Identification of Factors Associated With Blind Users' Help-Seeking Situations in Interacting With Digital Libraries

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A sight-centered digital library (DL) design with complex structures and multimedia formats poses significant challenges for blind users. This study is the first attempt to investigate the top three help-seeking situations as well as associated factors in blind users' DL interactions. A mixed-method approach was adopted for this study. Multiple methods were applied to collect data from 30 blind subjects: questionnaires, presearch interviews, think aloud protocols, transaction logs, and postsearch interviews. The paper identifies the top three help-seeking situations, and associated factors in relation to user, system, task, and interaction. Moreover, different types of main-level factors were tested to investigate if they are correlated to each type of top situation, and qualitative data of sublevel factors offer insight into how these factors are associated with various situations. Without a clear understanding of these situations and factors, the objective of universal access to information in DLs cannot be achieved. DL design implications are further discussed with the goal of providing system design recommendations for reducing blind users' help-seeking situations.

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Introduction

The web is sight-centered by design, posing significant challenges for nonvisual interaction, restricting the ability of blind users to easily acquire information from specialized information retrieval (IR) systems (Babu, 2011; Xie, Babu, Joo, & Fuller, 2015). Digital libraries (DLs) contain and manage a variety of content, including images, multimedia, books, newspapers, or maps. Although DLs have existed for over a decade, no single model exists for the design of DLs, and this heterogeneity creates difficulties and complications for users learning to use these specialized systems (Heradio, Fernández-Amorós, Cabrerizo, & Herrera-Viedma, 2012). This poses unique situations for blind users who are required to interact with different sight-centered DL designs.

Zha, Wang, Yan, Zhang, and Zha (2015) found that users are more likely to seek information in a DL if they can easily learn to operate or interact with the DL and perceive that it is useful, or if it helps them to quickly accomplish tasks. Help is an important topic in IR that allows researchers to explore aspects of how IR systems and use of help features support, or fail to support, information needs of users in digital environments. A help-seeking situation is defined as a user's need of help to overcome problematic situations during the search process to facilitate the achievement of their search goals. It is critical to identify types of factors that are

associated with the main types of help-seeking situations in order to reduce these situations. As factors tie closely with help-seeking situations, researchers start with the investigation of help-seeking situations. Blind users exhibit unique help-seeking situations in web interactions related to browsing and navigational difficulties, contextual problems, accessibility barriers, information overload, and avoidance behaviors (Andronico, Buzzi, Castillo, & Leporini, 2006; Borodin, Bigham, Dausch, & Ramakrishnan, 2010; Leuthold, Bargas-Avila, & Opwis, 2008; Vigo & Harper, 2014). Xie et al. (2015) provided a discussion on the topic of help-seeking situations in the preliminary research for this study. In these situations, users seek various types of help, through system help features (both explicit and implicit), to overcome problems faced during interactions. Although research addresses some problems encountered during blind users' general interactions in online environments, no research addresses factors leading to blind users' help-seeking situations in DLs. Xie and Cool (2009) identified user knowledge, system design, task dimensions, and interaction outcomes as main factors that influenced sighted-users' help-seeking situations in interacting with DLs. Previous research has found that user, system, task, and interaction factors influence information searching (Albertson, 2015; Dumais et al., 2016; Ingwersen & Järvelin, 2006; Kim, 2009; Li & Belkin, 2010), which sheds some light on factors behind blind users' help-seeking situations.

The existing literature does not adequately examine how blind users interact with DLs, or the typical problems encountered during interactions. As attention to the topic of blind users in DLs is scarce, it is critical to examine help-seeking situations that blind users face, and associated factors, when interacting with DLs. At the same time, the complexity of DL content with multimedia information, and complicated interface design with multiple access points, such as browsing options and a variety of features, increase the difficulty for blind users to use DLs effectively, introducing more help-seeking situations in the DL environment than other system environments. Without a clear understanding of these situations and factors, the objective of universal access to information in DLs cannot be achieved.

This paper first provides a background on literature related to help-seeking situations and associated factors to provide context for the current research. Following this, the research questions, hypotheses, and methodology are presented. In particular, a mixed-method of qualitative and quantitative approaches is applied to analyze the data. The findings focus on the main levels and sublevels of factors that are associated with the top three help-seeking situations. Finally, design implications and limitations of the study are discussed.

Literature Review

Help-Seeking Situations of Blind Users in Different Digital Environments

This section presents a summary of relevant literature on help-seeking situations of blind users in a variety of digital environments, including DLs. Because the literature is diverse, these situations are examined related to the following terminology in the literature: problematic situations, coping situations, usability and accessibility problems, and barriers. Help-seeking situations of general users of IR systems is also included to enhance the discussion. To minimize repetition in specific areas, help-seeking situations are simply referred to as "situations."

The sight-centered nature of the web gives rise to a variety of situations for blind users of IR systems. Interaction problems cause blind users to face a myriad of problematic or coping situations (Bigham, Cavender, Brudvik, Wobbrock, & Ladner, 2007; Borodin et al., 2010; Vigo & Harper, 2013, 2014). Despite the help of assistive technologies, blind users continue to face barriers when accessing electronic resources (Kumar & Sanaman, 2015). Typical problems and situations occurring in digital environments are summarized below.

Many situations blind users face are related to accessibility and usability, where users experience problems accessing content or using system features (Vigo & Harper, 2014). Accessibility and usability problems that lead to these situations are associated with poor system design in IR systems (Power, Freire, Petrie, & Swallow, 2012; Rømen & Svanæs, 2012; Vigo & Harper, 2014). Some accessibility problems are due to improper labeling of interface objects such as insufficient tagging of graphics, links, forms, or tables. Simple and familiar labels have power to facilitate recognition, simplify exploration, and denote useful information (Andronico et al., 2006; Lazar, Olalere, & Wentz, 2012).

