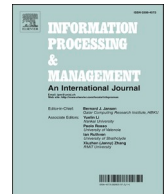




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Coping tactics of blind and visually impaired users: Responding to help-seeking situations in the digital library environment

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ABSTRACT

The authors conducted the first study to investigate the types of coping tactics that blind and visually impaired (BVI) users applied when they encountered difficulties interacting with digital libraries (DLs). Coping tactics are defined as diverse action choices used by BVI users to accomplish specific goals in response to different types of help-seeking situations. Sixty-four participants were recruited throughout the United States. Multiple data collection methods were employed to collect data: pre-questionnaires, think-aloud protocols, transaction logs, and diaries. The study identified 19 types of coping tactics associated with the top five help-seeking situations. The findings were further compared with prior research to highlight the tactics previously identified from non-DL environments and unique coping tactics found only in the DL context. On the one hand, BVI participants brought their 11 types of coping tactics from non-DL environments into the DL context. Among them, Searching for keywords and Seeking human help are the coping tactics employed to address all of the top five situations in the DL environment. On the other hand, the combination of structural complexity, use of multimedia formats, and sight-centered designs found in DLs force BVI users to apply eight unique coping tactics in the DL context. The linear way of going through the DL structure led BVI users to explore DL page structure. At the same time, they had to Explore an accessible alternative to deal with inaccessible multimedia content. To support the coping tactics adopted from non-DL environments, the design suggestions focus on directly resolving situations, offering more options within DLs, and creating or enhancing features based on BVI users' coping tactics. To support the unique coping tactics, the design implications concentrate on ways of reducing help-seeking situations.

1. Introduction

Despite the growing attention paid to disabilities and accessibility in library and information science (LIS) (Hill, 2013), the goal of universal accessibility and usability of information retrieval (IR) systems has yet to be fulfilled for vulnerable patrons such as blind and visually impaired (BVI) users (Jaeger, Bertot, & Franklin, 2010; Mátrai, 2018). In this study, BVI users specifically refer to those who do not have the sight necessary to see information displayed on a screen, thus having to rely on screen reader software in their everyday interactions with devices and IR systems. Digital libraries (DLs) have been widely developed as online collections of digitized or born-digital items to provide information resources for diverse user communities (Xie & Matusiak, 2016). Massive information

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resources, complex interfaces, layered structures of DLs, and heterogeneous content formats present ever-increasing challenges to the non-visual and linear interaction approaches of BVI users (Babu & Xie, 2017; Kuzma & Moscicka, 2018; Xie, Babu, Lee, Castillo, et al., 2020).

Given the sight-centered nature of the Web, BVI users are more likely than their sighted counterparts to encounter a variety of accessibility and/or usability challenges when interacting with IR systems (Berget & MacFarlan, 2020; Borodin, Bigham, Dausch, & Ramakrishnan, 2010; Kumar & Sanaman, 2015; Power, Freire, Petrie, & Swallow, 2012; Rømen & Svanæs, 2012), thus giving rise to various help-seeking situations (Lazar, Olalere, & Wentz, 2012; Lunn, Harper, & Bechhofer, 2011; Vigo & Harper, 2013, 2014; Xie, Babu, Joo, & Fuller, 2015). A help-seeking situation is defined as a problem that drives BVI users to seek help, either through help mechanisms/features of systems or human assistance, in order to facilitate their interactions and accomplish their goals/tasks (Xie, Babu, Lee, Castillo, et al., 2020). A limited number of studies indicate that BVI users employ various tactics to cope with help-seeking situations that hinder their interactions with the Web (Lazar et al., 2012; Lunn et al., 2011; Rodrigues, Nicolau, Montague, Guerreiro, & Guerreiro, 2020; Sahasrabudhe & Singh, 2020; Vigo & Harper, 2013, 2014). In this study, coping tactics refer to diverse action choices taken to accomplish specific goals in response to different types of help-seeking situations. Moreover, there has been no systematic research exploring the association between coping tactics and help-seeking situations.

Although there have been recent studies exploring help-seeking situations in DLs (Xie et al., 2015; Xie, Babu, Castillo, & Han, 2018), no research has examined the coping tactics applied by BVI users that correspond to potential help-seeking situations in DL contexts. To bridge the aforementioned research gap, this study investigates the association between help-seeking situations and coping tactics applied by BVI users when interacting with DLs. This paper intends to address the following research questions:

RQ1: What are the types of coping tactics that BVI users apply during their interactions with digital libraries?

RQ2: How do different types of coping tactics correspond to the top five types of help-seeking situations?

This paper is structured as follows. It begins by reviewing related literature on BVI users' tactics, coping tactics, and help-seeking situations in digital environments. It then presents the various data collection and data analysis methods of this exploratory study. The subsequent section reports the results relevant to types of coping tactics and their association with the top five types of help-seeking situations. In addition, the discussion involves both theoretical and practical implications to support BVI users' effective interactions with DLs. The paper concludes with the limitations of the study and future research directions.

2. Literature review

2.1. Types of tactics employed by BVI users in diverse digital environments

BVI users employ different tactics in digital environments compared to their sighted counterparts. Their tactics related to orientation, navigation, search, and browsing have been investigated in relevant studies, and these tactics are interrelated to each other. When BVI users first interact with an IR system, they need to become familiar with it. Recent studies compared blind and sighted users' orientation tactics in their initial exploration of a DL, pointing out that blind users were more likely to explore DL structure while their sighted counterparts tended to focus on browsing DL content (Xie, Babu, Lee, Wang, & Lee, 2020; Xie, Babu, Lee, Wang, & Lee, 2021).

Navigation tactics refer to action choices that BVI users take to purposefully move around a page and locate information of interest. Research shows that blind users apply recurring navigation tactics such as sequentially navigating the Web using arrow keys from top to bottom on a page; tabbing through links on the page; jumping from one section heading to another on a page; and using navigation functions of screen readers (Borodin et al., 2010; Jobst, 2009; Power et al., 2013; Sahasrabudhe & Singh, 2020). Trewin et al. (2010) further differentiated navigation tactics that visually impaired (VI) users applied for familiar web pages versus unfamiliar web pages. Recently, Moreno et al. (2018) pointed out that navigation tactics used by VI participants were associated with exploring navigation bars, clicking links on navigation bars, using scroll bars, and exploring page contents. The survey results from WebAIM (2019) echo the results from previous studies, showing that blind users often navigate through headings, links, and landmarks/regions to find information when interacting with a lengthy web page.

Search tactics refer to action choices that users rely on to intentionally seek information by formulating and reformulating queries or using search features. According to Sahib, Tombros, and Stockman (2012), VI users tended to formulate long and complex queries with a lower awareness of search support features and limited use of these features when initiating their search queries. Moreover, Sahib, Tombros, and Stockman (2014) indicated that the VI users tried to either find new information by submitting new queries and exploring new results or reviewing information from the previous session when resuming searches during multi-session tasks. Focusing on blind users' search query formulation tactics, Upadhyay (2020) concluded that blind users conducted more informational queries (queries generating multiple information patches) than navigational queries (queries used to reach specific websites). Research also shows that keyword search within a page is a tactic commonly used by BVI users to find desired information (Power et al., 2013; Sahib et al., 2012; Saqr, 2016).

