Global Landmarks in a Complex Indoor Environment

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Abstract

Wayfinding in complex indoor environments can be a difficult and disorienting activity. Many factors contribute to this difficulty, including the variable number of floors and half-floors paired with many different and often unpredictable ways to get from one floor to another. In order to explore how the spatial information of floor to floor transitions is represented cognitively, a user study was conducted at the Carnegie Museums of Art and Natural History that drew on experienced participants from the Visitor Services Department. The participants were asked to give wayfinding descriptions to and from several landmarks in the museums with the majority of the routes spanning multiple floors. It was found that floor to floor transition points were often represented as landmarks with notable locations in the Museums being represented with both functional and referential aspects. A functional aspect of a floor to floor transition points meant that its purpose in the wayfinding description was to provide a means to get from one floor to another. A referential quality meant that a floor to floor transition points was simply an indemnity and did not serve as a way to move vertically through the environment. This finding informs the discussion on global landmarks and their representation and salience in large complex indoor environments.

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1 Introduction

Human beings engage in wayfinding on a daily basis through a variety of indoor, outdoor, and transitional spaces [13]. If the final destination is familiar, then one often knows the path to take and can do so typically without complications. Conversely in a difficult environment, it is useful to determine why one gets lost and how this can be prevented in the future [4]. For this reason, large complex locations become perfect places to study since it is in these locations that wayfinding difficulties are likely to arise [11].

Environments such as large museums, large libraries [15], and large convention centers [12] present a unique and interesting set of wayfinding difficulties that require a distinct set of heuristics to understand fully [24]. Many aspects of large complex indoor environments make it difficult to "get one's bearings" when attempting to get from point A to point B [4, 11, 12]. One difficulty is that staircases, or floor to floor transition points, are often not depicted well on wayfinding aids. Battles and Fu [2] examined a variety of wayfinding strategies that are

adopted by travellers using a schematic map of a multilevel building. Frankenstein et al. [7] showed how the role of background knowledge is used to evaluate indoor landmarks. Other work in this area includes the examination of individual differences in indoor wayfinding abilities using space syntax as a tool to measure the complexity of the space [12].

This study blends the idea of complex indoor environments and transitional spaces by examining the way spatial information, and in particular the floor to floor transition points, is represented in cognitive maps in the context of global landmarks. Since this work is focused on an indoor environment, we consider how the floor to floor changes might be represented as a type of transitional space in the cognitive maps of participants familiar with the environment. In this context, we define a floor to floor transition point as a space where a traveller is neither on one floor or another, but somewhere in a transitional area between two coherent spaces. Part of the difficulty of these spaces lies in the fact that when individuals leave the transitional area, their direction of movement may be the same as when they entered or might differ by any number of degrees, depending on the number of switch-backs. As such, staircases and other floor to floor transitions are important to examine in detail, given that they are often points that people find confusing [12, 15].

In order to examine floor to floor transition points, we look at the wayfinding descriptions that might be given to patrons by the staff at a public museum. The primary goal of this study is to examine the cognitive maps formed by employees who are familiar with an environment and, in particular, the role of floor to floor transition points. Thus, this research adds to the existing literature by providing insights into the internal representations of floor to floor transition points in complex indoor environments space, specifically in the context of global landmarks.

2 Research design

2.1 Study environment

The environment chosen for the study was the Carnegie Museums of Art and Natural History, which consist of two contiguous buildings, one built in 1895 housing the Museum of Natural History and a second adjoining building built in 1974 housing the Museum of Art. Total area for the museums is approximately 45,900 square meters. The attendance per year is approximately 330,000 visitors of all ages. The floor design of the museums, as described by the Head of Visitor Services is "a maze." This environment was chosen because it is a large complex indoor space with several floor to floor transition points that do not connect floors in predictable ways.

In addition to the difficult floor to floor transition points, this building is also difficult to navigate for several additional reasons [11], including a lack of visual access, difficulty in creating a mental map, and the unpredictable layout of the floors and hallways. The Head of Visitor Services at the Carnegie Museums of Art and Natural History gave further insight into what he perceives the problems to be with wayfinding in the museums. Below are the reasons he cited for why the museums are difficult to navigate.

