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Jiebei Luo
Skidmore College, jluo@skidmore.edu

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Habitual wayfinding in academic libraries: Evidence from a liberal arts college

Jiebei Luo

Skidmore College, 815 N. Broadway, Saratoga Springs, NY 12866, United States

ABSTRACT

Habitual wayfinding is a revised wayfinding model for academic libraries, where there is a high percentage of repeat users. Using the unique spatial characteristics of a specific academic library, this study explores the wayfinding patterns of repeat users and evaluates the impact of patrons' travel habits on their library space usage. The GIS tool ArcMap is employed to visualize library traffic and detect potential patterns of habitual wayfinding. The impact of habitual wayfinding behaviors on library space usage is analyzed. Findings suggest that travel habits formed through past frequent actions can lead to consistent navigation preferences toward certain function units and significant usage differences even within the same function unit in a library. In addition to proposing this modified wayfinding framework and studying its relevance in explaining library space usage patterns, this study also makes a methodological contribution through a novel approach of detecting potential traffic patterns by visualizing routing data and quantifying its details at the route segment level. The framework, methodology, and findings have important implications for understanding space use in academic libraries and can be valuable to libraries considering conducting space evaluation and space rearrangement projects.

1. Introduction

As more patrons use the library as a space, space studies are drawing more attention from both professionals and practitioners in the field of library and information science. With the aid of GIS tools and geospatial research methods, librarians are increasingly involved in studying how library space is being used and how the space can be modified to better suit user needs. Specifically seeking to understand how patrons use library space, researchers have focused on wayfinding studies as one of the focal points within the domain library space studies.

2. Problem statement

Wayfinding in libraries, first discussed in the 1990s (Beck, 1996; Eaton, 1991), can be generally described as the process of a library user navigating the library space and making the travel plan (decision) to accomplish travel goals. Similar to wayfinding literature in other constructed environments (Dogu & Erkip, 2000; Jansen-Osmann & Wiedenbauer, 2004; Lawton, 1996; O'Neill, 1991; Soh & Smith-Jackson, 2004), studies on the library wayfinding problem generally place emphasis on library users who need visual cues, especially signage assistance, in accomplishing their travel goals during the wayfinding process (Eaton, 1991; Li & Klippel, 2012; Mandel, 2010, 2013; Tatarka, Larsen, Olson, & Kress, 2006). Beck's (1996) summary of the architecture literature from the 1970s and later library literature concerning library space issues points out that signage systems are regarded as essential wayfinding elements in the context of general library space.

However, unlike the scenarios typically raised in previous library wayfinding studies, users of academic libraries typically use the library space on a regular (rather than occasional) basis for various activities. In other words, a high percentage of academic library users repeatedly travel the same route or choose among a limited number of routes in a familiar environment without using any visual assistance, and their travel patterns are thought to be different from those of travelers in the general wayfinding process (Passini, 1996). Thus, patrons' wayfinding patterns in academic libraries may not be captured by previous library wayfinding studies. This case study bridges that gap by exploring the potential wayfinding patterns in a typical academic library and drawing implications to a broader range of similar academic libraries. The findings have relevance for libraries planning new building projects or renovating existing spaces and seeking to offer an improved patron experience.

3. Literature review

Wayfinding refers to a person using his or her cognitive and decision making ability to find his or her way to accomplish specific travel goals in a natural or constructed environment (Passini, 1996). This process is modeled in Fig. 1, where cognitive ability refers to a person's ability to understand the surrounding spatial characteristics, cognitive mapping is the spatial representation of the environment in a person's mind formed by the interaction between cognitive ability and the

E-mail address: jluo@skidmore.edu.

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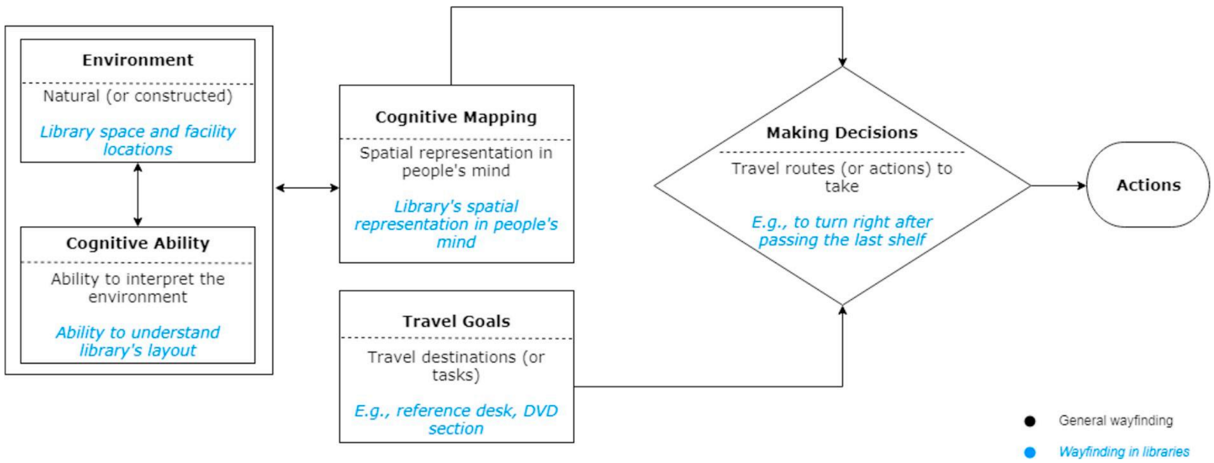

Fig. 1. Model of general wayfinding and wayfinding in libraries.

environment, and the travel decision is based on the input of cognitive mapping and the specific travel goal.

Accordingly, wayfinding in libraries refers to the process whereby a library user navigates the library space to reach his or her destination (Mandel, 2010). When a user enters the library space with a specific travel goal, such as going to the reference desk, the travel decision is made by the collaboration of the travel goal and cognitive mapping of the library space, which is formed by the interaction between the user's cognitive ability and the library's spatial characteristics.