Browsing tactics are defined as action choices made to quickly go through information, either with specific goals in mind or just casual reading. Takagi, Saito, Fukuda, and Asakawa (2007) found that blind users browsed a web page using two tactics: exhaustive scanning and gambling (probing) scanning. Sahib et al. (2012) discovered that VI users often exhaustively read the entire page content when reaching the search results page. While using exhaustive scanning, blind users may scan the content of a web page line by line using arrow keys (Takagi et al., 2007) or scan components of a webpage sequentially (Francisco-Revilla & Crow, 2010). Unlike exhaustive scanning, previous research found that blind users relied on probing (i.e., clicking a link and quickly returning to a page) more heavily than sighted users (Bigham, Cavender, Brudvik, Wobbrock, & Lander, 2007; Saqr, 2016). The third browsing tactic is characterized by relying on heading, description, URLs, links, and related keywords to scan search results (Upadhyay, 2020).

2.2. Types of coping tactics employed by BVI users corresponding to help-seeking situations

Despite applying the aforementioned types of tactics, BVI users are still likely to encounter various help-seeking situations primarily related to accessibility and usability. There are a variety of accessibility-related help-seeking situations for BVI users. Much research has been conducted to investigate coping tactics in response to accessibility problems. Bigham et al. (2007) observed that blind users used keyboard commands when interacting with inaccessible page elements, and they also avoided visiting pages containing dynamic content. Similarly, Borodin et al. (2010) found that screen reader users had difficulty with dynamic content and automatic refreshes, to cope with which they tended to ignore irrelevant dynamic content, or use screen reader commands to suppress automatic refreshes, and/or refresh web pages manually. Research also shows that BVI users often adopt the tactic of asking for human assistance when they cannot access the information for various reasons (Lazar, Allen, Kleinman, & Malarkey, 2007; Lunn et al., 2011; Vigo & Harper, 2013). According to Vigo and Harper (2013), BVI users were found to tab down or scroll down to escape from inaccessible content, while Borodin et al. (2010) observed that screen reader users explored surrounding web elements to understand inaccessible content/controls. In cases where there is a lack of alternative descriptions for images, BVI users frequently undertake impulsive clicking to find relevant information (Lunn et al., 2011; Vigo & Harper, 2013).

Also, BVI users have to deal with usability-related help-seeking situations. Confusion is a typical issue that they have to handle. For instance, Lazar et al. (2007) pointed out that screen reader users are likely to encounter confusing screen reader feedback and conflicts between screen readers and applications, and blind users rely on previous experience and ask for help to cope with these problems. Vigo and Harper (2013) emphasized that confusion can also arise from a lack of search results, difficulty distinguishing texts and links, encountering unexpected content, and unfamiliar features, to name a few. When BVI users are confused, they may employ various tactics, such as asking for human help to get confirmation or further instructions, impulsively clicking, exploring by moving around, narrowing down searches, going back to a familiar place, and re-doing (Lunn et al., 2011; Vigo & Harper, 2013). Getting disoriented or lost on a web page is a common usability situation for BVI users. Backtracking is a frequently adopted tactic to cope with this situation (Lunn et al., 2011; Saqr, 2016; Vigo & Harper, 2013). To cope with the disorientation, BVI users employed two tactics: going to the top of the current page and backtracking to a familiar location (Vigo & Harper, 2013). Moreover, coping tactics in response to cognitive overload have also been identified. For example, Lunn et al. (2011) found that BVI users adopted the masthead avoidance tactic to skip repeated components. In addition, BVI users can tab/scroll/arrow down quickly to go through web pages without listening to every element (Vigo & Harper, 2013).

2.3. Help-seeking situations for BVI users in a DL context

Help-seeking situations unique to BVI users in DL environments have been investigated. Xie and her colleagues (Xie et al., 2015; Xie, Babu, Castillo, & Han, 2018; Xie, Babu, Castillo, Lee, & You, 2018) examined BVI users' help-seeking situations in DLs and identified unique situations that they encountered, such as difficulty in accessing format information for an item, difficulty in finding alternative text for an image, difficulty in identifying the current location, difficulty in recognizing page loading status, difficulty in finding heading information, and difficulty in recognizing a label. Nevertheless, there is a lack of research in understanding how BVI

Table 1
Demographic data

Categories	Sub-categories	Onsite	Diary	Total
Age	18-29	6	7	13
	30-39	3	7	10
	40-49	8	6	14
	50-59	7	4	11
	>59	8	8	16
Gender	Female	17	17	34
	Male	15	14	29
Vision	Blind	26	21	47
	Visual Impaired	6	7	13
Ethnicity	Asian	3	2	5
	African American	3	3	6
	Caucasian	24	22	46
	Hispanic	1	4	5
Education Level	High School	3	1	4
	Associate	4	7	11
	Bachelor	10	9	19
	Master	13	14	27
	Doctorate	2	1	3
Searching Skill	Beginner	1	1	2
	Intermediate	17	10	27
	Advanced	13	18	31
	Expert	0	1	1
Use of Screen Reader	Years of using screen reader	17.29	15.22	16.24
Use of the Internet	Years of using the Internet	17.74	18.97	18.35
	Frequency of using Internet	6.66	6.69	6.67

users cope with help-seeking situations in DL environments.

3. Methodology

Since no prior research has been conducted to explore BVI users' coping tactics in the DL context and their corresponding help-seeking situations, the authors took the exploratory qualitative approach (Flick, 2019) to investigate this unfamiliar area. Diversity is the key to this methodology. Sixty-four participants with diverse demographic characteristics were recruited and grouped into two groups — onsite and diary groups — to interact with five different DLs. In this study, multiple data collection methods were employed: pre-questionnaires, think-aloud protocols, transaction logs, and diaries. Although both qualitative and quantitative data were

DL	Orientation	Specific Information Search	Exploratory Search
Artstor	Explore the various features and functions of this DL, in particular the navigation region, to gain a basic understanding of how it works.	Identify a work of art by Josef Albers focusing on geometric abstraction in the 1930s. Find out the material type and the name of the art gallery that houses it.	Find images or objects /artifacts related to Apollo that were created in the 4th century in Greece. Make sure each item either represents one distinct type of artwork or one distinct aspect of this search topic. Please find as many items as possible.
DPLA		Identify the sources of infection for the Spanish Influenza in 1918-1919, and name three recommended prevention methods.	Find items related to female aviators and their participation in air races in the 1900s. Please find as many items as possible from Digital Public Library of America as you can. Make sure each item either represents one distinct format or one distinct aspect of this search topic.
HaithTrust		Find the date when Rosa Parks was arrested. When did Rosa Parks take a leadership role in a branch of NAACP and what was her role?	Find items related to the Great Earthquake and Fire in San Francisco in the early 1900s. Make sure each item either represents one distinct format or one distinct aspect of this search topic. Please find as many items as possible from the digital library as you can.
LOC Digital Collections		Identify a work of art by Josef Albers focusing on geometric abstraction in the 1930s. Find out the material type and the name of the art gallery that houses it.	Find images or objects /artifacts related to Apollo that were created in the 4th century in Greece. Make sure each item either represents one distinct type of artwork or one distinct aspect of this search topic. Please find as many items as possible.
Mertz		Identify a flower that is the basis for one of the most expensive raw materials for perfume manufacture during the 1940s. What tree's flowers may serve as an alternative to this flower for creating perfume during the 1940s?	Find items about roses bloom in spring and how to take care them using as many sources from the digital library as you can. Make sure each item represents one distinct format or one distinct aspect of this search topic. Please find as many items as possible.