Multiple "half" floors: One of the challenges with wayfinding in the museums is the number of half floors throughout the space. For example, visitors often enter through the back of the museums because it is the entrance nearest to the parking garage. However, this entrance lies on a landing between the lower (basement) level and first (main) floor, which makes it difficult to represent on wayfinding aids. Often, the back entrance is shown as being on the first floor.

Both museums housed in one building: In addition to the size and complexity of the environment, the building houses both the Museum of Natural History as well as the Museum of Art. The experience designed to be a singular one since both museums overlap physically, but in reality people usually come to visit one or the other. This makes it difficult to communicate to patron's ideas about the space such as that you have to go through the Museum of Art to get to the Museum of Natural History.

No distinct entrance: Lastly, the museums lack a distinct main entrance. The most used entrance to both museums is the rear entryway because it comes from the parking lot and is located behind the Museum of Art. Because of the proximity of this entrance to the Museum of Art, patrons looking for the Museum of Natural History often get lost trying to find a distinct entrance for the Museum of Natural History regardless of signage indicating where the entrance is. In addition, the entrance is located near an entrance for employees and school groups. Often patrons who intend to enter through the back entrance of the museums end up entering through the "employee only" entrance.

These difficulties suggest that the Carnegie Museums of Art and Natural History can provide a rich study space in which to explore the role of floor to floor transition points in cognitive maps. In particular, the complex floor plan, multiple "half floors" and difficult mental map construction make it a rich environment for the study of indoor navigation.

2.2 Participants

Rather than examining the mental maps of the visitors to the museum, this study focused on the employees in the Visitors Services Department. This group is familiar with the space and is often tasked with working at the various help desks throughout the museums where they aid patrons in finding their way around the museums. Because of this experience, they are likely to have a robust internal representation of the environment. More importantly, they are accustomed to giving wayfinding descriptions that include just the public spaces and are communicated in ways that visitors to the museum would understand. 20 individuals participated in the study, 10 men and 10 women ranging in age from 19 to 77 years (SD = 15.15 years). At the time of the study they had been employed at the museums an average of 31.7 months (SD = 41.34 months).

2.3 Data collection and analysis

Participants were seated and asked to give 22 wayfinding descriptions from 17 origin and destination locations/landmarks in both verbal and sketch map form. Half of the participants were asked to give route descriptions 1–11 in sketch map form and 12–22 in verbal form. The other half gave descriptions 1–11 in verbal form and 12–22 in sketch map form. All participants were videotaped and instructed to give the description as if they are giving directions to a patron who was not familiar with the environment. In the sketch map portion of the study, participants were given a blank piece of paper and were asked to draw the path that would take the patron from the origin to the destination on the provided paper. In the verbal description portion, participants were asked to verbally give their descriptions. Participants were free to imagine the direction they were facing and generally used left/right/up/down as primary directional terms. Participants did not have access to the museum's maps during the study and were not corrected if the wayfinding description they gave was not correct or included the closed area.

Participants were then asked to complete a Santa Barbara Sense of Direction Scale [9] to measure their individual spatial ability. Finally, the study concluded with a map placement activity. During this activity, participants were given a copy of the current maps for the museum with the labels of all the locations/exhibits removed. Participants were asked to place 20 exhibits in their correct floor and location. The exhibits chosen included those that were the beginning and ending exhibits in the wayfinding portion of the study.

2.4 Sketch map analysis methods

Each sketch map provided during the study was assessed for accuracy and complexity. In order to assess accuracy the sketch map was compared to the real environment [16, 20]. To assess whether the placement of a landmark is accurate two criteria must to be met:

1. the landmark appears correctly in the sequence of landmarks encountered along the wayfinding description
2. the path connecting two landmarks accurately reflects any turns that would need to be taken in order to adequately get from Landmark A to Landmark B.