Blind users' situations are also associated with navigation problems. Despite applying various navigational approaches, blind users experience difficulties browsing due to structural and information architecture problems and the linear nature of screen reader navigation (Borodin et al., 2010; Brophy & Craven, 2007; Lazar, Allen, Kleinman, & Malarkey, 2007; Vigo & Harper, 2014). Due to the sequential nature of screen reader navigation, blind users may only access portions of the text on the page and thus suffer from a loss of contextual information (Andronico et al., 2006). Situations resulting from navigational problems also occur due to lack of navigational and interpretive cues (Leuthold et al., 2008), or no alternative text for pictures (Lazar et al., 2007). Kumar and Sanaman (2015) found that excessive graphics, hyperlinking, and tabulation hamper the accessibility of academic and special library resources for screen-reader users.

Information overload is also associated with situations, and is caused by static areas of websites that are repeatedly read by screen readers. Consequently, a user must expend additional cognitive effort to process information in small chunks to infer the structure of the entire page (Chandrashekar, 2010). This leads blind users to exhibit avoidance patterns when encountering rich, dynamic, and interactive web content (Bigham et al., 2007; Borodin et al., 2010). Vigo and Harper (2014) pointed out that individual user factors, such as a lack of assistive technology (AT) knowledge, or misuse of AT functionalities, also caused problems.

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Although the literature cited above focuses on situations of blind web users in general, scant research has investigated the experiences of blind DL users. In addition, studies that focus explicitly on situations in DL interactions are also scarce. Xie and Cool (2009) investigated help-seeking situations of 120 novice users in DLs and identified seven main categories of situations related to difficulties getting started, identifying relevant collections, browsing, constructing search statements, refining or monitoring searches, or evaluating search results.

Ultimately, problems blind users experience while interacting in DLs are not adequately understood. Although few studies investigate blind users' problems, a systematic examination of their situations and associated factors, has not yet been conducted. Recently, Xie et al. (2015) investigated the types of situations that 15 blind users face when using DLs and identified 17 unique situations in seven categories encountered in DLs. This research built a foundation for the current study, which conducts a more in-depth investigation and offers significant new contributions with 30 subjects. Although the previous paper emphasized types of help-seeking situations, this paper expands to investigate types of factors associated with the situations. Most important, the previous paper is solely qualitative, whereas the current study expands to apply a mixed-method approach by adding quantitative analysis.

Factors Associated With Information Searching and Help-Seeking Situations

Multiple factors are associated with help-seeking situations. Xie and Cool (2009) identified 16 types of affecting factors that can be summarized in the following categories: users' personal knowledge, previous experience, system design, task dimensions, and interaction outcomes. Because help-seeking is one type of information-searching behavior, factors affecting information searching may also be applied to situations. Previous studies that examined factors in this context are reviewed in relation to user, system, task, and interaction factors.

User factors affecting information searching mainly consist of different types of user knowledge, specifically, domain knowledge, system knowledge, and retrieval knowledge, which influence users' information searching and DL help-seeking behavior (Ingwersen & Järvelin, 2006; Marchionini, 1995; Xie, 2008; Xie & Cool, 2009). Kim (2009) confirmed that various actor attributes and characteristics, including domain knowledge and system knowledge, affect how users approach search tasks. Users' perceived knowledge level is also associated with users' search tactic selections (Xie & Joo, 2012). Researchers agree that domain knowledge is one of the top factors that impact users' information searching and help-seeking behavior in IR systems (Salmerón, Kammerer, & García-Carrión, 2013; Vakkari, 2016; Wildemuth, 2004; Wu, 2011). It can alter querying, document selection/viewing, and general task interactions (Zhang, Liu, Cole, & Belkin, 2015). Moreover, users' selection of search terms reflects existing knowledge structures and information needs (Vakkari, 2016). Topic familiarity is also associated with topic-related characteristics, interaction behaviors, topic completion ratings, and search system assessments (Albertson, 2010; Wildemuth, 2004).

System knowledge and IR knowledge are key user factors (Ingwersen & Järvelin, 2006; Kim, 2009; Marchionini, 1995). Hsieh-Yee (2001) identified user factors that influence information seeking as user's experience with computers, the internet, and IR systems. System and retrieval knowledge are types of cognitive structures that are important to the processes of information searching (Ingwersen & Järvelin, 2006). Chen and Macredie (2010) found that prior system knowledge serves as a contributing factor in determining whether a specific navigation strategy is beneficial, and that novice and expert users benefit from different types of navigation features. Expert users are more likely to use advanced search features, whereas novice users rarely use them (Hölscher & Strube, 2000; Markey, 2007; Xie & Joo, 2012). Researchers have also observed significant differences between novice and expert users regarding the number of pages viewed, solution time, and types of pages searched on the web (Saito & Miwa, 2001). Other results show that although there was no difference observed between novice and expert users in web browsing, expert users showed more proficiency in using keyword search (Lazonder, Biemans, & Wopereis, 2000). Van Deursen and Van Dijk (2011) believed users' level of internet skills is an important factor in helping users find relevant information and making distinctions between informational claims.

Research shows that system factors are significant and influential in information searching and help-seeking. IR systems are comprised of various components, including interface features, computational mechanisms, and information objects that affect users' information-searching behavior (Dumais et al. 2016; Ingwersen & Järvelin, 2006; Saracevic, 1997). The coverage, representation, and information presentation of information objects in DLs, along with ineffective search mechanisms, can result in situations related to poor system design (Xie & Cool, 2009). IR system design is an important factor affecting users' search tactics and satisfaction, overall interactions, and information-searching behaviors (Al-Maskari & Sanderson, 2010; Xie & Joo, 2012). Aleven, Stahl, Schworm, Fischer, and Wallace (2003) found that a variety of system-related factors contribute to help-seeking behavior. System-related factors, and specifically help systems, lead to differential learning outcomes and influence the effectiveness of system help. Information presentation factors, such as levels of image description, operate as factors affecting image retrieval (Jaimes, 2006). Hong, Thong, and Wai-Man Wong (2002) found that system characteristics, such as clear terminology and good interface design, had significant effects on perceived ease of use and enabled users to more easily interact with DLs. One way in which DL researchers have attempted to address information presentation problems is by facilitating natural language search in image collections

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TABLE 1. Data collection and data analysis.