Figure 1. Types of tasks

collected, this study focused on the application of the open coding technique in order to conduct qualitative analysis to understand the nature of coping tactics and their associated help-seeking situations.

3.1. Sampling

Sixty-four BVI participants were recruited through our partner BVI organizations, in particular, the National Federation of the Blind (NFB). Participants received the informed consent form prior to joining the study. Among the 64 participants, thirty-two participated in the study onsite while the other half completed the study offsite via diaries. Table 1 presents the demographic data of the participants. The table shows that the study sample represents participants with diverse backgrounds and IR skills. For Frequency of using the Internet, a 7-point Likert scale was used, with 1 indicating Never Used and 7 indicating Used All the Time.

For the onsite group, 32 participants joined the study in person and performed three search tasks using DLs. Among them, 24 participants were met at the NFB convention, where they were invited to join the study in the hotel rooms. Another eight participants came to our usability lab to complete their tasks. The protocols and procedures were consistently followed for the onsite study. For the offsite group, 32 participants completed the tasks on their own time while completing diaries. The reason that two separate groups of participants were recruited is that the study attempted to involve participants across the United States. Eight of the onsite participants were from the Midwest, and most of the onsite participants at the NFB conference were from the east coast. The diary participants were from all over the US. The diary also allowed researchers to use different data collection methods and let participants to use different screen reader software, enabling researchers to identify issues beyond a controlled lab environment.

3.2. Data collection methods

Multiple data collection methods, including pre-questionnaires, think-aloud protocols, transaction logs, and diaries, were employed in the study. In the pre-questionnaires, participants provided information regarding their demographic information, Internet experience, levels of subject knowledge, search skills/knowledge, system knowledge, and assistive technology use.

Five DLs (Artstor Digital Library, Digital Public Library of America [DPLA], HathiTrust Digital Library, Library of Congress [LOC] Digital Collections, and the LuEsther T. Mertz Library) were chosen for the study. To be selected, a DL must include a wide variety of content and media formats in which BVI users might be interested. Effort was made to choose a diverse set of DLs for the study. While LOC Digital Collections is a stand-alone DL with multiple digital collections, Digital Public Library of America and HathiTrust Digital Library represent federated DLs. Artstor Digital Library mainly consists of art images, and the LuEsther T. Mertz Library focuses on botanical and horticultural articles. Most importantly, none of the participants had used the selected DLs prior to this study.

Every participant worked on three tasks in LOC Digital Collections. For the rest of the four DLs, sixteen participants (eight from the onsite group and eight from the diary group) were randomly assigned to one of the DLs and instructed to complete three search tasks in each DL. To identify diverse types of interactions, each participant had to perform three tasks: an orientation task, a specific information search task, and an exploratory search task. In the specific information search, a participant looks for precise data or facts. In the exploratory search, a participant looks for items with common characteristics. Figure 1 presents all the tasks for the five DLs. The same tasks were assigned to both onsite and offsite groups. These tasks (orientation task, 10 minutes; specific search task, 15 minutes; and exploratory search task, 15 minutes) were created to simulate real-life search tasks that BVI users are likely to perform, and they help examine different types of help-seeking situations that BVI users experience.

For the onsite group, when performing these tasks, participants were asked to think aloud during their interactions with LOC Digital Collections and one other assigned DL. Think-aloud is one of the most effective data collection methods that captures not only how participants act but also their thoughts during their interactions with IR systems (Charters, 2003; Macias, Lee, & Cunningham, 2018). Previous research has identified several problems of using think-aloud for BVI users: infeasibility of listening to screen readers and speaking concurrently, lack of comments provided, interruption of task performance, and cognitive overload (Borsci & Federici, 2009; Chandrashekar, Stockman, Fels, & Benedyk, 2006). To avoid potential problems, we provided participants an opportunity to practice think-aloud during the orientation period. Offering participants the opportunity to practice think-aloud can reduce the interference factor. Previous research, including the authors' own work, demonstrates that BVI participants can talk about their experience and listen to screen readers simultaneously (Stefano, Borsci, & Stammera, 2010; Xie, Babu, Lee, Castillo, et al., 2020; Xie, Babu, Lee, Wang, & Lee, 2021). In addition, we also employed the diary data collection method, which does not require participants to think aloud to record their thoughts behind their coping tactics. Laptops with JAWS Screen Reader and Morae software were used for this study. JAWS is the most popular Screen Reader in the BVI community, and Morae is a usability and accessibility testing software that captures participant verbalization, screenshots, and transaction logs. Think-aloud protocols and transaction logs recorded participants' behaviors and their thoughts behind these behaviors, including the help-seeking situations they encountered and the coping tactics they applied during the search process.

For the offsite group, participants received instructions via email with a diary file. The diary file consisted of an instruction sheet for the diary, examples of diaries, links to LOC Digital Collections and another assigned DL, as well as explanations of the tasks to be completed. The participants were asked to perform the three tasks and complete the diaries in a location where they felt comfortable. For each diary, participants were instructed to provide the following information: date, type of browser, type of screen reader, amount of time for the task, results for the task, problems encountered, factors related to the problem, features and human help used to overcome the problem, and the eventual outcome. If the participant did not provide complete information, or if there was a mistake, a researcher would follow up with the participant upon receipt of the diary.

3.3. Data analysis

This study's unit of analysis is each coping tactic and the associated top five help-seeking situations that drive participants to apply these tactics. First, each transcript and diary were manually analyzed, and text related to coping tactics and associated help-seeking situations were highlighted based on the definitions presented in the Introduction. Each situation was marked at the point where the participant verbally communicated or recorded a need for help or expressed confusion in response to problems with a DL and its corresponding features. For each coping tactic, participants' actions, goals, and corresponding situations were analyzed. Second, each coping tactic and associated help-seeking situation were examined with tentative labels. Third, coping tactics and help-seeking situations were compared and conceptualized; similar coping tactics and help-seeking situations were assigned the same labels, respectively. Examples of types of tactics and help-seeking situations are presented in the Results, in which coping tactics are bolded and italicized while help-seeking situations are underlined.

Qualitative data collected from think-aloud protocols and transaction logs from the onsite group and diaries from the offsite group were examined for each of the research questions. The open coding technique, which is the process of breaking down, examining, comparing, conceptualizing, and categorizing unstructured textual transcripts (Strauss & Corbin, 1990) was utilized. Figures 2 and 3 present the coding scheme of the top five help-seeking situations and 20 types of coping tactics. In the coding schemes, situations and coping tactics are organized alphabetically, and definitions of each situation and coping tactic are provided. To avoid repetition, examples of situations and coping tactics are reported in the Results.

Five coders participated in the coding process. Two independent coders analyzed coping tactics and situations. According to Holsti's (1969) formula, the inter-coder reliability of situations and coping tactics are 0.92 and 0.923, respectively. Any disagreement between the two coders was further discussed with the research team until an agreement was made. Descriptive data analysis was also performed to determine the frequency of the types of situations encountered by BVI participants and the tactics they applied in their interaction process with the selected DLs.