Only sketch maps that met the requirements for accuracy were further analyzed. After removal of inaccurate sketch maps the dataset consisted of 168 sketch maps. Each sketch map was classified and sorted into one of the sketch map complexity types as specified by Appleyard [1] with the purpose being to assess the amount and quality of information in the cognitive map of the participants. According to this method, the complexity of a sketch map can be classified as containing either sequential elements or spatial elements, and by the amount of detail. Sequential maps can be further ranked in terms of complexity as (1) Fragment maps, (2) Chain maps, (3) Branch and Loop maps, (4) Network maps. Spatial maps can be ranked in complexity as (1) Scattered, (2) Mosaic, (3) Linked, (4) Patterned. As the rating goes up so does the complexity, meaning that a patterned sketch map shows more complexity than a scattered map for the spatially dominated maps. For sequentially dominated maps, network maps are more complex than a fragment map.

The frequencies of landmarks, path segments, and nodes [20] in the sketch map data were also counted. The purpose of this analysis being to allow for a measurement of which landmarks are important and which routes contain the most data. Landmarks with higher frequencies across all descriptions are likely the most important landmarks in the dataset.

2.5 Verbal analysis methods

Verbal data was transcribed and coded by the researcher. Landmark based theme analysis methods were applied to all landmarks mentioned, not just floor to floor transition points. The purpose of this analysis was to begin to determine how the coarseness of the spatial information communicated by participants linguistically compares to the coarseness the information in their representations of space [10]. The analysis of verbal and horizontal prepositions were examined as well as verbalizations connected to any mentioned landmarks. For example, if a participant says “The room is to the left of the big statue” this will be coded as the horizontal preposition “Left” with the room being related to the big statue.

Verbalizations focused on axial parts, distance of regions, and paths and trajectories were also assessed. Verbalizations that showed a relationship as axial parts would show a connectedness between the landmarks and often a symmetrical representation of importance for the landmarks on a cognitive map. Word such as “on top of” or “in front of” would connect two landmarks as axial parts. Distance of regions verbalizations showed a relationship between a pair of landmarks and their distance to each other. Words such as “near” and “far”

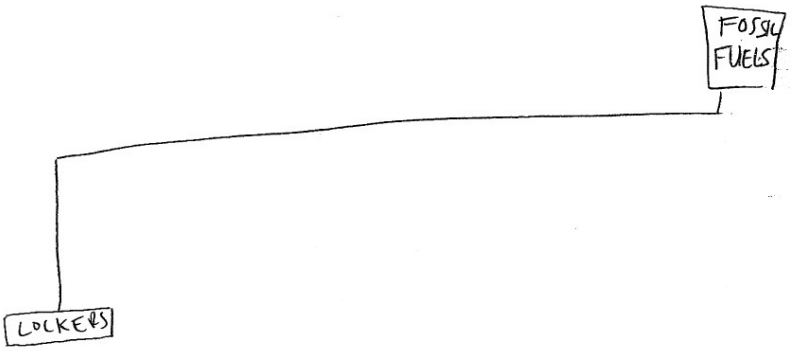

Figure 1 Sketch map from route 1 showing a less complex route.

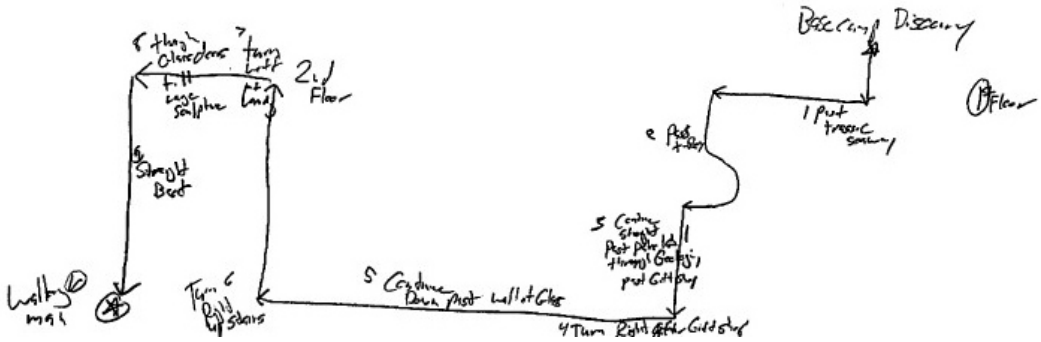

Figure 2 Sketch map from route 18 showing a more complex route.

illustrate a conceptual distance between two landmarks. Paths and trajectories verbalizations showed whether or not two landmarks were considered to be on the same path or in the same trajectory.