Research questions and hypotheses	Data collection	Data analysis
RQ 1	Think-aloud protocols; transaction logs; interviews	Descriptive statistics; Open coding; Taxonomies of types of help-seeking situations
RQ 2 H1–3		Correlation analysis
RQ 3		Open coding; Taxonomies of types of factors

through restructuring of data structures and metadata (Kovács & Takács, 2014).

Task factors also shape and influence how users search for information (Byström 2002; Li & Belkin, 2010; Vakkari, 2003). For instance, the type of task may lead to different information-seeking strategies (Talja & Nyce, 2015). The nature of the task (e.g., fact-based, open-ended, or object-oriented task) affects which search strategies the user may apply (Hsieh-Yee, 2001). Xie (2008) found that origination, types, and flexibilities of tasks influenced how users applied search strategies. Perceived task complexity is also an important factor in information searching (Byström, 2002). Liu (2015) developed a task difficulty scheme with 19 categories and their contributions toward task-related information retrieval.

Interaction between a user and a system is the central phenomenon of the information search process (Belkin, 1996; Ingwersen & Järvelin, 2006; Saracevic, 1997). Similarly, support for interaction is fundamental to DL design and evaluation. Albertson (2015) described how DL interactions may consist of actions being performed, as well as frequency of types of information search approaches, including search or browse approaches and types of system requests. Choi (2013) found that users progressively diversified and modified their search queries based on their interactions with search results. Specifically, Xie and Cool (2009) concluded that interaction outcomes, including the type and quantity of search results, codetermine the formation of situations.

Despite the attempts by researchers to find new ways of supporting DL users, the previous literature is lacking when it comes to understanding the factors associated with help-seeking situations in DLs. Moreover, there is almost no research that has been done regarding the factors that lead to blind users' help-seeking situations in DLs. Nevertheless, guidance (or help) has been designated as the 4th highest ranking in terms of highly used criteria for evaluation of a DL interface (Hariri & Norouzi, 2011). By understanding the factors behind these situations, DL interface design improvements will benefit all users, but most important, the underserved blind users.

Research Questions and Hypotheses

The sight-centered DL design with its complex structures and multimedia formats pose significant problems for blind users when searching for information. However, research has not adequately addressed these problems and related factors. This study intends to investigate blind users' help-seeking situations, and associated factors in DLs, and addresses the following research questions and corresponding hypotheses:

RQ1. What are the top three help-seeking situations that blind users encounter in interacting with a DL?

RQ2. Are there relationships between user, system, task and interaction factors and the top three help-seeking situations?

H(1): There is no significant relationship between user (H1a), system (H1b), task (H1c), or interaction (H1d) factors and the first help-seeking situation.

H(2): There is no significant relationship between user (H2a), system (H2b), task (H2c), or interaction (H2d) factors and the second help-seeking situation.

H(3): There is no significant relationship between user (H3a), system (H3b), task (H3c), or interaction (H3d) factors and the third help-seeking situation.

RQ3. What are the types of factors that are associated with the top three help-seeking situations that blind users encounter in interacting with a DL?

Methodology

This study intends to investigate the research questions and associated hypotheses presented in Table 1. Table 1 summarizes data collection and data analysis methods for the proposed research questions and associated hypotheses. Although an exploratory sequential approach is applied for the design (Creswell & Plano Clark, 2011), quantitative results of main-level factors associated with the top three help-seeking situations are first presented to justify the selection and presentation of qualitative examples of sublevel factors that offer insight into why help-seeking situations may occur.

Sampling

Thirty blind subjects were recruited from the Midwest region of the United States. To recruit subjects, fliers were distributed to different regional blind associations. Subjects were required to meet the following requirements: (a) legally blind, (b) 18 years of age or older, (c) use computers nonvisually by listening to screen-reader software, (d) have a minimum of 3 years of experience searching for information on the internet, and (e) comfortable with verbalizing one's thoughts in English. The objective of the recruitment was to find diverse blind subjects.

On average, the subjects had 13.5 years (4.98 SD) of experience using the internet, and 80% of subjects used the internet daily. In total, 50% of subjects were male and 50% were female. A majority of subjects (63.4%) were over the age of 50. A majority (56.7%) also indicated intermediate internet search skills. All subjects use screen readers as their primary AT. Subjects demonstrated a necessary level of skill using JAWS to complete assigned tasks. Subjects averaged

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13.6 years of experience in using a primary screen reader, with a range from 1.5–21 years. Using a 7-point Likert scale, subjects rated themselves at an average of 5.2 for familiarity with the primary screen reader used. Demographic characteristics are summarized in Table 2.

Subjects were invited to the usability lab in an iSchool of a state university. For six subjects who were unable to travel to the university, due to their location, the study was conducted at an off-site meeting space. All off-site procedures were consistent with the procedures applied in the usability lab. Subjects received a $100 gift card upon completion of the study.

Digital Library Site, Tasks, and Screen Reader

American Memory Digital Collections (http://memory.loc.gov/ammem) was selected for the user study mainly because it contains digital collections of interest to blind subjects. It is a national DL, and it includes various types of help features. Subjects were instructed to conduct three search tasks (see Figure 1). These tasks represent the three types of typical search tasks that users, including blind users, perform: known-item search, specific information search, and exploratory search (Xie, 2008). The time limitation of the study prevented the inclusion of more task types in this study.

In analyzing the three types of typical tasks that blind subjects perform, the authors identified a comprehensive list of help-seeking situations that blind subjects encounter in searching DLs.

For screen reader selection, JAWS 12.0 was installed on the experimental computers because JAWS is one of the most widely used screen readers among blind subjects (Lazar et al., 2007). JAWS 15.0 was used for the last six subjects. No discernable difference was observed between JAWS 12.0 and JAWS 15.0 versions.

TABLE 2. Demographic characteristics of subjects ($N = 30$).