The efficiency of the wayfinding process is mainly determined by a patron's cognitive level (generally distinguished by age) as well as a number of environmental factors, which mainly include spatial complexity, visibility and signage system design (Beck, 1996). Wayfinding studies in the library context have explored meeting patrons' wayfinding needs in a specific aspect, such as library signage design (Bosman & Rusinek, 1997; Mandel, 2013; Mandel & Johnston, 2016) or within a particular library user group, e.g., art library users (Carr, 2006) and public library users (Mandel, 2010, 2013).

A problem with most library wayfinding studies is that they tend to emphasize that the wayfinding decision is based on the interaction between the user's cognitive ability and available surrounding resources, especially visual assistance. In other words, the user needs to use his or her cognitive ability and available resources to accomplish the travel goal in the library space. However, in typical academic libraries, most students and faculty use the library space on a regular basis for various common activities, such as working on assignments, attending classes and meetings, printing, and socializing. This means that a high percentage of library users are familiar with the library environment, especially those frequently used areas. Therefore, the decision making process as defined in previous library wayfinding studies (Beck, 1996; Mandel, 2010) does not accurately describe the decision making process in wayfinding in many academic libraries. Also as Passini (1996) pointed out, decision making is only involved in the wayfinding process when people are travelling in unfamiliar environments. When patrons are navigating on familiar routes, their wayfinding simply requires decision execution, which consists of the travel goal, such as the reference desk and its corresponding behavior (e.g., turning right after passing the last book shelf). This process can be summarized and refined as the "perception-action feedback" model (Passini, 1996).

The influence of patrons' travel habits, conceptualized as the goal-directed type of automaticity in travelling (Aarts, Verplanken, & van Knippenberg, 1997), has never been investigated in the library wayfinding studies, especially not in academic library settings. Aarts and Dijksterhuis (2000) studied the influence of travel habits on travel mode and introduced the concept of automatic activation of goal-directed behaviors. Their findings on the relationship between travel habits and travel behaviors provides another angle from which to interpret patrons' wayfinding behaviors in academic libraries. Aarts and Dijksterhuis tested the association strength between the travel goal (e.g., making a trip to the university) and the action taken (e.g., taking a bike), and reached the conclusion that a travel mode formed by everyday habits can be automatically associated with travel goals and difficult to suppress. In other words, when the same action is performed many times in the past, its subsequent behavior becomes increasingly governed by an automatized cognitive process (Ouellette & Wood, 1998). Similarly, Aarts et al. (1997) pointed out that when travel habits are strong, factors involved in reasoned considerations (i.e., cognitive deliberations), such as travel distance, departure time, and weather conditions, are taken less by travelers when making their travel decisions.

4. Methodology

4.1. Habitual wayfinding model

The habitual wayfinding conceptual framework proposed in this study incorporates the viewpoints of general wayfinding in libraries (Beck, 1996), wayfinding in familiar environments (Passini, 1996) and Aarts and Dijksterhuis' (2000) automatic activation of goal-directed behaviors. The habitual wayfinding model posits that for a regular academic library user, when he or she is navigating the library space with a travel goal, the travel decision is made through the collaboration of on-site decision making (i.e., decision making in the general library wayfinding model) and automatized cognitive processing formed by travel habits. In the habitual wayfinding model, travel habits are thought to be the dominant factor influencing a user's travel plan. That is, the addition of travel habits changes the input composition of the decision making module. The model can be illustrated by a flow chart (Fig. 2).

Given the fact that frequent library users usually mingle with infrequent users in most academic libraries, it is empirically challenging to identify and study behaviors directed by travel habits. In order to collect the routing data relevant to the proposed habitual wayfinding model, a controlled space with particular spatial characteristics is needed to help inhibit wayfinding behaviors directed by deliberate cognitive thinking and determine navigation routes made by travel habits. The Lucy Scribner Library at Skidmore College provided the ideal spatial characteristics necessary for this case study design.

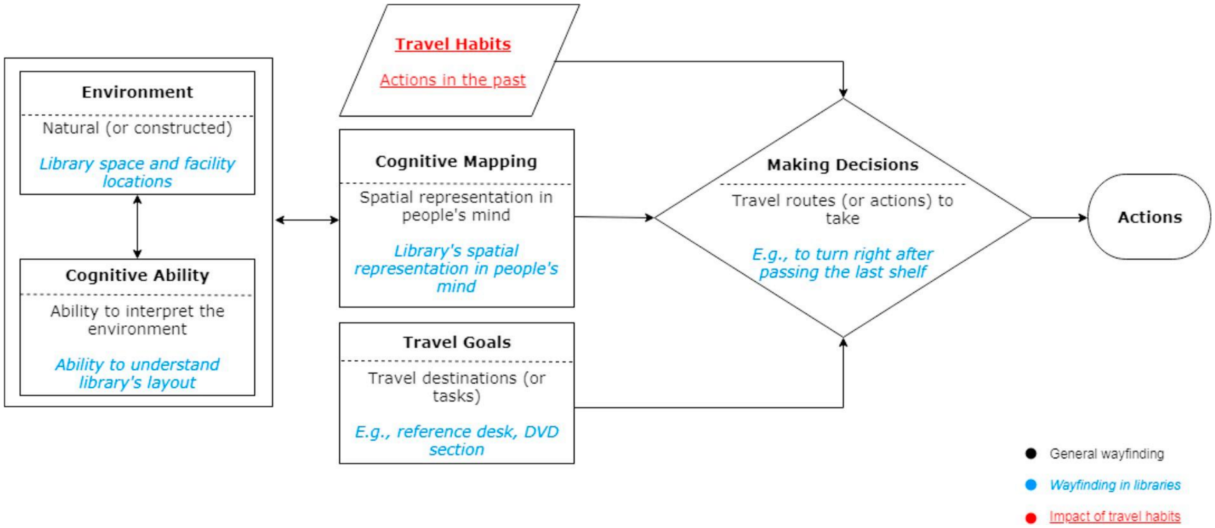

Fig. 2. Model of habitual wayfinding in academic libraries.