Verbalizations were also analyzed for the relationships between two landmarks. This method focuses on prepositions by taking into account figure and ground objects in addition to the preposition itself. Consider the following example from Landau and Jackendoff [14]:

- The bike (figure) is near the garage (ground object).
- The garage (figure) is near the bike (ground object).

Although these two sentences communicate a spatial relationship between two objects, they have different figures and ground objects making their implication about the importance of the two objects different. Ground objects usually have, properties that facilitate search and "in many contexts, they should be large, stable, and distinctive" [14].

3 Results

3.1 Sketch map analysis results

Each of the 20 participants completed sketch maps for 11 route descriptions, resulting in 220 sketch maps available for analysis. The level of detail varied greatly across destinations and across participants as shown by two example sketch maps shown in Figure 1 and Figure 2. These figures display two different wayfinding descriptions drawn by two different participants.

Table 1 Number of maps rated and their map type.

Overall Map Type	Map Type	Rating	Number of Maps
Sequential	Fragmented	1	15
Sequential	Chain	2	66
Sequential	Branch and Loop	3	17
Sequential	Netted	4	6
Spatial	Scattered	1	13
Spatial	Mosaic	2	30
Spatial	Linked	3	39
Spatial	Pattered	4	29

Sketch map complexity was analyzed using the methods described previously. The number of sketch maps that met the criteria for each Appleyard [1] classification is shown in Table 1 with examples from the study shown in Figure 3. Although each type of map was shows, the most used map type was a sequential chain map.

3.2 Verbal analysis results

Due to a technology error that resulted in data loss, the verbal data from eight participants was not able to be analyzed. The remaining data included 14 participant's verbal wayfinding descriptions for nine routes making the total number of descriptions collected 126 descriptions.

Not surprisingly, in terms of horizontal and vertical prepositions, verbalizations that included floor to floor transition points also were often accompanied by "up" and "down" but were the most often accompanied by the word "to." In total, 139 wayfinding descriptions given by participants across all routes contained these two words. The frequency of horizontal and vertical prepositions for all landmarks as well as the type of relationship the preposition indicates are shown in Table 2.

An analysis of verbal prepositions focused on determining figure and ground objects showed that floor to floor transition points were verbalized as ground objects in 59.9 % of the verbalizations. This slight preference for verbalizing a floor to floor transition point shows that participants may have thought of the transition points as reference points when giving wayfinding descriptions.

3.3 Vertical transitional space analysis

The verbal analysis was conducted on the subset of 14 participants also included an analysis that focused on floor to floor transition points as vertical transitional spaces. This analysis was based on the verbalizations found to be indicative of an indoor/outdoor transitional space introduced by Kray et al. [13]. The purpose of this analysis was to determine the importance of floor to floor transition points as landmarks in the study space with the potential representation of a floor to floor transition point as being type of transitional space. In this analysis, we extend the original theory by examining the use of transitional words by looking at their frequency in the verbal descriptions. Table 3 shows that the grand staircase was the most commonly mentioned vertical transition, but that another twelve locations were mentioned by at least one participant, which included seven staircases, four elevators, and one ramp.