Category	*N*	Percentage
Age		
18–29	4	13.3
30–39	1	3.3
40–49	5	16.7
50–59	11	36.7
60+	8	26.7
Not specified	1	3.3
Ethnicity		
Caucasian	24	80
Non-Caucasian	6	20
Frequency of internet use		
Occasionally use	1	3.3
Often use	5	16.6
Daily	24	80
Information search skills		
Beginner	1	33.3
Intermediate	17	56.7
Advanced	11	36.7
Expert	1	3.3
Vision lost		
Acquired blind	9	30
Congenital blind	19	63.3
Don't know or no response	2	6.6

Data Collection

Multiple methods were used to collect data in the following order:

1. **Questionnaires**: First, subjects completed a questionnaire requesting their demographic information, internet experience, and search skills via email.
2. **Presearch interviews**: Second, the researchers solicited subjects' perceptions of help features and their help-seeking behaviors in using the internet; considering the unique needs of the subjects and collecting in-depth responses, interview was employed to facilitate data collection.
3. **Think-aloud protocols and transaction logs**: Third, subjects were instructed to "think aloud" during the search process. To prepare subjects for thinking aloud, participants received instruction with examples of prompts for verbalizing during the search process. In addition, subjects were allowed 10 minutes to orient and familiarize themselves with the DL and the process of thinking aloud. Morae 3.1 was used to capture subject-DL interaction activities and verbal think-aloud during the information search process. The think-aloud

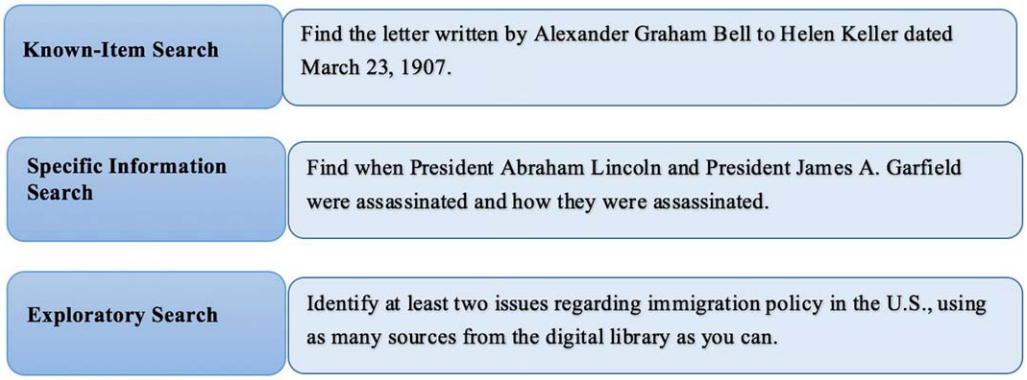

FIG. 1. Three types of search tasks. [Color figure can be viewed at wileyonlinelibrary.com]

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Help Situation Categories	Difficulty with help
Help Situation Type	Difficulty understanding labels
Factors	Unclear labeling
Existing help features used	
Task	Task 3
Human help	
Desired help features	
Outcome of the situation	Unsuccessful
Help situation number	S16s28

Key

Quote/Description:

1) Pre-state (The state before the emergence of help-seeking situation.)
2) Help-seeking situation in ***bold italics***
   Existing help used: **bold red**
   Human help: **bold blue**
   Desired help features: **bold purple**
   Outcome: **bold**
   Factors: **bold green**
3) Post action (The action the subject takes after the help-seeking situation.)

Example

1) Subject alternates between two information resources and proceeds to opens JAWS Links list to review the links on the page.
2) . . .
   <left bracket. 0 7 9 0 2 5 0 0 slash 0 0 1 d t.>
   Those are the dates. NO. Those are different. ***I'm not quite sure what this is.*** DT DT is date?
3) Subject uses Links List and selects the link for "Rights and Reproductions."

FIG. 2. Coding scheme for help-seeking situations and factors. [Color figure can be viewed at wileyonlinelibrary.com]

protocol has been widely used in previous usability studies with screen reader subjects (Stefano, Borsci, & Stamerra, 2010). In this study, no subjects complained about thinking aloud during the process of information search.

4. **Postsearch interviews**: Fourth, after the searches were completed, subjects were interviewed about their interactions with the DL, regarding help-seeking situations encountered, associated factors, help features used, and desired help features. Subjects also provided an overall assessment of the DL and its help features. Interviews and recorded data, which include subjects' verbalization and screen reader information, were transcribed for data analysis.

Data Analysis

The unit of analysis is each help-seeking situation and associated main-level and sublevel factors that lead to the situation. Each situation was marked at the point where the user verbally communicated a request for help, or expressed confusion in response to problems with the system and its corresponding features, and when there was a clear outcome for the situation. Situations included all cases that impede subjects' interactions with the system. Main and sublevel factors associated with situations were color-coded based on the coding scheme.

Qualitative data collected from think-aloud protocols and transaction logs were examined for the three search tasks. An open coding method was applied for the three search tasks, which is the process of breaking down, examining, comparing, conceptualizing, and categorizing unstructured textual transcripts (Strauss & Corbin, 1990). A coding scheme (Figure 2) was developed to identify the following aspects: situation category and type, example (with quotes), factors associated with the situation, existing help features used, desired help features, and outcome of the situation. This paper focuses on the identification of the top three help-seeking situations, associated main-level factors, and their relationships. It also illustrates key sublevel factors related to each main-level factor category.

Four coders participated in the coding process. Two independent coders analyzed situations, selecting a random sample from the 30 subjects. According to Holsti's (1969) formula, the intercoder reliability of situations identified between the two coders was 0.932.[1] Types of main and sublevel factors were also identified by the two coders and discussed with two other coders until an agreement was made. Disagreements or questions for situations and factors were

[1]Reliability = $2M$ /(N 1 + N 2), where M is the number of coding decisions based on the agreement of two coders, and N 1 and N 2 refer to the total number of coding decisions by each of the two coders.