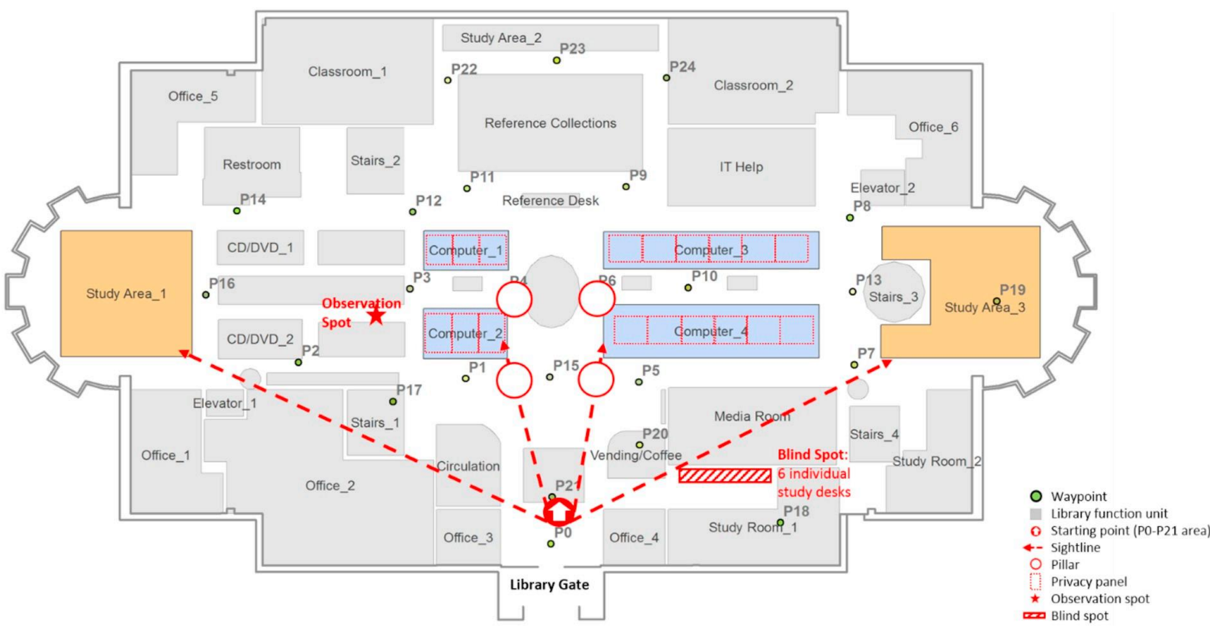

Fig. 3. First floor layout of the Lucy Scribner Library building.

4.2. Background and spatial characteristics of the Lucy Scribner Library

As the only library in Skidmore College, a four-year private liberal arts college located in upstate New York, the Lucy Scribner Library, particularly its first floor, is among the highest traffic zones on campus. The majority of library services are provided on this floor, including public computers, printers, circulation, reference, IT help, classrooms, group study rooms, open study areas, self-service café, periodicals, and CD/DVD rentals. Various academic activities, such as studying, printing, reference services, and in-class teaching, are all conducted on this floor (Fig. 3). The relatively remote location of Skidmore campus largely limits access by the general public, and the multi-functionality of the library building results in heavy usage by Skidmore students and faculty for various academic and non-academic activities. It is reasonable to posit that a high percentage of the walk-in patrons are regular users. In addition to the normal academic and social activities, other services provided in the library building, such as IT help, free printing, the Writing Center, and the library course LI 100, are all heavily used by first-year students. Since these multiple function units are visited by first-year and transfer students right after the fall semester starts, it is reasonable to include them as regular users in the two sampling periods (Week 10 and Week 15).

The Lucy Scribner Library is a symmetrically constructed building. The majority of library services are provided on its first floor and several major function units, such as public computers and open study areas, are arranged in symmetric locations on both sides on this floor. As Fig. 3 shows, when patrons enter the library, i.e., arriving at P0-P21 area,[1] and are about to make decisions on choosing computer seats, their sight is largely blocked by two large pillars on each side, privacy panels installed on every computer desk, and a few library function units. In this case, patrons are unable to determine which side has more

[1] Waypoint P0 is the library entrance, and waypoint P21 is the library lobby including special collection display area. Thus, waypoints P0 and P21 serve as the first two waypoints in all pathways recorded in this study.

vacant computer seats by looking from the P0-P21 area, nor can they see the status of the open study areas located at the further end of both sides. In other words, before patrons can see which side has more vacant seats to make their travel plans, they already have to make their navigation decisions, e.g., proceeding to the group study area (Study Area_1) on the left side. Taking advantage of this particular space layout feature that inhibits patrons' deliberate thinking in their wayfinding ensures that the majority of the routing data falls into library patrons' habitual behaviors.

The impact of other confounding factors that may potentially influence users' wayfinding is considered minimal in the context of this study, because the majority of the library users are students (with similar levels of cognitive ability) and it takes them the same effort to reach the function units symmetrically located on both sides of the floor plan due to spatial characteristics. Therefore, it is reasonable to assume that the observed routing data collected on this floor can be employed to directly test habitual wayfinding behavior without the interferences caused by other spatial syntax (Li & Klippel, 2012) in library wayfinding, including space visibility, layout complexity, and signage system (Beck, 1996).

4.3. Data

4.3.1. Data collection

The routing data were collected in two one-week periods in the fall 2016 semester. Given the seasonality factor in a typical semester at Skidmore, Week 10 with no major exams or campus wide events was selected as the first week (W1, D1-D7); Week 15, the last week following the regular class schedule before final exams was selected as the second (W2, D8-D14). Three daily time slots (8:30 am-9:30 am, 3:30 pm-4:30 pm, and 7:30 pm-8:30 pm; with no morning slots on weekends) were designated for recording library users' navigation routes on the first floor.[2] Most classes at Skidmore College are scheduled from Monday through Thursday, which results in a rapid traffic drop in the library on Friday, especially in the afternoon hours. On the other hand, the traffic starts rising quickly on Sunday since Monday is usually the due day for class assignments. Taking such class arrangement effects into consideration, the second and third slots on Friday (to be assigned as weekend slots) were switched with the corresponding slots on Sunday (to be assigned as weekday slots) in order to distinguish the library's busy and non-busy days in data processing.