4. Results

This study's findings focus on 1) the types of coping tactics that participants applied to deal with their help-seeking situations in their process of completing the three tasks; and 2) the specific types of coping tactics that participants employed to solve each of the top five situations.

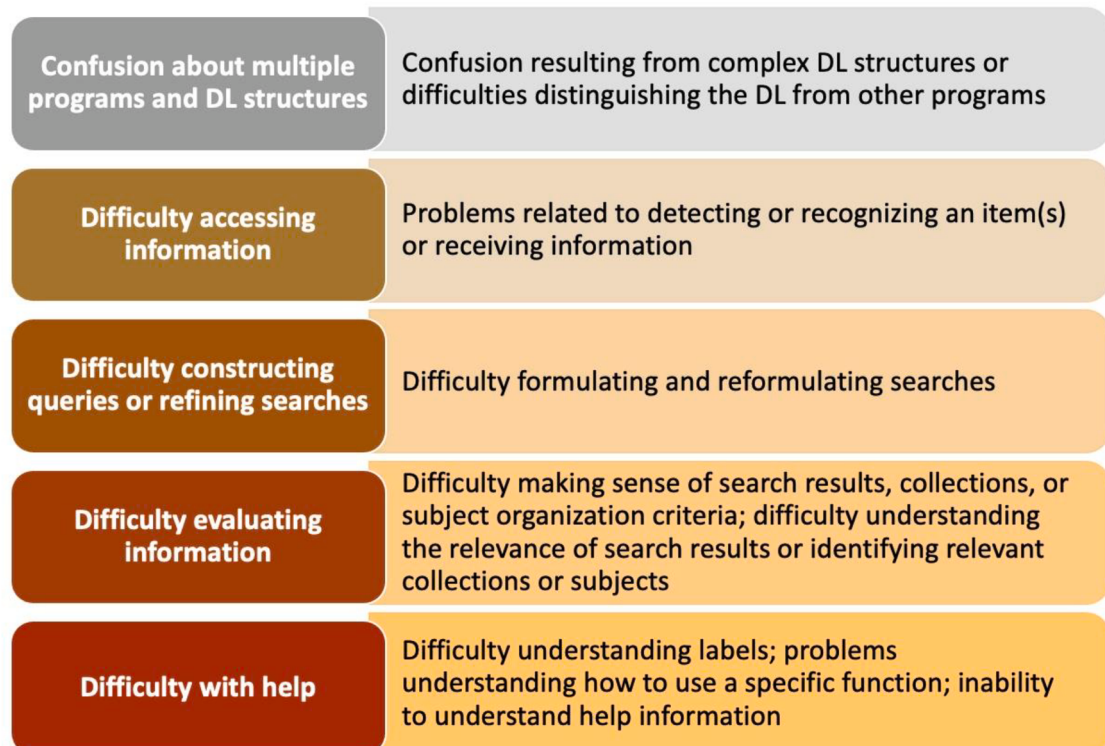


Figure 2. Types of help-seeking situations

Acronym	Coping tactics	Definitions
CCL	Checking current location	Verify user's current location within a DL by locating to the top of a page or using H function to check whether users are in a right section or right content
CFR	Checking format of search results	Examine the content format of search result, including opening or navigating to individual results to distinguish between text and image items
CHP	Checking help pages	Try out available help, including the Help page, the Search Tip page, other help-oriented pages or Screen Find function, to seek guidance on effectively accessing and using a DL
CSF	Checking system feedback	Look for clues regarding DL state by listening to screen reader announcements or system sounds, and surveying adjoining content with navigation keys, to detect changes/updates in a DL
DLP	Decoding the location of a DL page	Access an address bar and/or reading through a DL page to understand the location within a DL to identify users' locations
DRI	Disregarding redundant information	Ignore seemingly repetitious or unnecessary DL content by arrowing past duplicate links or skipping over meaningless headings to get to more relevant or meaningful information
DSC	Delving into subcategories	Go into a specific topic by going into subcategories of a topic or a collection in a DL to locate wanted information
EAA	Exploring an accessible alternative	Access alternative items due to a roadblock of an initial attempt by seeking different items from previous attempt to achieve a similar or related information
EAN	Employing alternative non-visual interaction approach	Activate advanced screen reader functions, using shortcuts or switching screen reader to make sense of problems encountered during an interaction with a DL
ENF	Employing non-DL navigation features	Use navigation functions or navigation shortcuts not provided by a DL to navigate to a specific section or a content or to reorient themselves in a DL
EPS	Exploring DL page structure	Scan major components of a DL page by arrowing down, navigating through link lists, skipping to headings or regions to locate relevant sections to understand the page structure
ERF	Exploring relevant features	Try seemingly useful DL features or screen reader functions to figure out how to utilize the feature or access desired information relevant to problems at hand and utilize a DL more efficiently
GCC	Gleaning contextual cues	Browse areas around inaccessible item or incomprehensible content/control in search of clues, including adjacent text, document, or section title, to interpret what this item/content/control
ICI	Inspecting content of a retrieved item	Carefully read a retrieved item, by each line or section title on the DL page as well as text of a collection item, to check every piece of relevant information or get a general idea about a retrieved item
NBP	Narrowing down, broadening up, or paralleling search	Modify searches by trying different search terms, using advance search features, or using search limiters to generate relevant search results
RRP	Refreshing or re-starting a page	Open a new browser, start from the beginning, or refresh the page to be reoriented or to be able to see a change in a page
SFK	Searching for keywords	Search for a related word or phrase within a page to locate desired features/sections or to evaluate the relevance of the retrieved results
SHH	Seeking human help	Ask assistance from a sighted person or another visually impaired person to receive guidance or reassurance of unperceivable elements, items or pathways
SII	Skipping over inaccessible or incomprehensible information	Bypass problematic DL components, including unlabeled links, image items, or confusing text, to avoid accessibility or comprehensible issues in effective DL interaction
SRL	Scanning through result list	Look through presented search results by navigating or arrowing up or down a page to identify relevant items

Figure 3. Types of coping tactics

4.1. Types of coping tactics

BVI participants applied 20 types of coping tactics in their interactions with DLs. Table 2 presents the frequency of the types of coping tactics. Based on the frequency data, the coping tactics are grouped into three groups. The first group is the highest frequency coping tactic group that contains coping tactics that were each applied more than 20 times. The top six coping tactics in this group are: Narrowing down, broadening up, or paralleling search (NBP); Exploring relevant features (ERF); Searching for keywords (SFK); Exploring DL page structure (EPS); Gleaning contextual cues (GCC); and Exploring an accessible alternative (EAA). NBP was applied 89 times among these tactics, ranking as the most frequently applied tactic by BVI participants. Interestingly, the second most frequently applied tactic, ERF, was applied 45 times, which is just over half the frequency count of NBP. The second group includes coping tactics that were applied more than 10 times but not more than 20. A total of eight coping tactics fall into this group: Refreshing or re-starting a page (RRP); Inspecting content of a retrieved item (ICI); Seeking human help (SHH); Checking help pages (CHP); Skipping over inaccessible or incomprehensible information (SII); Employing non-DL navigation features (ENF); Checking system feedback (CSF); and Scanning through result list (SRL). The number of applications of tactics in this group ranged from 10 to 16. The last group includes the least frequently applied tactics by BVI participants to cope with their difficulties, each of which was used less than 10 times. A total of six coping tactics are in this group: Employing alternative non-visual interaction approach (EAN); Delving into subcategories (DSC); Checking format of search results (CFR); Decoding the location of a DL page (DLP); Disregarding redundant information (DRI); and Checking current location (CCL).