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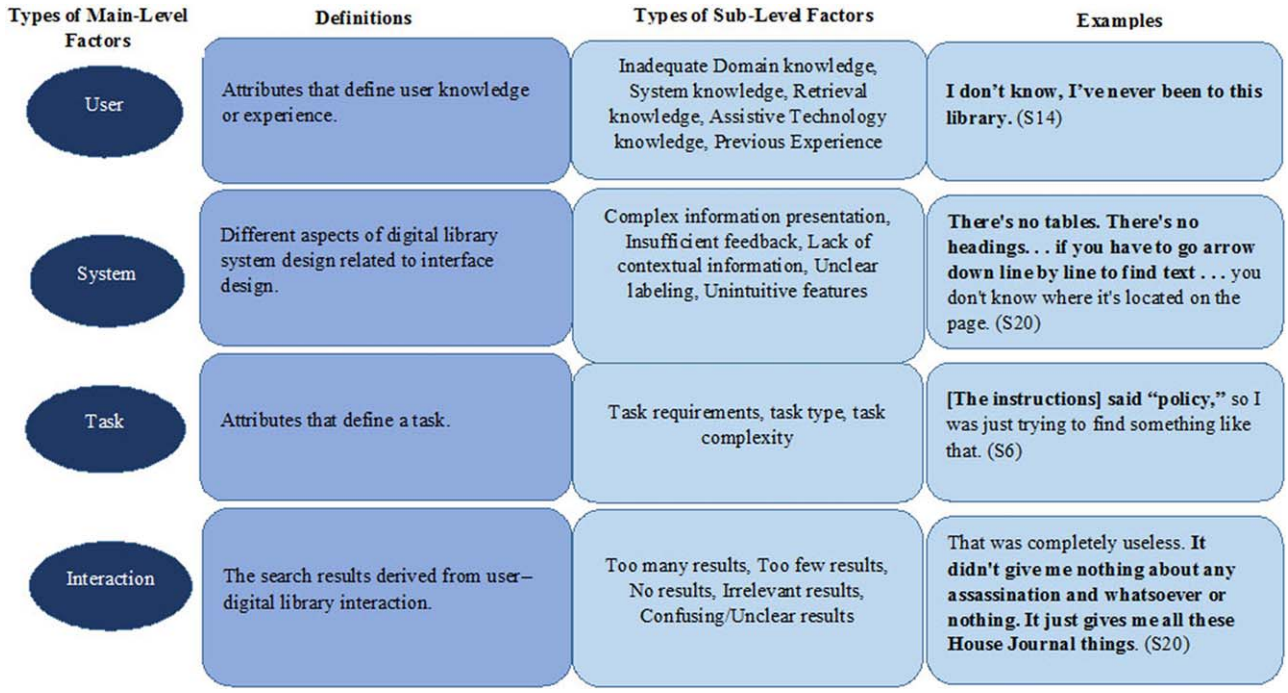

FIG. 3. Types of main-level factors, definitions, types of sublevel factors, and examples. [Color figure can be viewed at wileyonlinelibrary.com]

resolved by group discussions among the four coders to ensure the reliability of data analysis.

Based on the coding scheme, blind subjects encountered 872 unique situations, which were identified from the analysis of 90 search sessions. Taxonomies of situations are based on each individual situation identified from the search processes of the 90 sessions. Upon identification of types of situations, the researchers calculated the frequency and percentage of each type of category. These situations can be classified into the following types: (a) difficulty accessing information, (b) difficulty evaluating information, (c) difficulty with help, (d) difficulty locating information, (e) difficulty refining and limiting collections or results, (f) difficulty identifying current status or path, (g) confusion about multiple programs or structures, (h) avoidance of format, approach, or input fields, and (i) difficulty constructing searches.

In addition, descriptive analysis for situations was calculated and reported in the Results. These situations not only represent the most frequently occurring situations, but also reveal unique problems of blind subjects and therefore have important implications for system design.

Simultaneously, associated factors that led to each situation were identified. In all, 2,102 sublevel factors were observed across all 872 unique situations. In many situations, more than one factor was observed. All sublevel factors for each situation were further grouped at the main level for quantitative analysis, and qualitative analysis focused on the discussion of both main-level and sublevel factors for each situation. These factors represent four main types: user, system, task, and interaction emerged during the analysis. Figure 3 presents types of main and sublevel factors, definitions, and examples. Qualitative examples of situations and associated factors are provided in the Results section to prevent duplication. Considering the space limitations, only the top three situations and associated factors are reported in the Results. Although main-level factors are emphasized, the results show examples of sublevel factors associated with main-level factors, to illustrate more specificity and detail at the sublevel.

Pearson's correlation coefficient analysis was performed to test whether there are relationships between different types of main-level factors including user, system, task, or interaction, and a specific type of situation. Pearson's correlation coefficient is a measure of the strength of a linear relationship between paired numeric data. Frequency of situations encountered, and frequency of associated main-level factors corresponding to the situations, were calculated for the analysis.

Results

The results of the study focus on answering the research questions regarding top situations and the associated main-level factors. Because of space limitations, the authors only report the top three situations, as well as leading main and sublevels of factors that contribute to these situations.

To address RQ1, the top situations were selected based on their frequency of occurrence and their uniqueness in relation to blind subjects. The top situations include: (a) Difficulty Accessing Information, (b) Difficulty Evaluating Information, and (c) Difficulty With Help. Simultaneously, four types of factors emerged from the data: User, System, Task, and Interaction. Specifically, sublevel user factors

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Types	Definitions
Difficulty accessing information	Problems related to determining item format, detecting alternative text, or pre-existing text in an input box, receiving system feedback, or downloading/streaming content.
Difficulty evaluating information	Difficulty making sense of search results, collections, or subject organization criteria; difficulty understanding the relevance of search results or identifying relevant collections or subjects.
Difficulty with help	Difficulty understanding labels; problems understanding how to use a specific function; inability to identify relevant help or understand help information.
Difficulty locating information or features	Difficulty finding specific information or features in the DL pages.
Difficulty refining/limiting collections or results	Inability to filter out irrelevant information resources; difficulty narrowing or limiting specific collections, subjects or results.
Difficulty identifying current status or path	Problems identifying the current location, returning to home or a previous page, getting started or proceeding, recognizing page loading status, or monitoring searches.
Confusion about multiple programs or structures	Confusion resulting from complex DL structures or difficulties distinguishing the DL from other programs.
Avoidance of format, approach, or input fields	Avoidance of visual items, browsing approaches, in-depth exploration, or search input fields.
Difficulty constructing search statements	Difficulty formulating search statements or queries.