This study followed Mandel's data collection method (Mandel, 2010) for recording patrons' navigation routes on the first floor. During the sampling period one librarian stayed behind one end of a shelf (as shown in Fig. 3); this allowed her to capture most routes without obstructing patrons' regular navigations. The librarian first recorded patrons' navigation routes on a print-out map and then converted the raw graphical routing data to numeric information in an Excel spreadsheet for each observation slot. All paths began as patrons entered the library (P0-P21 area) and ended when they reached their destinations.[3] Each routing record also route ID, date, period, week/weekend, group/individual, and destination.

4.3.2. Data structure

Departing from Mandel's method of processing routing data, 25 waypoints (P0-P24) were designated on the floor map for data collection (Fig. 3) during preparation. Routes were recorded in the fashion of a sequence of binary numbers, where 0 indicated no-passing and 1 indicated passing, e.g., r85: r1100000101100001000000000.[4] Table 1 shows an example of a routing record. The structure of the routing data provided great flexibilities for data processing in the analysis.

Table 1
Routing data structure in Excel spreadsheet.

Headers	Example record	Remarks
Week	1	Week 10
Record ID	22	Unique route entry ID (total entries: 3043)
Date	10/24/2016	Sampling date
Preriod	1	Morning slot
Weekday	1	Weekday (0: weekend)
Individual	1	Individual (0: group)
Right/Left	r	Right
Destination_Details	Computer_4	Destination details
Destination	Computer	Destination
RouteDetails	r1100000101000000000000000	Combination of passing/ no passing points
RouteID	r79	Unique route ID (total uniqe routes: 119)
P0-P24	0/1	0: no passing; 1: passing

Table 2 shows sample routing records converted into an Excel spreadsheet. As column RouteDetails shows, distinct routes are identified by the sequence of binary numbers and assigned unique identifier (RouteID) in the data set. By using filter and pivot table functions in Excel, the data set can be easily aggregated to any higher levels (e.g., a particular day or all weekday mornings) and transformed to multiple variations for different study purposes. Given that routes toward public computer areas and open study areas are selected as the analysis objects in the study, the records with destination information (Destination_Details) matching the criteria (Computer_1/2/3/4 and Study Area_1/3) were first selected through the filter function. Next, since the goal of the analysis is to examine library users' wayfinding patterns during different periods of a day, different days of a week, and different time periods during a typical academic semester, additional information in columns Week, Destination_Details, Period, and Right/Left were then included, and counting figures under different combinations could be conveniently obtained through the pivot table function in Excel.

4.3.3. Data limitations

Typical limitations in observational data (Mandel, 2010) also exist in these data. For example, six individual study desks located on the corridor toward group study rooms were blind spots from the observation spot (Fig. 3). Given that more users travel to group study rooms in general, destinations of the routes toward that specific corner were all recorded as group study rooms. In some rare cases, where patrons stopped and started conversions with other people during their wayfinding process, the function unit within the shortest distance was recorded as the destination in the dataset.

4.4. Statistical analysis

The selection of the statistical analysis objects was based on two criteria: the frequency of the travel actions taken and the disturbances caused by other spatial characteristics on the first floor. Ouellette and Wood (1998) examined the strength of the relationship between a person's travel goal and its associated action in their study of habitual behaviors. They suggested that the relationship is stronger when the action was repeated more frequently and conducted in a more stable context. With regard to minimizing the influences of other wayfinding factors on users' travelling decisions, the routing data to be selected should belong to the function units symmetrically located on the first

[2] The regular library hours are 7:30 am to 1:00 am from Monday to Thursday; 7:30 am to 10:00 pm on Friday; 9 am to 10 pm on Saturday, and 11 am to 1 am on Sunday.

[3] A patron's destination was defined as a function unit where the patron made a full stop in his or her navigation route. Stairs and elevators were regarded as destinations when the patron traveled to other library floors.

[4] All routes start from P0-P21 area (waypoints P0 and P21). As a result, the binary number combination of all routes starts with "r11…".

Table 2
Raw routing data examples.

Week	Record id	Date	Period	Weekday	Individual	Right/Left	Destination_Details	Destination	RouteDetails	RouteID	P0	P21	P15	P1	P2	P3	P4	P5	P6	P24
1	22	10/24/2016	1	1	1	r	Computer_4	Computer	r1100000101000000000000000	r79	1	1	0	0	0	0	0	1	0	0
1	214	10/24/2016	2	1	0	r	Study Area_3	Study Area	r1100000101000000000000000	r79	1	1	0	0	0	0	0	1	0	0
1	1076	10/28/2016	3	0	1	r	Computer_4	Computer	r1110000000000000000000000	r94	1	1	1	0	0	0	0	0	0	0

Note: columns P7-P14, P16-P20, and P22-P23 are omitted here to conserve space.

floor. In other words, the routing data to be analyzed should contain the same spatial syntax on both sides.

The goal of the statistical analysis was to test whether habitual wayfinding would cause the average route counts toward certain areas on one side to be significantly higher than the other side given the symmetric floor layout. A two-sample *t*-test (assuming equal variances) was employed to test whether the means of the route counts on two sides were significantly different. In this analysis, routing data collected on weekdays and weekends were tested separately in order to distinguish the travel patterns on busy and non-busy days. To account for the inconsistency of the number of public computers between the two sides (20 computers are located on the left side and 50 on the right), the mean value of route counts, defined as route counts divided by the number of computers, was used instead of the actual total counts. The null hypothesis can be summarized as follows:

H_0. *The average route counts of computer areas on two sides are the same at any time.*

And the alternative hypothesis is:

H_1. *The average route counts of computer areas on one side are significantly more than the other side at any time.*

5. Findings

The study was conducted in two stages. First, routing data were collected in the sampling periods and visualized in ArcMap to detect potential patterns of habitual wayfinding. In the second stage, a two-sample *t*-test was employed to examine whether significant usage difference due to habitual wayfinding existed between the routes to the same function unit on both sides of the symmetric floor plan.

5.1. Visualization of habitual wayfinding routes

The collected routing data were cleaned and organized in Microsoft Excel. After removing the routes not qualified for the study (i.e., routes toward other library floors), 1834 valid records were obtained for further visualization and analysis. Route entries for the top three most chosen destinations on the first floor (Table 3) were visualized in ArcMap by day of the week and time of the day (Figs. 4 to 9). Steps in the visualization process are summarized in Appendix A.