4.2. Types of coping tactics corresponding to help-seeking situations

The results related to the relationship between coping tactics and the top five help-seeking situations are illustrated in Figure 4. The top five situations based on the frequency data are: Difficulty evaluating information (71), Difficulty accessing information (69), Difficulty constructing queries or refining searches (64), Difficulty with help (57), and Confusion about multiple programs and DL structures (42). Eleven types of tactics were used in three or more situations: SFK, SHH, NBP, ERF, GCC, EAA, RRP, ICI, CHP, SII, and SRL. Among these 11 types of tactics, SFK and SHH were employed in all top five types of situations. NBP, ERF, and CHP were employed in four situations. GCC, EAA, RRP, ICI, and SRL were each utilized in three different types of situations. In addition, the bold lines in Figure 4 represent the high-frequency tactics that are applied more than 20 times.

This section presents each situation along with the associated coping tactics and example quotes from the data. In the quotes, the situations are underlined, and the coping tactics are bolded and italicized. Each participant number is the combination of “Participant group,” “Name of the DL,” “Assigned participant number,” and “Task type/Task number.” For participant groups, Onsite participants are coded O, and Offsite participants are coded F. The first letter of the DL is used for the name of the DL. The Task Type is either coded as O for Orientation Task or T for Search Task. For example, in the subject number F-M-M7-T2, F, M, M7, and T2 stand for Offsite, Mertz Library, Assigned participant number, and Search task 2, respectively.

4.2.1. Difficulty Evaluating Information

Difficulty Evaluating Information is associated with 11 types of tactics: NBP, ICI, SFK, GCC, CFR, DSC, SHH, DRI, CHP, ERF, and EAA. The tactic NBP (31) ranked first based on frequency data associated with Difficulty Evaluating Information. When faced with this situation, the participants attempted to refine their search queries or search limiters to alter their current situation. For example, it was

Table 2
Frequency of types of coping tactics

	Types of coping tactics	Frequency
1	Narrowing down, broadening up, or paralleling search (NBP)	89
2	Exploring relevant features (ERF)	45
3	Searching for keywords (SFK)	31
4	Exploring DL page structure (EPS)	28
5	Gleaning contextual cues (GCC)	21
6	Exploring an accessible alternative (EAA)	20
7	Refreshing or re-starting a page (RRP)	16
8	Inspecting content of a retrieved item (ICI)	16
9	Seeking human help (SHH)	16
10	Checking help pages (CHP)	15
11	Skipping over inaccessible or incomprehensible information (SII)	14
12	Employing non-DL navigation features (ENF)	11
13	Checking system feedback (CSF)	10
14	Scanning through result list (SRL)	10
15	Employing alternative non-visual interaction approach (EAN)	9
16	Delving into subcategories (DSC)	6
17	Checking format of search results (CFR)	3
18	Decoding the location of a DL page (DLP)	3
19	Disregarding redundant information (DRI)	3
20	Checking current location (CCL)	2
	Total	368

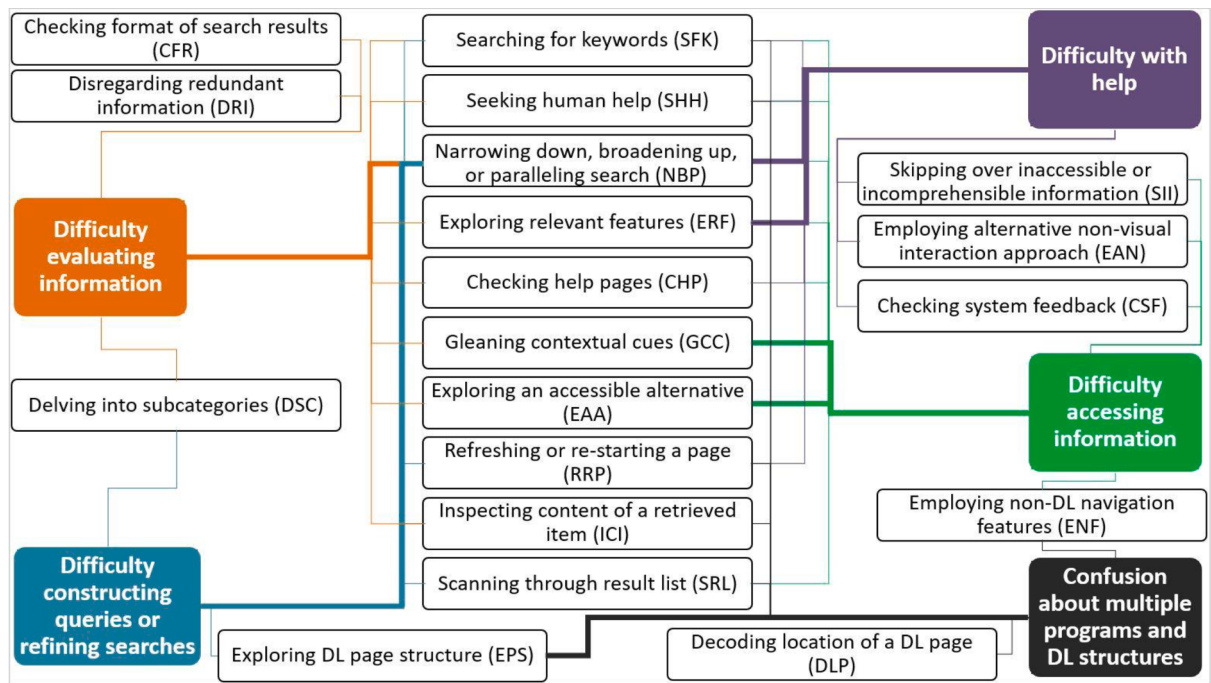


Figure 4. Types of coping tactics corresponding to different types of help-seeking situations

difficult for FMM7 to make sense of the results because the DL did not offer the snippet that contained the context related to her search query as other Web search engines for her to quickly make relevance judgment of each item. She had to listen to the whole article to assess each item. For that reason, her coping tactic was to narrow down her search as an alternative approach by adding another phrase. Providing additional context led to a new set of reduced search results that linked the two search terms together. As a result, she hoped she would be able to make effective relevance judgement for search results to complete the task.

The results provided no information as to why the item matched the search string and what the context of the match was. I received many results for Journal of the New York Botanical Garden when searching for “rose” and it would have taken a very long time to parse through each return and look for instances and context. When I tried adding “spring bloom” to my search string, I often found... When searching a web search using Google or Bing, for examples, not only is a link returned, but also some information as to the context from which the search string was found. (F-M-M7-T2)

4.2.2. Difficulty Accessing Information

To cope with the difficulty accessing information, the participants used 12 types of tactics: EAA, GCC, ERF, NBP, CHP, EAN, SII, SFK, SHH, ENF, CSF, and SRL. Among these tactics, the participants often applied EAA (15) and GCC (14). EAA is the most frequently used tactic when confronted with difficulty accessing the desired information. For example, FHH8 sought an alternative page to access related information in the table of contents when faced with inaccessible documents.