FIG. 4. Types of help-seeking situations and definitions. [Color figure can be viewed at wileyonlinelibrary.com]

FIG. 5. Frequency of types of help-seeking situations. [Color figure can be viewed at wileyonlinelibrary.com]

mainly consist of Inadequate System and Domain Knowledge, whereas system sublevel factors are composed of Unclear Labeling, Complex Information Presentation, Unintuitive Features, Insufficient Feedback, and Lack of Contextual Information. In addition, Irrelevant or Confusing Results are the primary interaction sublevel factors. Task factors are not discussed because no significant correlations were found between task factors and situations.

Top Help-Seeking Situations

Blind subjects encountered different types of situations in their interactions with the DL. Three top situations were identified based on the open coding and frequency of occurrences of situations from a total of 872 observed situations. Figures 4 and 5 present each type of situation, associated definitions, and frequency data, respectively.

Among the 872 situations, the top three situations selected for further illustration are: Difficulty Accessing Information, Difficulty Evaluating Information, and Difficulty With Help. To avoid repetition, examples for each type of situation are presented along with main and sublevel factors associated with the top situations. In the following examples, quotes related to specific factors are bolded.

Factors Associated With Top Help-Seeking Situations

The results of RQ2 and associated hypotheses are presented to identify both main and sublevel factors worth discussing for RQ3. Relationships were found between specific

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TABLE 3. Correlation analysis of top help-seeking situations and associated main-level factors.

Help-seeking situations	User	Sig.	System	Sig.	Task	Sig.	Interaction	Sig.
Difficulty accessing information	**.567***	.001	**.783***	.000	-.023	.904	.139	.464
Difficulty evaluating information	**.801***	.000	**.783***	.000	.028	.883	**.709***	.000
Difficulty with help	**.747***	.000	**.938***	.000	-.024	.900	.201	.287

*Correlation is significant at the .05 level (2-tailed).

types of main-level factors and the top three help-seeking situations. The results indicated that the following null hypotheses are rejected: H1a, H1b, H2a, H2b, H2d, H3a, and H3b. The remaining null hypotheses are accepted: H1c, H1d, H2c, H3c, and H3d.

Table 3 presents the correlation analysis between different types of main-level factors including User, System, Task, and Interaction, and situations consisting of Difficulty Accessing Information, Difficulty Evaluating Information, and Difficulty With Help. More specific correlation test results on main-level factors are reported below. To save space, nonsignificant test results are omitted in the text.

A positive correlation was found between System factors ($r = 0.783$, $p = .000$), or User factors ($r = 0.567$, $p = .001$) and Difficulty Accessing Information. Positive correlations were found between User factors ($r = 0.801$, $p = .000$), System factors ($r = 0.783$, $p = .000$), or Interaction factors ($r = 0.709$, $p = .000$) and Difficulty Evaluating Information. There was a strong positive correlation between System factors and Difficulty With Help ($r = 0.938$, $p = .000$), and a positive correlation between User factors and Difficulty With Help ($r = 0.747$, $p = .000$). The correlation results indicate that blind users' top situations are associated with User, System, and Interaction factors, but are not associated with Task factors. Qualitative data offer detailed explanations in terms of how these factors influence the top situations.

To address RQ3, below are highlighted the main-level factors associated with the top three help-seeking situations that blind users encounter in interacting with a DL. Additionally, examples of bolded sublevel factors are included to illustrate the role that the factors play in the help-seeking situations.

Factors Associated With Difficulty Accessing Information

Difficulty Accessing Information is the most frequently occurring situation that blind subjects encountered. It is a physical situation related to an inability to access information in accessible formats needed to achieve a task. For blind subjects, information was most easily accessed in the format of text or audio format. Common situations related to difficulty accessing information include difficulties related to finding alternative text, identifying preexisting text in an input field, accessing features, and/or receiving system feedback. System and User factors were associated with Difficulty Accessing Information.

Two System sublevel factors emerged for Difficulty Accessing Information: Complex Information Presentation and Insufficient Feedback. Complex Information Presentation, such as excessive or unclear information, made it difficult for blind subjects to identify accessible content or meaningful descriptive information about the information resource or collection. For example, S23 was unable to access alternative text for an item due to excessive metadata.

> <turn to page button. . .the Capitol and the Bay col. a. turn to page button. link Pre. link Prev page. link Prev page vertic. blank. the Capitol and the Bay colon vertical bar.> **This is kind of useless. Ok so I found this book but I have no idea how to access it. I can get the cover page or the bibliography information. But no information in the book.** (S23)

The next example illustrates how Insufficient Feedback contributed to Difficulty Accessing Information. S3 had a problem in accessing text for an image, but the link did not take her to the text. The feedback did not explain what happened.

> <Link view text.>I guess I don't have to click on an image this time. **I'm just going to click on "view text."**<Enter. View text visited link.> {New page loads, an empty search results list.} Blank. **We were unable to find any matches for your search. Blank.>Okay. I don't know what happened there.** (S3)

Two User sublevel factors emerged as the main user factors for Difficulty Accessing Information: Inadequate System Knowledge and Inadequate Assistive Technology Knowledge. The following situation reflects a common problem among blind subjects who lacked DL knowledge and were unable to access alternative text for images. S12 was not familiar with whether the system consistently referred to text in the same way in different resources.

> I'm looking for some sort of text to see **if I can even use this resource to identify what the issue is**. This one, **if there is a transcription link, they named it differently**, or I'm just passing it up. But that word is not up there. . . **I don't know what that would be. An item list of what? I'm in an item. I don't know what that would mean** . . . This resource is not accessible. (S12)

In the next example, the User factor, Inadequate Assistive Technology Knowledge, played a role. Although S8 thought that JAWS could be used to identify if there was preexisting text in the search box, S8 experienced difficulty in properly activating JAWS to read the text.