Figs. 4 to 9 suggest that public computers and open study areas on the right side are the most chosen destinations (except for the weekend days) regardless of time of the day or day of the week when patrons are navigating the first floor. That is, notably more patrons choose their destinations on the right side than the left.

5.2. Summary statistics

Based on the visualized navigation routes, the public computer and open study areas were the most chosen travel destinations on the library first floor, which means that travelling to these two function units was among the most repeated actions when users were navigating the first floor. The summary statistics obtained through Excel Pivot Table (Table 4) provided further detailed evidence: the routes toward these

Table 3
Top 3 most chosen wayfinding routes with passing waypoint details.

Map	Most chosen routes	2nd chosen routes	3rd chosen routes
Full	r72 (P0-P21-P5)	r95 (P0-P21-P15-P6)	r80 (P0-P21-P5-P7)
Weekday	r72 (P0-P21-P5)	r95 (P0-P21-P15-P6)	r36 (P0-P21-P15)
Weekend	r72 (P0-P21-P5)	r80 (P0-P21-P5-P7)	r34 (P0-P21-P1-P2-P16)
Morning	r72 (P0-P21-P5)	r36 (P0-P21-P15)	r95 (P0-P21-P15-P6)
Afternoon	r72 (P0-P21-P5)	r95 (P0-P21-P15-P6)	r80 (P0-P21-P5-P7)
Evening	r72 (P0-P21-P5)	r95 (P0-P21-P15-P6)	r80 (P0-P21-P5-P7)

Fig. 4. Top 3 most chosen wayfinding routes visualization in ArcMap (full sample).

two destinations accounted for over 70% (computer areas 52.2%; open study areas 19.5%) of all navigation routes on the first floor (Table 5).

Thus, according to the selection criteria stated in Section 4.4, the routing data toward public computer areas were selected as the primary analysis object. As a comparison, the routing data to the open study areas were also tested to determine whether travel habits also affected the less frequently taken travel actions (compared to the routes to public computer areas).

5.3. Two-sample t-test results

The *t*-test results of the routes to public computers areas appear in Table 6. When compared by day of the week, except for the days on the second weekend (4.4% of total routes to public computer areas), the

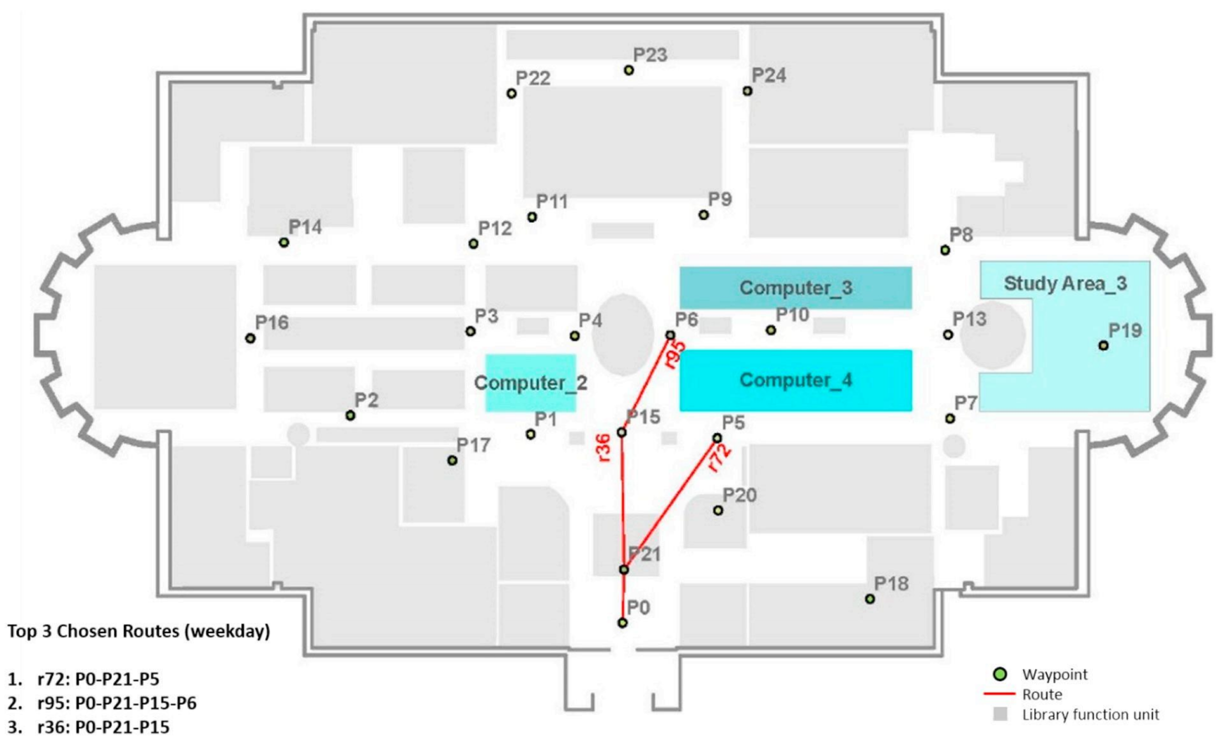

Fig. 5. Top 3 most chosen wayfinding routes visualization in ArcMap (weekday).

