has been used only once or twice. For example, facets like *Topic* and *Author* do not have any particular popular values. As a whole, these facet values are collectively helpful for users, but there is no single frequently selected value, due to the unlimited enumerative nature of these facets.

Two unique facets in Primo, *Show only* and *Collection*, were frequently used. Through *Show only*, users were able to refine their search to *Peer-reviewed Journals, Full-text Online*, or *Physical Items Available*. Using *Collection*, users can limit their search to different collections, such as *Elsevier, JSTOR, and Gale*. The *Show only* and *Collection* facets represent the concept of the "single entry for all library resources," and the logs showed that users were able to use them. There are also some unique facets for VuFind that were frequently used, for

TABLE 4
Quantitative Measures of Queries in Primo

	Nonelectronic Resources	Electronic Resources
Query length (*M, SD*)	5.1 (5.4)	4.1 (4.0)
No. of query submissions (*M, SD*)	3.6 (5.4)	2.6 (2.3)
% of searches that were reformulated	61.0%	57.8%

example, *Genre*. Through *Genre*, users are able to filter their search *to Fiction, Non-fiction, Biography*, and so on. Primo does not show *Genre* as a facet, partly because of the overlap between *Genre* and *Format*. For example, in Primo, both *Genre* and *Format* facets would have *Electronic Books* as a value.

Query formulation/reformulation for electronic resources in Primo. To compare how users formulated search queries for traditional items and electronic resources, we examined search queries for Primo (because only Primo has incorporated the electronic resources in addition to the nonelectronic). Table 4 compares the average query length (the number of words used in a query), the number of query submissions per search session, and the percentage of the searches that were reformulated. As shown in this table, query length for electronic resources is shorter than nonelectronic resources. Primo users submitted 3.6 queries for nonelectronic resources and 2.6 queries for electronic resources on average per search. In this study, users may be more efficient in searching electronic resources because they performed fewer search iterations. The fewer search iterations for electronic resources suggest that users were able to find electronic materials quickly in Primo and thus did not additional iterations of search query.

The percentages of the searches that were reformulated are about the same for nonelectronic resources (61.0%) and electronic (57.8%). That means less than half of the searches in Primo (i.e., 42.2% for electronic and 39.0% for nonelectronic resources) had only one query submission. These percentages are roughly consistent with previous studies. For example, Spink, Wolfram, Jansen, and Saracevic (2001) concluded that around half of users (52% of the users in the 1997 Excite dataset and 45% of the users in the 2001 Excite dataset) reformulated or made modifications to their initial queries.

Qualitatively speaking, we observed that most queries for electronic resources are "topic" search where users were most likely to be exploring a topic. Topics were mostly about academic interests, such as *carbon capture risk, survey validity,* and *death penalty*, and college courses, such as *organic chemistry, curriculum,* and *English as a second language*. Known-item close-ended search, such as a journal's title, an author's name, were used less than topic search. Titles at an article level were

even more rarely seen. This is quite different from nonelectronic resource searches, most of which are titles and authors' names of books (Niu & Hemminger, 2010).

As to the query reformulation, three reformulation strategies are identified from the log data: narrowing, parallel, and broadening. More users tended to narrow a search than to broaden one. Narrowed queries are typically longer than the original ones and are assumed to lead to higher satisfaction (Belkin et al., 2003). Users narrowed down most searches by adding one or several terms to append some specific information, such as content, time, or format. Examples of narrowing searches are as follows:

- *exercise and neuroscience → exercise and neurodegenerative disease*
- *Maos land reform → Maos land reform 1920–1945*
- *elaboration likelihood → elaboration likelihood model*

Parallel movement of searches involves synonym replacement, format change, and spelling correction. Some examples are as follows:

- *World War II → World War 2*
- *proofreading English as a second language → proofreading non-native*
- *what is gender → gender defined*

In general, many of the queries beyond the first iteration were simple deviations from the initial one. Some the query modifications were performed to correct typographical errors. This observation is in line with White and Marchionini's (2007) finding that many further queries were simply "syntactic variants" of the initial one. Therefore, the initial query is very important in determining search success.

Compared to narrowing or paralleling movements, broadening activities were much less common for patrons. Most broadened queries were the shortened version of the previous queries and were created by removing one. Some examples are as follows:

- *Susan Branje → Branje*
- *Exp heat transfer fluid mech → Exp heat transfer*
- *Economic argument for a two-year degree → economic argument for technical education*

If users modified their original queries more than once, they rarely persisted in narrowing down or broadening up through successive trials. Most users would use mixed strategies of narrowing, broadening, and parallel. Some examples are as follows:

- *ban plastic →plastic harmful → plastic bags*
- *reticulorumen mixing → rumen mixing → rumen → rumen physiology*
- *ababo → Abaco → psycinfo → academic search premier*

5.2. Results From the User Study

Characteristics of the participants. The eight participants included four undergraduate students, two master students, and two doctoral students. There were six female and two male students, and the average age was 24.8 (*SD* = 2.8). Participants had generally good experience of finding books and articles on library website based on their self-report (see Table 5). Based on the self-report results, the eight participants represent the mainstream users of discovery tools (Vu, Hanley, Strybel, & Proctor, 2000).