DOI: 10.1002/asi

> Well as far as I can tell there's nothing in there. **<Root JAWS to PC. Num lock on.>Uh oh. <Num lock off. PC cursor. [Beep.] Space. Space. Space. Space**. . .>**No, I'm not sure. The only way I know to check, is to do this through JAWS**. . . (S8)

Factors Associated With Difficulty Evaluating Information

Difficulty Evaluating Information is a cognitive situation relating to difficulties evaluating the relevance of digital collections or information resources. Three types of main-level factors were associated with this situation: User, System, and Interaction factors.

Inadequate System Knowledge was a key User sublevel factor. Subjects who struggled to identify relevant collections or information resources expressed a lack of knowledge on how to search within collections or what information the resources contained. In addition, subjects had difficulties making distinctions between different aspects, functions, and regions of the DL. S28 indicated that Inadequate System Knowledge contributed to difficulty evaluating search results.

> What I don't really know is how to search within these documents for something more specific. **You know, I guess my lack of familiarity with the site is kind of** . . . (S28)

Two System sublevel factors emerged as notable factors: Lack of Contextual Information and Complex Information Presentation. Due to Lack of Contextual Information, it was difficult for subjects to comprehend search results, collections, or subject organization criteria. S30 reviewed several search results, but was unable to evaluate the relevance of items because no contextual information was available to indicate what the resources contained.

> It's just bringing up some sort of relevant information, but **it's not showing why that's relevant. It's not showing you, for example, when you do a Google search, or when you look at certain places** . . . **you'll see a little snippet of what it could be**, and then you know . . . It's just saying, look at this thing from 1846 to wherever . . . **it's so general that I don't know.** (S30)

Complex Information Presentation reflected a problematic structure and organization of information that made it difficult for subjects to make sense of information in the DL. Subjects were overwhelmed due to the quantity and format of available information, and had difficulties distinguishing useful from irrelevant information. S21's experience is one example:

> I'm feeling so stressful . . . **you're getting lost in too much information** and then you're feeling like and virtual find like control-f so you can type something in and search you know on the page but **it still doesn't work because the content is so confusing** so it still doesn't give you like related information. . . (S21)

One Interaction sublevel factor frequently led to Difficulty Evaluating Information: Irrelevant or Confusing Results. Subjects experienced difficulties evaluating the relevance of search results due to Irrelevant or Confusing Results that appeared in the results list. Difficulties ensued when the results appeared to have little to do with the original query, as in the example of S7.

> It's seeing a lot of records here that aren't 2013, because **we're not in the 39th Congress** . . . **all those are from the wrong year**. . . **I don't know why some of these things would come up.**. . .**Why would there be notes to Congressional congresses of early in the last century when 2013 was part of the match?** (S7)

Factors Associated With Difficulty With Help

Difficulty With Help is a cognitive situation related to difficulty understanding implicit and explicit forms of DL help. Some DL features that were intended to be helpful caused significant problems for blind subjects. DLs feature a variety of implicit and explicit help features, ranging from broad to very specific features (Xie et al., 2015). System and User factors were associated with Difficulty With Help.

Two notable sublevel system factors emerged for Difficulty With Help: Unclear Labeling and Unintuitive Features. Subjects could not identify the meaning of features, headings, links, and form fields due to nondescriptive or confusing labels. S16 located a link to a resource, but the Unclear Labeling of the link caused confusion, creating difficulty in understanding what the link referred to.

> **<left bracket. 0 7 9 0 2 5 0 0 slash 0 0 1 d t.>** Those are the dates. No. Those are different. **I'm not quite sure what this is. DT DT is date?** (S16)

The System factor, Unintuitive Features, was associated with Difficulty With Help, particularly difficulty using a specific function, such as the search mechanism and search results filters or facets. During clumsy or failed interactions, subjects found it difficult to use advanced search features, and were unclear regarding specific functions. Unintuitive Features prevented S4 from using an advanced search feature.

> If I want to do a search by keyword, **I am not understanding how I can do a search by keyword. Because it is not a link, but author, title, and genre are**. (S4)

Two User factors emerged as critical sublevel factors for Difficulty With Help: Inadequate System Knowledge and Inadequate Domain Knowledge. Inadequate System Knowledge was a contributing factor and S30 experienced difficulties where the system was not providing adequate help as to how to find information.

DOI: 10.1002/asi

> **As far as finding anything here, it just is so goofy.**. . . **I can't place it.**. . . I mean it was hard enough to find specific information. When we're trying to find more general information . . . **I don't even know where to begin**. (S30)

Inadequate Domain Knowledge also served as a contributing User sublevel factor. Domain Knowledge relates to the subjects' understanding of the search topic, which is important in DLs, where materials are indexed using historical terminology that may be unfamiliar to subjects. S9 had difficulty understanding specific browse categories and how they would help in achieving the task.

> <Prosperity and thrift colon. Blank. An American time capsule colon three centuries of broadsides and other printed ephemera.>**I don't even really understand that, so I wouldn't choose that.** (S15)

Discussion

This study established that blind users face unique help-seeking situations in their interactions with DLs. Based on the hypotheses results, these situations were significantly associated with User, System, and Interaction factors, but not the Task factor. It seems that blind subjects encounted more problems in relation to the sight-centered design of DLs that do not take blind users' needs into consideration and do not consider the challenges that DL complexities pose for blind users. They are frequent users of web search engines but are not familiar with DLs. In addition, the selected task types might not cover all the task types, and might make a difference. As to the Interaction factor, it is only significantly associated with difficulty evaluating results, mainly because interaction results are more related to the search results than accessing information and using help features. The findings have significant design implications.

Design Implications for Reducing Help-Seeking Situations Associated With User Factors

Inadequate knowledge related to DL systems, assistive technology, and domain represent important User sublevel factors influencing diverse situations. DL design needs to incorporate designs or features that enhance blind users' knowledge structures. Inadequate System Knowledge created difficulty for blind users in understanding the DL site structure, information organization, information evaluation, and functions of available features. Inadequate System Knowledge can be supported through instructional and contextual features, such as an inclusive demo or tutorial about the DL, or by providing context-sensitive help. By providing an overview of features available in the DL, the user will be able to create a mental model of the DL site structure and features (Leuthold et al., 2008). This tutorial should be categorized by types of features supporting different types of search (e.g., Keyword search, Browse), and outline the structure of the site, considering sighted as well as nonvisual needs. The tutorial should be accessible from all pages. Moreover, this tutorial should include well-structured instruction on how to use the DL, with an explanation of how the site and collections are structured, including facilities designating global structures and local structures that offer flexible pathways (Chen & Macredie, 2010). Step-by-step instruction on navigating the DL with the screen reader also can be a compelling aid.