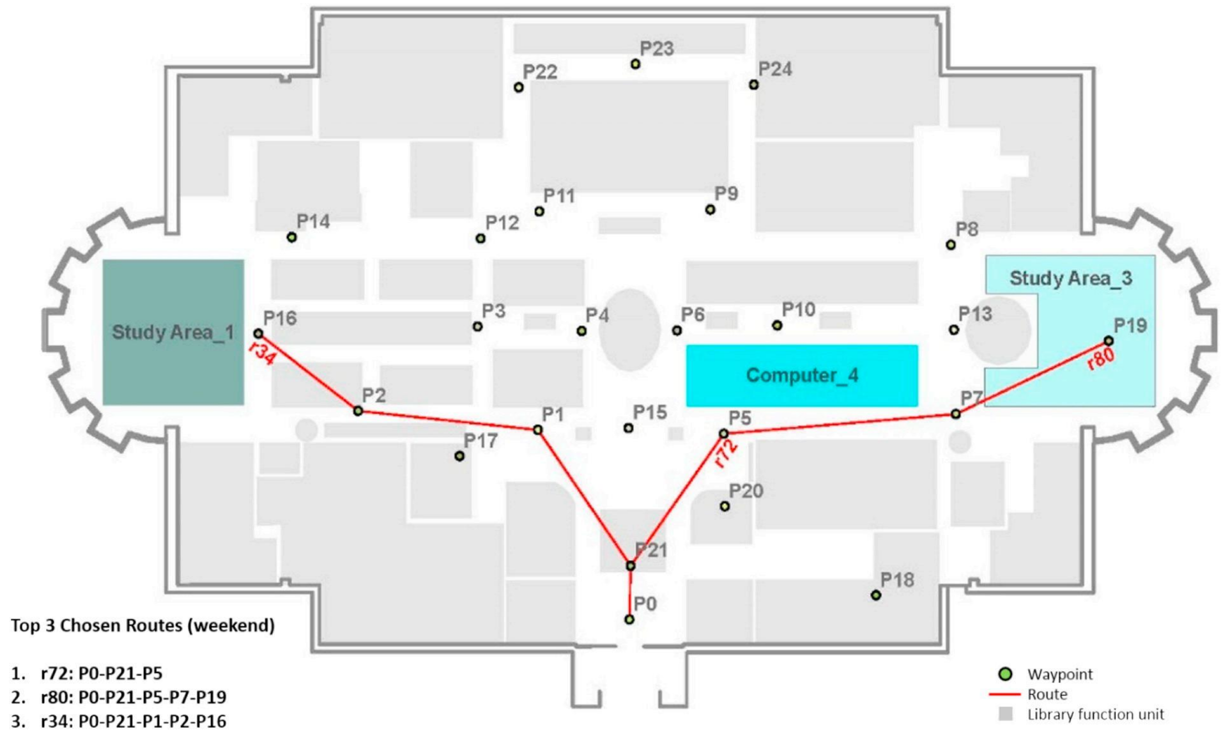

Fig. 6. Top 3 most chosen wayfinding routes visualization in ArcMap (weekend).

average route counts toward the public computer areas (Computer_3 and Computer_4) on the right side are significantly higher than the left side (Computer_1 and Computer_2) (p-value < 0.1). Thus, the null hypothesis is rejected; habitual wayfinding leads to a significantly higher traffic to the computer areas on the right side than the left side on all weekdays and the first weekend (i.e., 95.5% of total routes to public computer areas). When the routing data are examined by period of the day, a significantly higher traffic volume to the right side was demonstrated in the t-test results on weekday afternoons and evening slots. For the only exception on weekdays, although the t-test outcome of the morning slots was not statistically significant, its sign is consistent with other findings and the p-value (one-tail p-value = 0.138) is quite close

Fig. 7. Top 3 most chosen wayfinding routes visualization in ArcMap (morning).

Fig. 8. Top 3 most chosen wayfinding routes visualization in ArcMap (afternoon).

to the 10% significance threshold. With regard to the navigation routes on weekends (6.8% of total routes to public computer areas), the difference of traffic volume between two sides failed to demonstrate a consistent destination preference of our users.

Table 7 shows the *t*-test results of the open study areas. Similarly to public computer areas, the mean values of route counts to the open study area on the right side (Study Area_3) were consistently larger than the left side (Study Area_1) in all days and time periods throughout the

Fig. 9. Top 3 most chosen wayfinding routes visualization in ArcMap (evening).

Table 4
First floor route entries by function unit.

Destination	RouteCounts	RouteCounts %
Computer	958	52.2%
Study Area	358	19.5%
Circulation	74	4.0%
Vending/Coffee	66	3.6%
Classroom	63	3.4%
Study Room	58	3.2%
Fountain	43	2.3%
Others	214	11.7%
Total	1834	100.0%

Table 5
Route entries for four public computer areas and two open study areas.

Destination	Weekday	Weekend	w1	w2	p1	p2	p3
Computer_1	58	4	25	37	15	33	14
Computer_2	142	16	79	79	54	73	31
Computer_3	176	15	100	91	38	100	53
Computer_4	509	38	300	247	166	253	128
Study Area_1	121	24	75	70	15	84	46
Study Area_3	142	26	75	93	21	92	55

Note: w1 = Week 10; w2 = Week15; p1 = morning slot; p2 = afternoon slot; p3 = evening slot.

Table 6
t-test results for the routes to public computer areas.

	Mean count difference	Total counts
By Day		
w1_weekday	−0.48**	477
w2_weekday	−0.234*	412
w1_weekend	−0.2*	27
w2_weekend	0.105	42
By Period		
p1_weekday	−0.063	273
p2_weekday	−0.17*	400
p3_weekday	−0.138**	216
p2_weekend	−0.015***	59
p3_weekend	−0.033*	10

Note: w1 = Week 10; w2 = Week15; p1 = morning slot; p2 = afternoon slot; p3 = evening slot.
Mean difference is constructed as left side counts minus right side counts.
***p < 0.01. **p < 0.05. *p < 0.1.

Table 7
t-test results for the routes to open study areas.

	Mean count difference	Total counts
By Day		
w1_weekday	−0.034**	132
w2_weekday	−0.158***	148
w1_weekend	−0.045	18
w2_weekend	−0.087	15
By Period		
p1_weekday	−0.024*	36
p2_weekday	−0.027	154
p3_weekday	−0.034	96
p2_weekend	−0.067	22
p3_weekend	−0.045	5

Note: w1 = Week 10; w2 = Week15; p1 = morning slot; p2 = afternoon slot; p3 = evening slot.
Mean difference is constructed as left side counts minus right side counts.
***p < 0.01. **p < 0.05. *p < 0.1.

entire sampling period. However, except for weekday mornings (11.8% of total routes to open study areas), no statistically significant traffic differences between the two sides was found. The results suggest that when travel actions were repeated less frequently (compared to the travel actions associated with the public computer areas), although a certain level of destination preferences was consistently reflected in the sample (i.e., through visualization in ArcMap), the impact of travel habits (developed through less frequently taken actions) on patrons' wayfinding did not show statistically significant differences.