Success of search task performed. Overall, most participants were able to successfully complete the testing tasks. Of the 48 tasks performed by the eight participants, 34 were successful. On average, participants successfully completed four tasks out of the six testing tasks. Six out of the eight participants selected VuFind for the first three close-ended tasks, whereas all of them chose Primo for the next three open-ended tasks.

Task 3, which asked for the call number and location of a book, had the most search success (eight of eight). For this task, most participants typed the author name or book title as the initial query. Most participants wanted to be as specific as possible at the very beginning of the search. Task 1 and Task 2 also had a very high success rate (seven of 8). Most participants started the search with the book title or the author's name. The only participant who failed Task 1 misspelled a word. For Task 2, most people used *Audio Visual* and *Books* under the *format* facet to find the correct items. The only failure of Task 2 was from the participant who chose Primo for this task. Primo grouped all versions of Wizard of Oz books into one result item, and the participant did not click the link ("Click here to view 2 versions") in the results list to locate a particular book.

Task 6 had the least number of successes, followed by Task 5. Both Task 6 and 5 are the open-ended tasks that required participants to find recent journal articles in the area of supply chain management. Based on our observation notes, the challenge for most participants was to differentiate between searching for journals (as publications) and searching for articles published

in relevant journals. Participants who completed Task 6 and 5 successfully all used facets in their search process. The commonly used facets were: *Subject* (*Supply Chain Management*), *Creation Date* (*After 2006*), and *Format* (*Articles*).

Participants' ratings. At the end of the test, participants were asked to rate VuFind and Primo using the SUS questionnaire. Table 6 shows the descriptive statistics for the SUS ratings. The average total rating is 75.7 (79.7% of the full score, 95 = 19 × 5) for VuFind and 76.0 (80.0% of the full score) for Primo, both of which are well within the highly rated everyday product range (Kortum & Bangor, 2013). One-way analyses of variance did not show any significant difference between the ratings of statements for VuFind and Primo (minimum *p* = .26).

Participants' comments. In addition to the SUS ratings, participants made comments about the two discovery tools. Most negative comments were about the facets and the search results display. A number of participants were not clear about the difference between the facet values *journals, articles*, and the *ejournals* when they were asked to find journal articles. One participant commented that the facets on the left column contain a lot of information for her to process. Another participant said that for general search, he would browse the results for the first three to five pages, and for specific item search, he would type more keywords in the search box so what he wants is usually on the first page of the search results. Three participants thought the facet "creation date" gave too wide ranges and there was not an easy way to quickly narrow down to a specific date range. One participant expressed his confusion about whether "creation date" means publish date or the record creation date. Another participant suggested that the author facet should have ordered the author names alphabetically so they were able to find a particular one. The current interface ordered them by the number of associated results.

As to the search result display, some search results of Primo showed text such as 9999 as the creation date, which was probably due to errors in the metadata. Similarly, book cover images were not always available in VuFind and Primo, making the search results display inconsistent. Primo showed a generic image for multiple versions of books or videos, which was not helpful for users to identify a particular version. Primo aggregated items with multiple versions into one item in the search results. However, the aggregated item's title cannot be directly clicked like other single items. Instead, Primo displays a link below the title showing "Click here to view 2 versions," which most participants did not pay attention to initially.

6. DISCUSSION AND CONCLUSIONS

Results from the transaction log analysis and user testing of this study have contributed to the understanding of user search behavior with the two discovery tools. We find both commonalities and differences for users' interactions between VuFind and Primo. Commonalities include (a) *keyword* search was dominant in text search for both tools, (b) faceted actions were less common compared to text search, (c) most search sessions were very brief with only a few actions (less than four

TABLE 5
Descriptive Statistics for Participant Experiences

Experience of	*M*	*SD*	Min.	Max.
Finding books on library website	4.5	0.5	4	5
Finding articles on library website	4.0	1.1	2	5
Using scholarly databases like Web of Science and Academic Search Premier	3.3	1.2	1	5
Using general search engines like Google and Yahoo	4.8	0.5	4	5
Using Google Scholar	3.8	1.4	1	5
Using the University Libraries website	4.1	0.8	3	5

Note. Items in the table were measured by 5-point Likert scale ranging from 1 (*never*) to 5 (*a great deal*).