Plain text version of document page does not contain text transcript... On search results page, open the full view of the War Blindness... Operated “plain text” button/link. Resulting page states that there is no OCR transcript for the document... Used the next page links and table of content to reach pages that have been OCRed. (F-H-H8-T1)

GCC is the tactic in which participants browsed around the adjacent area of an inaccessible item or content to identify clues to figure out the content of an item. FLA6 encountered a problem in accessing photos due to missing image captions about the photos presented in the DL. The lack of alternative text caused her to browse around the DL page adjacent to the photos that could allow her to infer their content.

Pictures without captions... Images need description to be fully accessible... this time the section description on the web page included enough information about the content of the image to determine it was relevant to my search. (F-L-A6 -T2)

4.2.3. Difficulty Constructing queries or Refining Searches

Difficulty constructing queries or refining searches was associated with nine types of tactics: NBP, SHH, CHP, SRL, ICI, SFK, EPS, RRP, and DSC. Similar to Difficulty evaluating information, NBP (40) was also the most frequently applied in Difficulty constructing queries or refining searches situation. In this situation, the users were faced with difficulty generating relevant search results to solve the assigned tasks, which triggered users to modify their searches to seek more relevant search results. For example, OLM5 had difficulty obtaining any results from the search, which led her to broaden up the initial search by simplifying the search terms.

<NO results found for Rosa Parks NAACP> And there is no results. K so...I'm surprised that there's no results. *laughs* um but I'm gonna see what the suggestions are...*Ok so I'm gonna take out the NAACP and just search for Rosa Parks.* (O-L-M5-T1)

4.2.4. Difficulty with help

When encountering Difficulty with help situations, participants utilized a total of 11 tactics: ERF, NBP, SII, CHP, CSF, EAN, EAA, SFK, SHH, GCC, and RRP. ERF (21) was the most frequently applied strategy during Difficulty with help. The participants attempted to solve this situation by trying seemingly useful DL features or screen reader functions to find out how to use features or to access related information associated with their situation. FAA7 expressed his difficulty using the search feature and needed to understand how to utilize the search result filter. He tried different methods to explore the search filter feature by browsing through a list of available filter options.

Search results filters should be presented in a simpler format for assistive technology users, such as a combo box. Each of the filters is identified as a button that can be activated. Each search filter criterion to narrow the list of results is tagged as a button. It makes setting filters much harder to perform with assistive technology programs. I used the arrow keys and F key to browse through the various filters. (F-A-A7-T2)

NBP (12) was also used often in dealing with Difficulty with help. FAA3 expressed difficulty understanding how to use the Advanced Search feature in the DL. This confusion caused her to disregard the Advanced Search feature. Instead, she decided to create her own advanced search by typing in additional keywords as an alternative approach to accomplish her task.

When performing an advanced search and attempting to select a time range, I was unable to use the spin box to select a date... While in the form field with JAWS set to forms mode, I could arrow once or twice to select the next or previous year or two before I would get kicked out of the field...I simply typed my desired year into the textbox and fortunately this worked. (F-A-A3-T1)

4.2.5. Confusion about multiple programs and DL structures

Confusion about multiple programs and DL structures was associated with nine types of tactics: EPS, ERF, SFK, RRP, DLP, SRL, ICI, ENF, and SHH. Confusion about multiple programs and DL structures is related to a disoriented state in understanding the structure of a DL, result layout, or presentation of available categories. EPS (18) was applied most frequently in this situation to make sense of the page structure. OLM1 was unfamiliar with the structure of the results page of the DL. In order to solve this situation, she navigated through link lists to understand the presented page structure.

{She lands at the search results page.} So, I'm gonna do um <links list>...So I was putting the links uh in an order so I did insert f7 and that's supposed to put it to the links so I could see what's there. I guess that happens if you're not familiar with a particular web page if you've never I don't know if I've ever really just gone to the Library of Congress. Probably not...So you have to if you don't have any initial familiar knowledge with the page how the page is laid out um you know then you kinda just have to guess explore for yourself. (O-L-M1-O)

4.2.6. Coping tactics associated with only one situation

Within these five types of help-seeking situations, three coping tactics were uniquely applied to a specific help-seeking situation: CFR, DRI, and DLP. CFR was applied to investigate presented results and distinguish them as text or image items when facing Difficulty evaluating information situations. FLA7 illustrated the difficulty of identifying the types of retrieved content when looking through search results. He clicked individual results to determine the content type to overcome this difficulty.

Search results do not alert assistive technology users to the type of content that will be displayed. It is not easy and clearly identified to assistive technology users if search results will be text content, images of a subject or historical event etc....Pages had to be opened and reviewed to see if text content was displayed or if it was an image depicting an event. (F-L-A7-T1)

Some BVI participants relied on DRI to move away from seemingly repetitious or unnecessary content in Difficulty evaluating information situations. For example, FLD6 was faced with confusion in perceiving DL content clearly due to redundant headers. She had to arrow through duplicate links to understand the presented links on the page.

Digital collections appear to be listed twice, links that is. The screen reader reads them twice...Just basically keep arrowing through understanding the problem exists. Also used the INSERT+F7 command to bring up the links list once in the area of the specific links list; even though the links do show up twice even in the links list... The outcome is that I can still get to the links but they appear twice and might actually confuse the end user. The links may also be to other things on the web site, but they are perceived as mislabeled. (F-L-D6-E)

DLP was applied to identify current locations when participants are faced with Confusion about multiple programs and DL structures. To illustrate, FDD3 was faced with difficulty recognizing his location when using a DL. He applied both actions, including accessing the address bar and reading through the page that was associated with the tactic to understand his location.

Knowing where you are in the library...Getting information as to your placement in the library and knowing when you navigate away from the digital library to an external site...Accessing the address bar and reading through the web page using standard navigating commands. (F-D-D3-T2)

5. Discussion

5.1. Theoretical implications

The theoretical significance of the study can be discussed as it relates to prior research in non-DL environments and our own work in the DL context. While previous research has identified a variety of coping tactics that BVI users must apply in order to resolve their problems in non-DL web environments, none of them has examined the coping tactics that BVI users employ in a DL. Moreover, the literature has not clarified the relevance of a coping tactic to diverse problems and vice versa. The authors of this study have conducted a series of studies on blind users' help-seeking situations in diverse DLs, including understanding the help-seeking situations of blind users (Xie et al., 2015), identifying factors associated with blind users' helping-seeking situations (Xie, Babu, Castillo, & Han, 2018), creating design guidelines based on BVI users' helping-seeking situations (Xie, Babu, Castillo, Lee, & You, 2018) and implementing help features to reduce five critical help-seeking situations that BVI users faced (Xie, Babu, Lee, Castillo, et al., 2020). However, this part of the literature has only focused on the help-seeking situations that BVI users encounter; it has not further explored their behaviors when reacting to these situations in the DL context. This study extends the authors' prior work to further identify the coping tactics that BVI users undertake to deal with their help-seeking situations in the DL environment.