6. Discussion

6.1. Visual evidence for habitual wayfinding

The findings suggest that public computer and open study areas on the right side are the most chosen destinations (except for the weekend days), regardless of time of the day or day of the week when patrons are navigating the first floor. Patrons choose their destinations on the right side notably more often than the left. The exactly symmetric layout eliminates other confounding factors in wayfinding, such as different spatial syntax on two sides that can possibly affect patrons' travel decisions. Also, when they enter the library (P0-P21 area) and are about to choose computer seats or open study tables, users can barely determine which side has more vacant seats by looking from where they stand. Therefore, it is reasonable to believe that when directed by travel habits, preferences for certain navigation routes do exist in their wayfinding. For repeat users in an academic library, wayfinding is more likely to be influenced by the habits formed by the actions taken frequently in the past.

A variety of factors can potentially explain the formation of such travel patterns. In this case study, more public computers were provided on the right side, patrons might have had more positive past experiences of finding vacant seats on that side, or at least they consciously or subconsciously believed that more vacant seats would be available on the right side. Therefore, such observed travel preferences may not fully demonstrate the precise impact of travel habits. And it is necessary to further examine whether statistically significant usage differences for the same function unit on two sides still exists after controlling for the number of public computers.

6.2. Applications of habitual wayfinding in academic libraries

For a broad range of academic libraries, a considerable number of patrons are repeat users who travel on their familiar routes on a regular basis. Although general wayfinding and habitual wayfinding can both exist, travel habits may play a more important role than deliberate cognitive thinking in the academic library setting, especially for libraries that serve as the only library on campus and therefore subject to heavy usage by students, faculty and staff. This would also be true when institutions are in relatively isolated locations, which can largely reduce the access from people foreign to the library space. It is important to distinguish the habitual wayfinding framework from the general library wayfinding model and study how they can affect daily operations in academic libraries. Compared to prior studies in library science that use GIS tools, such as Bradley and Mandel (2010), the methodology employed in this study allows routing data to be flexibly processed for various statistical analysis and can be particularly applicable to space studies in library research. The framework, methodology, and findings from this case study has important implications for the understanding of space use for a broad range of academic libraries and would be valuable to any library considering conducting space evaluation and space rearrangement projects. Two potential applications are provided here to motivate further discussions.

6.2.1. Use of the traffic difference due to habitual wayfinding

Librarians with an understanding of habitual wayfinding and its

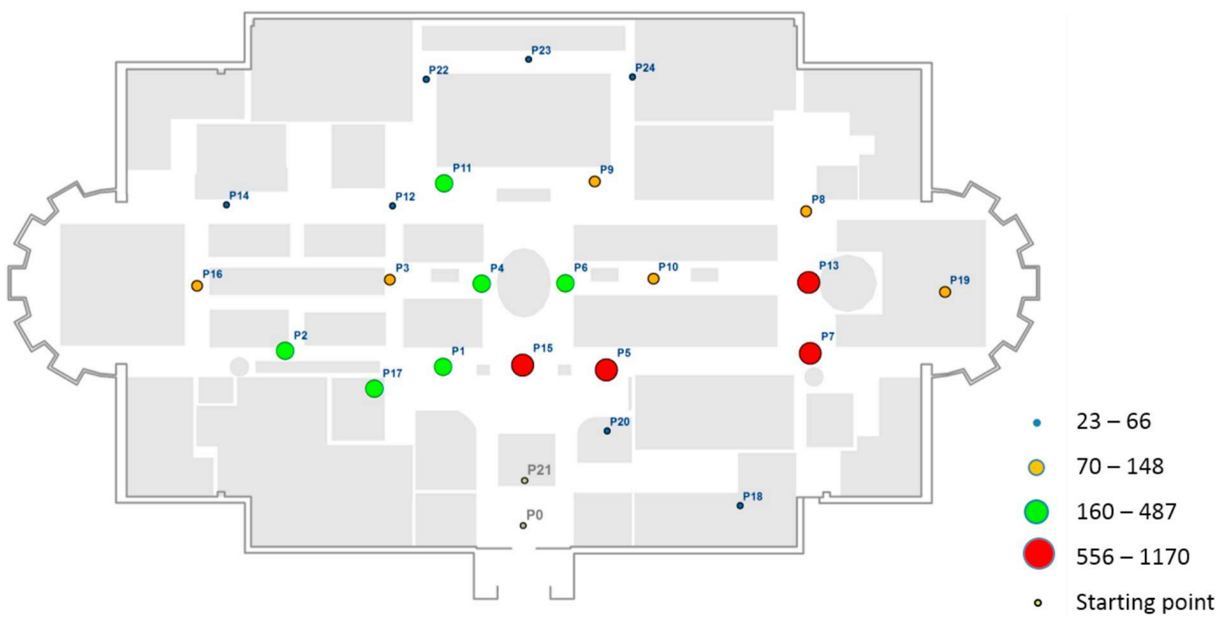

Fig. 10. Hot spots (high-traffic spots) on the library first floor.

potential influence on library traffic could incorporate this into consideration of location choices for library events and daily work. For example, based on the first floor hot spot map (Fig. 10) obtained through visualization, event promotion materials should be placed in the highest traffic areas (e.g., each waypoint with > 500 visits) on the right side, such as area near waypoints P5, P7, P13 or P15. As for in-library activities (e.g., the Scribner Library Therapy Dog Day), in order to provide easy access for the participants and also minimize disturbances to other regular library users, the location should be arranged in a relatively low-traffic area on the left side of the first floor, such as the area close to waypoint P16. With regard to daily operations, given that travel habits can cause significantly higher traffic in certain areas, a bulletin board or LED monitor for information display in the library should be placed near the area of waypoint P5. For function units requiring constant maintenance, such as loading paper to printers, more attention should be given to placing the units in higher traffic areas, e.g., the two printers close to the computer areas on the right side.

6.2.2. Methodology for collecting and processing routing data

The richness of the recorded route entries provides flexibility in processing and calculating routing data for different kinds of studies. For potential applications in a different setting, such as locating popular routes or spots in the library regardless of destinations during different time periods, the destination information can be easily dropped from routing data and aggregated to different levels, for example, by a single waypoint (i.e., hot spots), two waypoints (i.e., route segments), and multiple waypoints (i.e., routes). As shown in Figs. 10 and 11, when the density information of waypoints and route segments is imported into the geodatabase, the most crowded spots and route segments regardless of destination can be easily visualized in ArcMap.