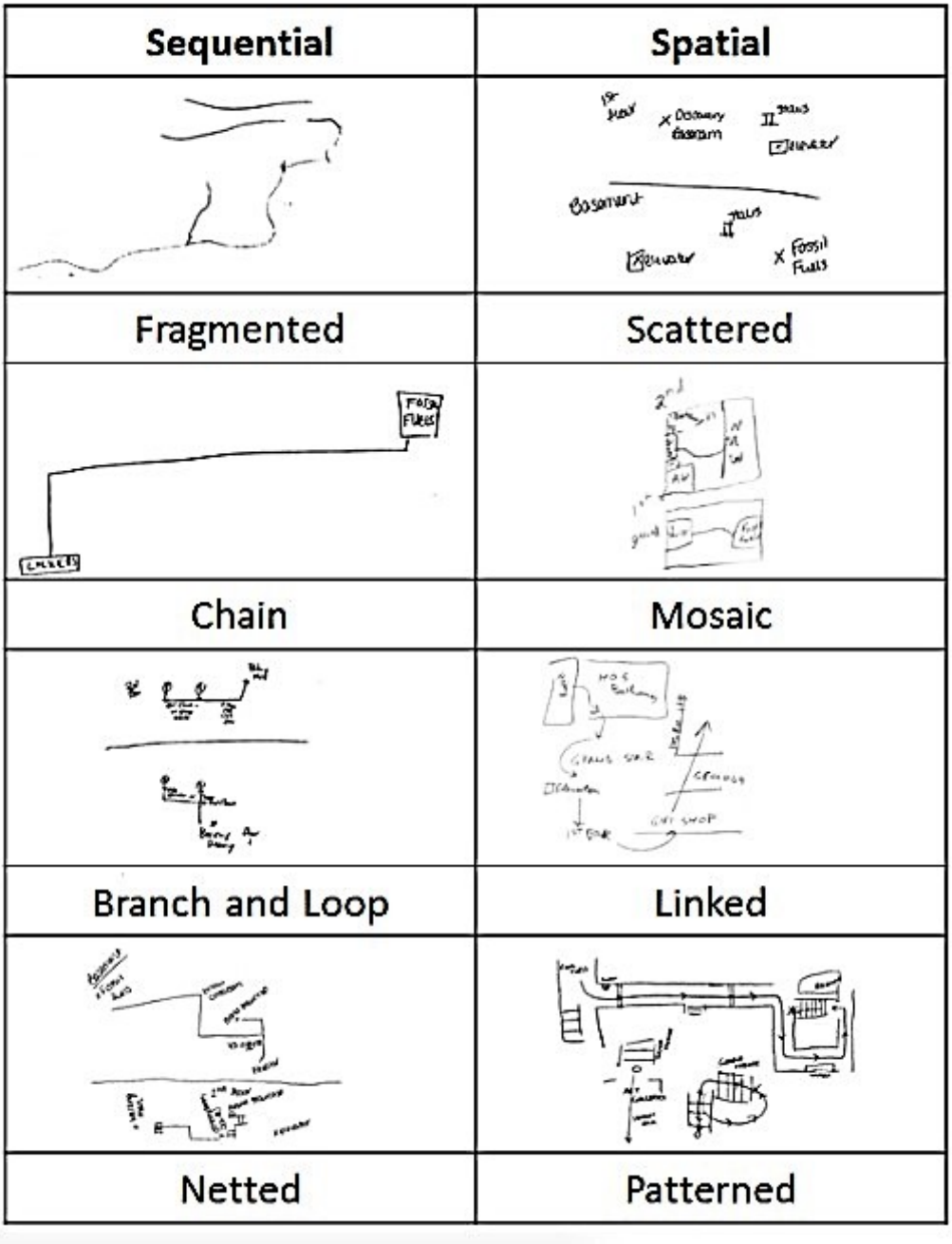

Figure 3 Examples of all types of maps based on Appleyard (1970).

Table 2 Frequency of verbalizations to describe paths.

Word	Word Type	Frequency
To	Verbalization-Paths-and-Trajectories	281
Down	Verbalization-Paths-and-Trajectories	133
Up	Vertical-Preposition	115
Left	Horizontal-Preposition	92
Right	Horizontal-Preposition	72
In	Verbalization-Relative-Distance-of-Region	71
From	Verbalization-Paths-and-Trajectories	64
On	Verbalization-Relative-Distance-of-Region	33
End	Verbalization-Axial-Parts	21
Around	Verbalization-Paths-and-Trajectories	17
Front	Verbalization-Axial-Parts	12
Top	Verbalization-Axial-Parts	11
Towards	Verbalization-Paths-and-Trajectories	10
Bottom	Verbalization-Axial-Parts	7
Behind	Verbalization-Axial-Parts	6
Side	Verbalization-Axial-Parts	5
Along	Verbalization-Relative-Distance-of-Region	3
Over	Verbalization-Paths-and-Trajectories	2
Far	Verbalization-Relative-Distance-of-Region	2
Above	Vertical-Preposition	2
Over	Vertical-Preposition	2
Backward	Verbalization-Paths-and-Trajectories	1
Away	Verbalization-Paths-and-Trajectories	1