In response to the top five help-seeking situations, 64 BVI participants applied 19 types of coping tactics. These coping tactics can be further associated with previous research on IR (non-DL) contexts and new tactics in the DL context (see Figure 5), and frequency of each type of coping tactic is presented in red. These tactics are organized by frequency. The results of this study not only reinforce some of the findings of previous research but also highlight some unique discoveries in relation to the relationships between help-seeking situations and coping tactics in the DL environment.

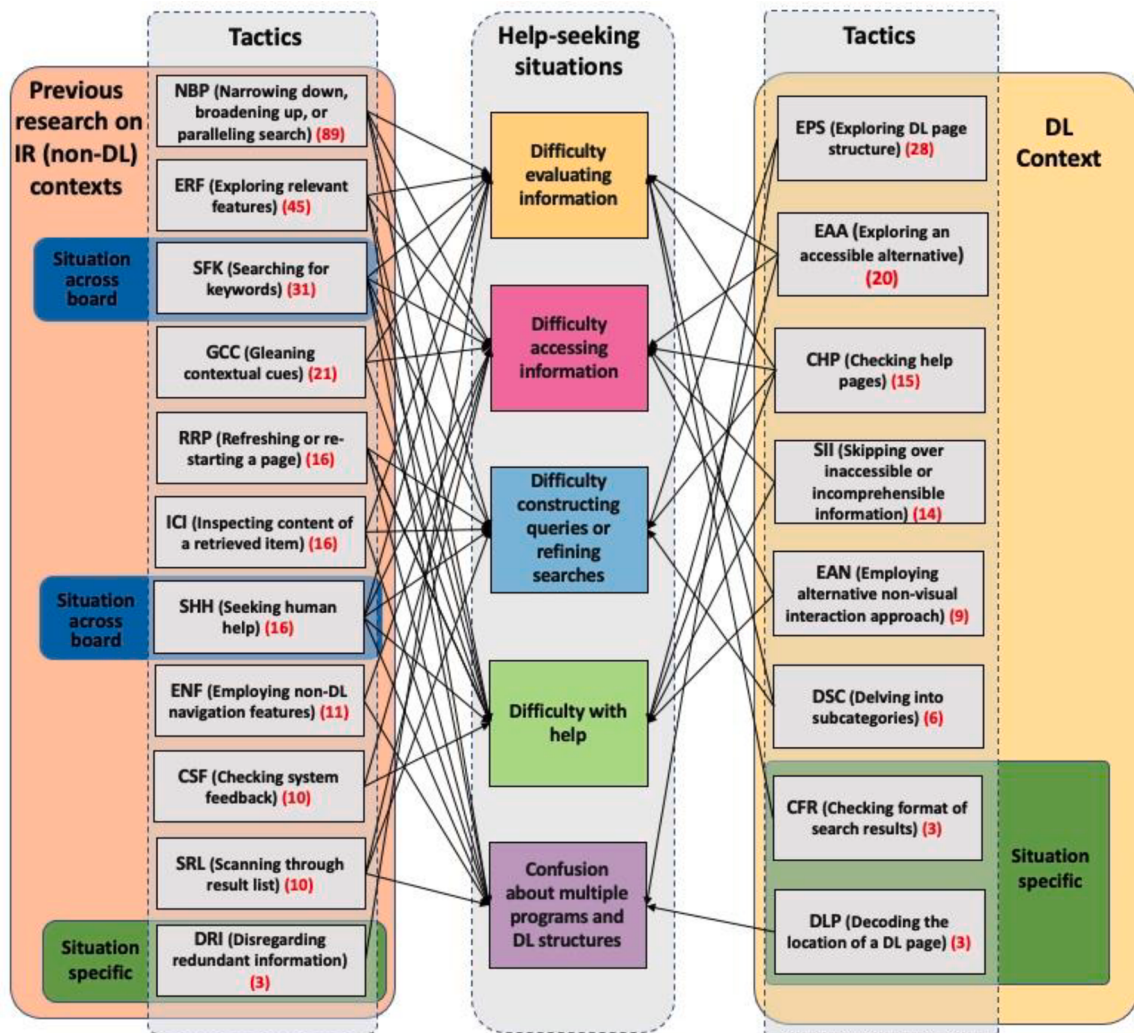


Figure 5. Types of coping tactics applied in DL and non-DL IR contexts

On the one hand, BVI participants applied coping tactics that they were familiar with in non-DL IR contexts to the DL environments. SFK and SHH were the two coping tactics most frequently employed to address all of the top five situations in the DL environment. Interestingly, both of these tactics have been identified in previous studies. Instead of going through the whole page, SFK is the key coping tactic used when encountering problems finding relevant information on a web page (Borodin et al., 2010; Lunn et al., 2011). Also, in web page environments, asking someone for help (SHH) was a popular coping tactic when BVI users encounter accessibility and usability problems (Lazar et al., 2007; Lunn et al., 2011; Vigo & Harper, 2013, 2014). At the same time, NBP and ERF were the coping tactics applied in four of the five top situations. These tactics are also not new for BVI users. Vigo and Harper (2013, 2014) discovered that blind users frequently used NBP and ERF as alternative approaches when they did not know how to proceed. In the DL context, NBP was one of the most applied tactics to deal with not only Difficulty constructing queries or refining searches but also Difficulty accessing information, Difficulty evaluating information, and Difficulty with help. Interestingly, when BVI users encountered problems evaluating information, they used NBP to narrow or broaden their search results. When they had problems using help features (e.g., advanced features), they gave up using the feature and tried to manually recreate the advanced feature by narrowing down through the queries. ERF is the second most frequently applied coping tactic used by participants in interacting with DLs in all situations except Difficulty constructing queries or refining searches. In both non-DL and DL environments, users used ERF to experiment with unfamiliar features. Three additional tactics (GCC, RRP, and ICI) correspond to three situations. While GCC was applied by BVI users in non-IR environments to comprehend inaccessible content or controls (Borodin et al., 2010), in the DL context, users were able to better infer the content of an inaccessible item, thanks to additional context clues such as metadata, section description, etc. Comparatively, RRP was an easy tactic to use when they encountered a problem in a non-DL environment (Lunn et al., 2011; Vigo & Harper, 2013), and it was applied especially when BVI users were confused by the multiple programs. Not surprisingly, ICI is employed by BVI users in all web environments, including DLs, to find the information contained in a page.

On the other hand, this study presents the unique coping tactics that BVI users have not previously used in non-DL IR environments. A combination of structural complexity, use of multimedia formats, non-standardized layout, as well as sight-centered designs make DLs quite intimidating for a screen reader user (Xie, Babu, Castillo, & Han, 2018). The complexity and dynamic nature of DLs creates more help-seeking situations and therefore requires associated coping tactics from BVI users. Unlike web search engines with simple interfaces, DLs normally have a more complicated browsing structure to allow users to access an item through multiple access points. BVI users' linear way of going through the DL structure forces them to create coping tactics to deal with the unique design of DLs. First, BVI participants had to apply EPS to skim the main components of a DL page and understand the DL structure. Second, when they were unable to apply their mental models and previous experience in interacting with the Web, BVI participants had to use CHP to consult the help pages of a DL to further learn how to effectively use it. Third, they attempted to devise their own ways (EAN) to navigate a DL by relying on screen reader software rather than using a DL's navigation features. Fourth, they employed DSC to further scan the subcategories of a topic or collection of a DL to find relevant information. Inaccessible items and incomprehensible content or controls posed a challenge for BVI users in their interactions with DLs. BVI participants took several alternative approaches to solve their problems. First, they employed EAA to access alternative items to find similar information. Second, they applied SII to bypass the problematic DL components or visual content.