6.3. Study limitations

Limitations in this study emerge from the scale of the routing dataset and the institutional features of the Scribner Library (e.g., being the only library in a private liberal arts college). Further investigation could extend the scope of the data collection to institutions of different natures and backgrounds (e.g., universities with graduate students or campus located in metropolitan areas) and build a more comprehensive routing dataset. Also, as this case study was conducted in an academic library located in the United States, its findings are possibly affected by the right-hand driving orientation on the road. Although pedestrians' orientation tendency in one country does not necessarily align with its rules of the road (Helbing, Buzna, Johansson, & Werner, 2005), similar research conducted in left-hand traffic countries will be of value in complementing the habitual wayfinding framework proposed in this study. Also, with the wide availability of mobile apps that can track and record travelers' walking paths, the study of habitual wayfinding could be conveniently extended to a broader range of spaces, such as other floors in the library building or virtually any other high-traffic indoor spaces on campus.

The specific layout features of the Scribner Library (more public computers are located on the right side) might limit applicability of the findings to other libraries. Bitgood (2006) proposed the term "economical strategy" and pointed out that the crowd tends to choose a path that takes less effort when navigating in a certain environment. This suggests that the action of turning to right takes less effort than turning to left for right-handed people. In the present study, factors such as more public computers and tendency to choose the right side can be regarded as the more economical options for patrons simply because the majority of the population is right-handed and patrons may subsequently believe that it is easier to find vacant seats on the right. Therefore, the findings of habitual wayfinding behaviors in Scribner could be influenced by these economical options. In addition, in many other academic libraries, an important patronage base comes from new users unused to the library environment who may require spatial aids to assist them in fulfilling their travel goals. In order to further generalize the framework and evidence of habitual wayfinding presented in this study to a broader spectrum of academic libraries, researchers would also need to take into account other wayfinding studies that are complementary in scope, such as Li and Klippel (2012) who adopted spatial and behavioral approaches to predict new users' directional needs, and potentially develop a more generalized model of wayfinding.

7. Conclusion

In addition to proposing a new framework, this study also makes a methodological contribution through a novel approach of detecting potential traffic patterns by visualizing routing data and quantifying the details at the route segment level. The framework, methodology, and

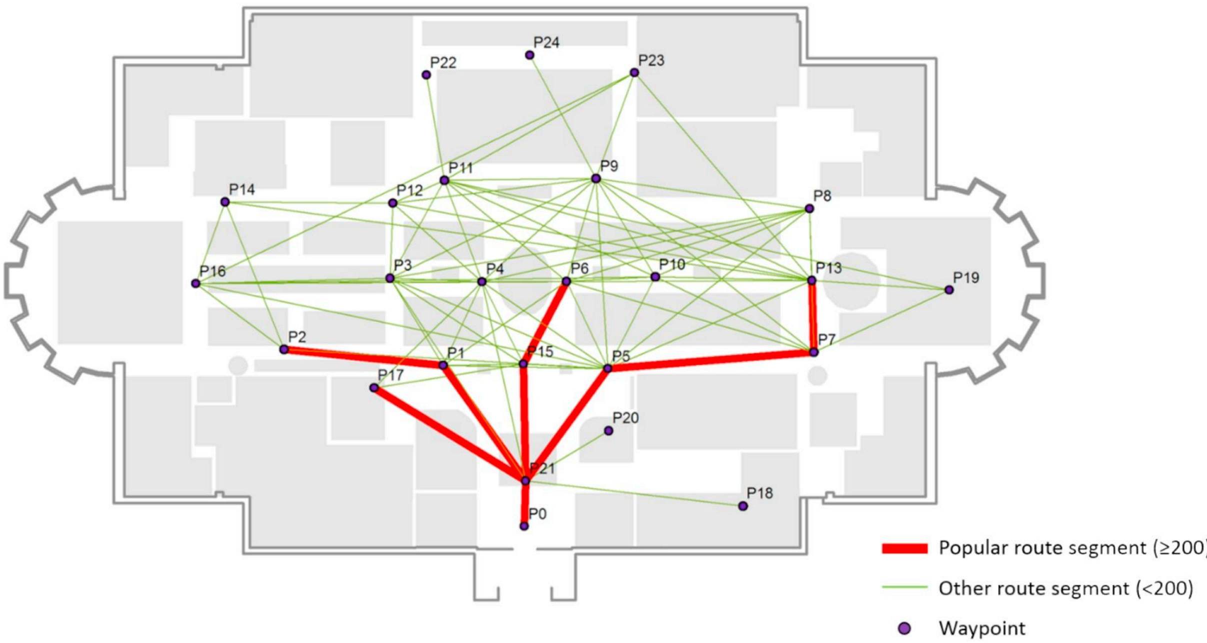

Fig. 11. Popular route segments on the library first floor.

findings taken together offer new ways to think about space navigation and use in academic libraries. This should prove to be of value to libraries considering space evaluation and space rearrangement projects. Decisions informed by user behavior in spaces are likely to result in more effective and efficient space design and space allocation.

Appendix A. Steps in visualizing the navigation routes in ArcMap

1. Create the library first floor map with waypoints and function unit name information in AutoCad and print the map for data recording;
2. Import the CAD file into ArcMap and create a geodatabase to nest needed layers (shape files) including function area layer, waypoint layer, and route layer for further analysis and visualization;
3. Locate an observation spot which is able to maximize the observation scope and minimize the obstruction to regular patrons, and record patrons' navigation routes on the print-out map.
4. Enter the route records from the print-out map into Excel worksheet and reorganize route data by waypoint, destination and route in Excel;
5. Feed the aggregated data obtained in Step 4 into ArcMap geodatabase imported as a table and make joins with the tables of layers created in Step 2 accordingly;
6. Visualize the results and findings in ArcMap.

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Jiebei Luo is a reference librarian at Skidmore College's Lucy Scribner Library. She earned her MLIS degree from Rutgers University. Her current research interests include open access, scholarly communication, library assessment, evidence-based statistical analysis, data visualization and data literacy instruction.