4 Discussion

Employees who must navigate large indoor spaces on a daily basis while providing guidance to others have likely encoded noted locations, regions, and relationships into a cognitive map. Although the complexity of the cognitive maps varied as shown in Figure 3, transition points from region to region and notable landmarks were present in most representations. In line with the past literature, the floor to floor transition points at the Carnegie Museum of Art and Natural History were represented as important landmarks in the cognitive maps of participants in both sketch map and verbal tasks [6]. The Grand Staircase in particular was a floor to floor transition point that was verbalized and drawn often. The vertical transitional space analysis showed that the Grand Staircase was the floor to floor transition point verbalized the most as a possible transitional space.

From here we begin to ask what characteristics of a floor to floor transition point, particularly the Grand Staircase, makes its representation in the cognitive map of a participant distinctive? And were there any landmarks that were more distinctive than others? By defining a landmark as anything that stands out from a scene [19] this discussion explores the characteristics of floor to floor transition point representations that make them ideal candidates as global landmarks. The focus here is on the characteristics of the floor to floor transition points that allowed them to become distinct. These characteristics include:

Table 3 Frequency of floor to floor transition points on maps.

FTF Type	Name	Frequency
Staircase	Grand Staircase	40
Staircase	Back Staircase	25
Staircase	Spiral Steps	18
Staircase	Scaife Steps	11
Staircase	Library Steps	3
Staircase	Portal Steps	2
Staircase	Jane Steps	2
Staircase	HOA Steps	1
Elevator	Back Elevator	21
Elevator	Silver Elevator	21
Elevator	Rental Locker Elevator	12
Elevator	Scaife Elevator	2
Ramp	Basement Ramp	3

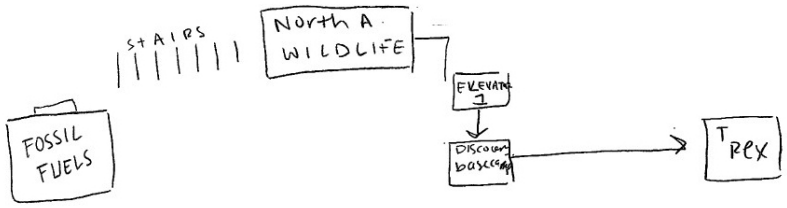

Figure 4 Example of generic unnamed stairway and unnamed elevator.

1. Descriptive names for distinct floor to floor transition points.
2. Dual representation – both functional and referential for distinct floor to floor transition points.
3. Where the floor to floor transition points lie structurally in the museums.

4.1 Descriptive names for distinct floor to floor transition points

As with landmarks in any context, floor to floor transition points were represented at varying degrees of importance in the cognitive maps of participants [18, 23]. Most wayfinding descriptions used generic floor to floor transition points such as "the stairs" or "the elevator." The verbal analysis included phrases such as *"what you're going to do is take the stairs up to discovery basecamp and make a left at the top of those stairs"* which show a generic, unnamed, communication of a floor to floor transition point. Sketch map data showed that most floor to floor transition points were thought of generically. Figure 4 shows the generic representation of a stairway as well as an elevator, which are used for movement of the traveler. Figure 5 shows a stairway used for movement, but also a Spiral Staircase which is the landmark to orient the traveler along the path.

Although most floor to floor transition points were mentioned generically, some were explicitly named. These were the Grand Staircase, the Spiral Staircase, the Silver Elevator, and the Gold Elevator. These were referred to by name in several of the verbal and sketch map descriptions. It is interesting to note that in these cases participants used these specific names. This communicates a global understanding of what these landmarks were, indicating