In contrast to SFK and SHH that were applied across situations, there were three coping tactics (CFR, DLP, and DRI) that were each only used in one situation. CFR and DRI were only associated with Difficulty evaluating information, and DLP only applied to Confusion about multiple programs and DL structures.

5.2. Practical implications

The findings of this study generate valuable implications for the design of DLs to support BVI users. For the coping tactics that BVI users adopted from non-DL environments into the DL context, three types of design suggestions are proposed. First, DL design needs to support BVI users and directly solve these situations so that BVI users will not need to apply these alternative coping tactics. For example, NBP was used as an alternative approach to deal with Difficulty evaluating information because this tactic was most familiar to BVI users. As DLs do not offer snippets of search results, BVI participants had to apply NBP as an alternative approach to reduce the search results and look for clues themselves. Previous research in non-DL environments suggests including search previews of each document, overviews/summaries of search results, and grouping research results as clusters (Al-Thani & Stockman, 2018; Aqle, Al-Thani & Jaoua, 2020; Sahib et al., 2012). These recommendations can be brought to the DL environment to assist BVI users to effectively evaluate search results. Second, DL design needs to offer more options that facilitate the use of DLs by BVI users. GCC is an indirect approach for BVI users to access an otherwise inaccessible item. In addition to trying to make every item accessible, DLs need to provide more context cues for BVI users, such as section overviews, related resources, and description elements for each item. Third, DL design needs to create or enhance DL features to incorporate some of the coping tactics into system design. Seeking human help is one of the frequently applied tactics in non-DL environments because there is not much help support from the IR systems. In the DL context, human help can become one option for online help in the form of contacting librarians synchronously or asynchronously. In addition, the design of help mechanism needs to take into consideration how BVI users seek help from human helpers. Offering a multimodal representation of awareness information, as recommended by Al-Thani and Stockman (2018), such as the audio alert of a "new chat message," can encourage BVI users to actively interact with other users as well as librarians in the DL environment.

For the unique coping tactics generated from BVI users' interaction with DLs, the authors focus on the specific design implications that support these tactics by reducing the help-seeking situations in the following areas: 1) Improving the design of DLs to effectively guide users when exploring DL structures. Here are the design suggestions to support EPS: (a) page content organized into topical sections; (b) accessible section headings with meaningful section titles; (c) meaningful labels for links, form fields, and other active

elements; and (d) logically grouped active elements and features. 2) Offering accessible alternatives to inaccessible content. Here are the design suggestions to support EAA: (a) transcripts for scanned image items; and (b) descriptive audio for video items (text or audio description of pictures/broadsides/graphics). 3) Helping BVI users to adapt to DLs by creating better DL help mechanism to support receiving guidance on effective DL access and use. Here are the design suggestions to support CHP: (a) compulsory DL user orientation for first-time visitors; (b) prominently located links to Help, Search Tips, and Screen Reader Tips sections on DL pages; and (c) context-sensitive help tips at known accessibility pain points (e.g., visual items, browse categories). 4) Facilitating BVI users' ability to bypass inaccessible or incomprehensible content. Here are the design suggestions to support SII: (a) skip-over-image feature; (b) shortcut to relevant content beyond auxiliary or ambiguous information; (c) meaningfully-labeled unique links; and (d) accessible section headers with meaningful titles. 5) Making the DL design to support utilizing advanced screen reader function. Here are the design suggestions to support EAN: (a) compatibility with all screen reader software; and (b) support for keyboard shortcuts for common operations; and 6) Assisting BVI users in effectively exploring subcategories. Here are the design suggestions to support DSC: (a) logically categorized topics and collections; (b) meaningfully-labeled subcategories clarifying the relationship with the associated topic/collection; (c) supplementary text for subcategory links describing topics or collections; and (d) prominently located Return to Home button on individual subcategory pages.

6. Conclusion

This study was undertaken to discover how BVI users cope with problems that arise when interacting with a DL using screen reader software. It represents the first attempt to systematically investigate the coping tactics employed by this vulnerable group of DL users in various help-seeking situations. Focusing on the five most frequently encountered situations by 64 BVI participants, this study identified 19 unique coping tactics in response to one or more of these five situations. The tactics ranged from common tactics, like Searching for keywords and Seeking human help that were utilized across all five situations, to specialized tactics, like Decoding the location of a DL page that was uniquely applied in response to Confusion about multiple programs/structures. While 11 out of the 19 tactics find resonance in existing literature, the remaining eight tactics are entirely novel. Together, these coping tactics and associated help-seeking situations offer valuable clues regarding a BVI user's mental model for retrieving information from a DL.

This study makes both theoretical and practical contributions to the field of library and information science. Its theoretical contribution is a broad understanding of how BVI users react (both tactically and strategically) to the roadblocks and challenges presented by the DL. Practically, it contributes design implications on how to support the coping tactics that screen reader users employ when faced with accessibility or usability problems in DL interactions. This study serves as the foundational research to develop the know-how for offering appropriate and useful help features to make DLs and other digital information resources inclusive for patrons who rely on assistive technologies to consume information.

There are several limitations of this study. The first limitation is its sample size. The 64 participants were divided equally between the onsite think-aloud and offsite diary groups and further sub-divided into four DL groups. While this is fine for an exploratory study, the data is not large enough for statistical analysis. Future research should conduct a wider-scale investigation involving a larger sample using multiple DLs for better comparison and statistical generalizability. The second limitation is its restricted scope regarding coping tactics. While it focuses on examining which tactic a participant employs in response to a help-seeking situation, it does not further analyze the efficacy of this tactic in overcoming the problem being faced. This type of knowledge is useful in developing interventions in the form of help tips and user instruction. Future research should go deeper into the process to identify which types of coping tactics better help BVI users in successfully negotiating situations.

Future research should also go beyond computer-mediated DL use. An increasing number of BVI individuals are moving away from desktops and laptops to smartphones and tablets as their preferred computing devices. These smart devices afford novel gesture-based interaction with DLs, as well as non-linearized information processing for BVI users. New and emergent technologies could afford new types of coping tactics that merit systematic investigation in future research.

6.1. CRediT authorship contribution statement

Iris Xie: Conceptualization, Methodology, Formal analysis, Investigation, Supervision, Project administration, Funding acquisition, Writing –Original Draft, Writing - review & editing. **Rakesh Babu:** Methodology, Formal analysis, Investigation, Funding acquisition, writing – Original Draft. **Tae Hee Lee:** Data curation, Visualization, Writing – Original Draft. **Shengang Wang:** Formal analysis, Writing – Original Draft. **Hyun Seung Lee:** Formal analysis, Writing – Original Draft.

Declaration-Of-Competing-Interests

None

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