Inadequate Domain Knowledge requires help understanding specialized terminology, formulating search queries, interpreting search results, and accessing instruction systems. Possible help features for users unfamiliar with specialized terminology could include provision of meaningful explanations either via contextual clues, Alt Text, or accompanying text. Help in formulating search queries and interpreting search results may be provided via natural language interfaces and search aids.

Inadequate Assistive Technology Knowledge is another important User sublevel factor behind blind users' situations. It created difficulty determining appropriate screen-reader commands for effective accessing, navigating, and evaluating information. Possible help features to address such situations include three kinds of navigational aids suitable for screen-reader access: (a) tips for screen-readers regarding access of information in the DL; (b) section titles coded for heading navigation, providing direct access to section titles using the H shortcut; (c) direct access to relevant content on the page (e.g., Skip links to the search results section). Such features will help users avoid listening to irrelevant information on a page before accessing relevant content (Chandrashekar, 2010; Vigo & Harper, 2014).

Design Implications for Reducing Help-Seeking Situations Associated With System Factors

Unclear Labeling is a key System sublevel factor associated with various situations. To reduce situations, descriptive unambiguous and consistent labels to previous pages, homepages, and search results pages need to be prominently placed for blind users to facilitate recognition and simplify exploration, easing their cognitive load in questioning the meaning of labels (Andronico et al., 2006; Lazar et al., 2012). As an enhancement, lengthier descriptions or alt-tags provide blind users with meta-information, where context might typically be lost (Lazar et al., 2007). Clear terminology and good interface design enable users to more easily interact with DLs (Power et al., 2012). These navigational labels should provide clues to the user to understand differences between DL navigational areas.

Complex Information Presentation is the second critical System sublevel factor behind multiple situations. It reflects structural and information architecture problems, and creates difficulty for users to navigate and browse (Borodin et al., 2010; Vigo & Harper, 2014). Complex Information Presentation also causes problems for subjects to make evaluative judgments, distinguish useful from irrelevant information, or

DOI: 10.1002/asi

understand how to navigate through complex structures. Simultaneously, DL design needs to offer direct links to assist users skipping over unnecessary, irrelevant content, or text previously visited. Because DLs offer complex metadata, one recommendation is to provide context-sensitive metadata. Most important, blind users need direct access to alternative text resources in DLs, as images and graphics are typically avoided. Restructuring of data structures and metadata can also assist in improving information presentation (Kovács & Takács, 2014). Developing a simple interface with minimal graphics, hyperlinking, and tabulation will help to reduce information overload (Kumar & Sanaman, 2015). Most important, the DL structure and its functions, including help mechanisms, need to be designed to assist blind users to make sense of them.

The third System sublevel factor, Unintuitive Features, reveals that the DL failed to present component parts, corresponding utilities, and expected outcomes of using a feature. The design of system features needs to be simple and usable because blind users tend to avoid rich, dynamic, and interactive content (Borodin et al., 2010). Blind users need to be aware of how the features relate to one another and how to activate features with screen readers (Leuthold et al., 2008). Context-sensitive help that are readable by a screen reader must be provided, and instruct on what the feature consists of, how to enter and use the feature, and how to activate the feature.

The fourth System sublevel factor is Insufficient Feedback. Design implications related to Insufficient Feedback consist of creating help features offering clear feedback, such as search suggestions, including query autofill features. Search boxes should automatically be cleared upon search activation; existing text in the search box should prompt the screen reader with a notification, as blind users may not receive adequate clues from the screen reader regarding existing text in a search box. Clear and instructional feedback for all errors should also be provided. Offering contextual information for search results, collections, or subject organization criteria is critical for the fifth System factor, Lack of Contextual Information.

Design Implications for Reducing Help-Seeking Situations Associated With Interaction Factors

Designers from the DL perspective should provide additional assistance to help blind users recover from failures (Vigo & Harper, 2014) by suggesting that users try an alternate approach or a different strategy. For users who receive Irrelevant or Confusing Results, design implications include providing more context for search results, such as descriptive snippets of text with relevant key terms that identify why items appear in the search results. This implication is especially pertinent to DLs, which may generate results in a folder format where the folder name is vague and nonspecific, and the item is embedded within the folder.

The DL design implications discussed above correspond to blind users' unique perceptions, actions, and cognitions in information search. It is important to experimentally validate these design improvements with blind users before they become design principles and standards for accessible and usable DLs.

Conclusion

This study represents the first attempt to systematically examine the DL interactions of blind users to understand the nature of unique help-seeking situations and associated main-level and sublevel factors. Blind users experience unique situations not only related to inaccessibility but also comprehension and confusion. Moreover, multiple System factors and User factors are mainly associated with these situations. Findings have significant design implications for the field. Different types of design implications focusing on offering help features to reduce situations by targeting corresponding factors are provided.

This study also has its limitations. First, study subjects were recruited from the U.S. Midwest, and hence are not representative of the entire population of blind Americans. Second, only the American Memory Digital Collection was examined, implying that the findings might not be applicable to DLs employing diverse design models. Third, the selected search task types cannot account for all task types that blind users perform in DLs. Fourth, the process of thinking aloud might not enable all subjects to report the entire set of situations observed during their search. Fifth, the statistical analysis of the main-level factors and situations does not account for secondary factors behind certain situations. Future research shall conduct a wider-scale investigation using multiple DLs with diverse design models, involving a more geographically diverse sample of blind Americans, consisting of additional types of assigned and self-generated tasks, employing a combination of think-aloud protocols, transaction logs, and diaries to produce complete and statistically generalizable results. In addition, new help features will be created and tested to support blind users' effective interaction with DLs. Finally, identified help-seeking situations will be compared to the existing web accessibility standards and further used to create DL guidelines on accessibility, usability, and utility.

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