TABLE 6
Descriptive Statistics for the SUS Ratings of VuFind and Primo

Statement	VuFind		Primo	
	M	SD	M	SD
I can usually complete a search task using this search tool.	4.4	0.7	4.3	0.5
I am successful in general in finding information useful to my study or research using this search tool.	4.2	0.9	4.0	0.5
Overall, this search tool is useful in helping me find information.	4.3	0.5	4.3	1.0
I usually achieve what I want using this search tool.	4.0	0.6	3.9	0.8
The information and materials I obtain from this search tool are usually useful.	4.2	0.6	4.1	0.6
This search tool usually covers sufficient information that I try to explore.	4.2	0.7	3.8	0.9
It is easy to find the information or materials that I want using this search tool.	3.6	1.0	3.8	0.7
This search tool is easy to use in general.	4.1	1.0	4.1	0.6
I can find information I need quickly using this search tool.	3.5	1.1	4.0	0.8
This search tool is well designed to find what I want.	3.9	0.6	3.9	1.0
It is easy to search for things on the new library website.	3.9	0.9	4.0	0.9
I get the search results quickly when using this search tool.	3.8	0.8	4.1	0.6
It is easy to learn to use this search tool.	4.2	0.7	3.9	1.0
The terminologies used on this search tool are easily understandable.	3.8	1.2	3.8	0.7
This search tool offers easy-to-understand menus.	3.7	1.1	4.1	1.0
This search tool has appropriate information to help me do I need to do.	4.0	0.9	4.1	0.6
It should not take a great effort for new users to become proficient with this search tool.	4.3	0.9	4.0	1.1
The information on this search tool is well organized.	3.9	0.9	4.0	0.9
I feel very confident using this search tool.	3.7	1.3	4.0	0.9

query submissions) and the queries users typed into the search box were usually two- or three-term words, and (d) most search sessions (>50%) had the original queries reformulated. User testing showed that most people were able to finish most tasks successfully with both tools and users' ratings across the two were fairly consistent.

User behavioral differences of the two discovery tools are that Primo had a higher percentage of *keyword* searches and a lower percentage of *title, author, subject*, and *call number* search. There were some frequently used facets that were unique for Primo, such as *Show only* and *Collection*. With Primo, most queries for the electronic resources were topical words indicating the subject or relevancy of the information need. People formulated shorter and fewer queries for electronic resources compared to those traditional nonelectronic materials. The most frequent way of reformulating queries is the parallel movements where the modified queries were simple deviations from the initial search query. During the user testing, participants were able to choose the best appropriate tool for a particular task type, that is, most participants used VuFind for books and media and Primo for articles. After the search, most users' negative comments were about the article search and were about the facet implementations and the result display.

Limitations of this study lie in the drawbacks of the two research methods. Through transaction log analysis, a potential limitation for session-level analysis is the identification of the session boundaries. Without applications to track when sessions begin and end, any session identification method is always an estimate. In addition, the logged data do not capture the requests cached on the local machine or proxy servers. In addition, log analysis was not able to determine searchers' intentions, demographics, and satisfaction. Its limitations could be complemented by user studies. We discussed possible explanations of the observations made from transaction logs, but those explanations may need further investigation.

We admit that eight participants did not represent a large sample size. However, we have seen enough behavior convergence from the eight participants and therefore decided to stop recruiting at this number. In addition, the experiment was not a traditional strict Latin-square design. We made it loose and exercised not much control on it because we wanted it to be a follow-up and complementary to the log analysis. We did not want to break the natural user behavior too much.

The six tasks used for the searches were intended to be of two types (close-ended and open-ended). In this study, all the close-ended tasks were for finding books and all the open-ended tasks

were for finding articles, which may not resemble users' actual situations. We are interested in studying close-ended tasks for articles and open-ended tasks for books in the future user tests to minimize the material type's influence on the users' preference on the discovery tools. In addition, search task complexity by nature is fuzzy and not rigorous enough to make the tasks "similar" for both discovery tools. The lack of a clear definition for task complexity has hindered the construction of the topics due to the lack of guidance criteria in the field. Participants varied in their interpretations of the topics, and some of them had previous knowledge that made them perceive a task to be easy. In terms of task efficacy, the degree to which tasks depend on the interface, and to what degree they depend on individual differences, is difficult to discern. With hindsight, the tasks were controlled at the aggregate level.

The study's goal was to investigate people's search behavior with the two discovery tools at a general level. We tried to avoid making any direct quantitative comparisons because there were many confounding factors, such as the underlying collections, the way the search box interprets queries, the layout of the interface, and the facet implementations that might have impacted the data. These confounding factors have greatly affected the quantitative comparisons between VuFind and Primo. During the user testing, we asked participants to choose between VuFind and Primo to minimize any direct comparisons.

This study's results demonstrate the importance of maintaining consistency and avoiding confusions for discovery tools. Future implementation work should be focused on incorporating more high-quality content including high-quality metadata and facets and minimizing the information barriers that result from the presentation of the various library resources. As libraries are implementing new discovery tools, the integrated approach we developed in this study involving transaction log analysis and user testing could be extended to similar situations for assessing users' search activities, in effect providing an empirical basis for selection of search options, facets, and search results presentation in discovery tools.

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