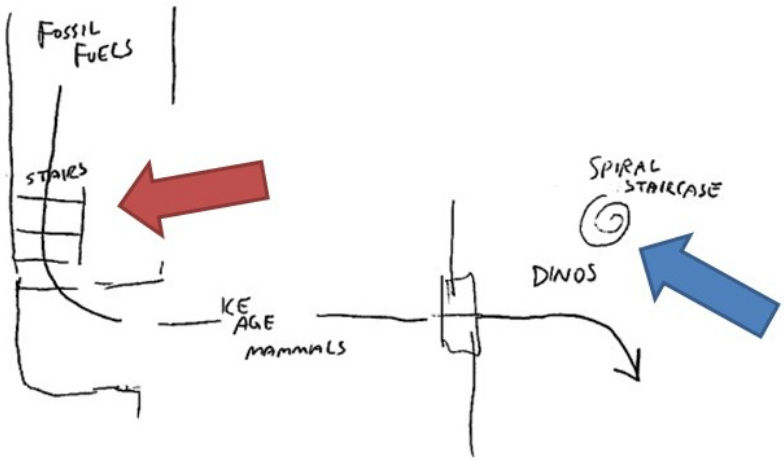

Figure 5 Figure showing functional floor to floor transition points (red arrow added) as well as referential floor to floor transition points (blue arrow added).

that they might be important. An interesting observation is that these floor to floor transition points, in particular, are visually distinguishable from other labeled entities in the museums. It is likely that this distinguishability is what makes the Grand Staircase, the Spiral Staircase, the Silver Elevator, and the Gold Elevator important landmarks in the environment [17, 21].

4.2 Dual representation – both functional and referential for distinct floor to floor transition points

A dual representation of a floor to floor transition point means that the point is represented not only as a way to get from floor to floor, but as a reference point for wayfinding in general. A functional quality of a floor to floor transition points meant that its purpose in the wayfinding description was to provide a means to get from one floor to another. A referential quality meant that a floor to floor transition points was simply an indemnity and did not serve as a way to move vertically through the environment. All floor to floor transition points were represented as being functional in at least one description. However; some floor to floor transition points that were represented referentially as well. Figure 5 shows a sketch map from the study that shows two stairways: One being included for function (red arrow) and one being a landmark (blue arrow). An interesting observation is that the referential floor to floor transition points are also given a descriptive name while the functional floor to floor transition points are generic.

In this particular environment of the Carnegie Museums of Art and Natural History, the floor to floor transition point that was most often represented as both a functional and descriptive landmark in both verbal and sketch map descriptions is the Grand Staircase. Figure 6 shows an example of the Grand Staircase being portrayed as a functional floor to floor transition point, while Figure 7 shows the Grand Staircase as a landmark floor to floor transition points.

An interesting example from the verbal analysis showing the Grand Staircase as a landmark was as follows: *"go out to the front of the building by the Grand Staircase and take the elevator down to two."* In this case the Grand Staircase is being referred to by its descriptive name, but then the participant tells the addressee to use the elevator to go down to two. This verbalization shows a deliberate instruction to use the elevator to complete

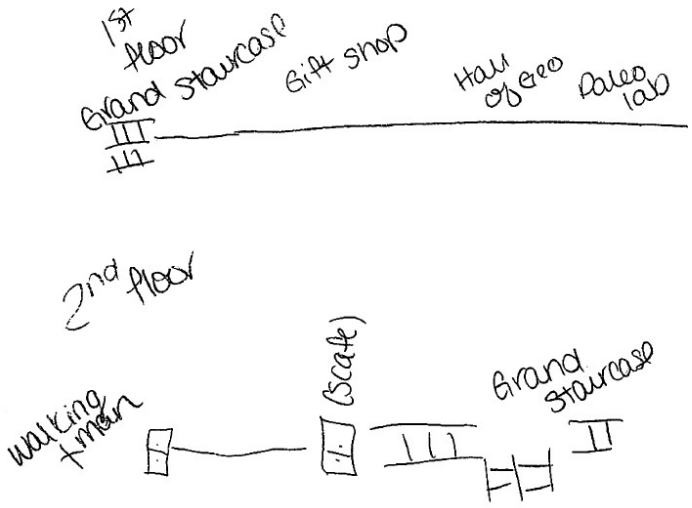

Figure 6 The Grand Staircase as a named functional floor to floor transition points, moving the traveller from the 1st to the 2nd floor.

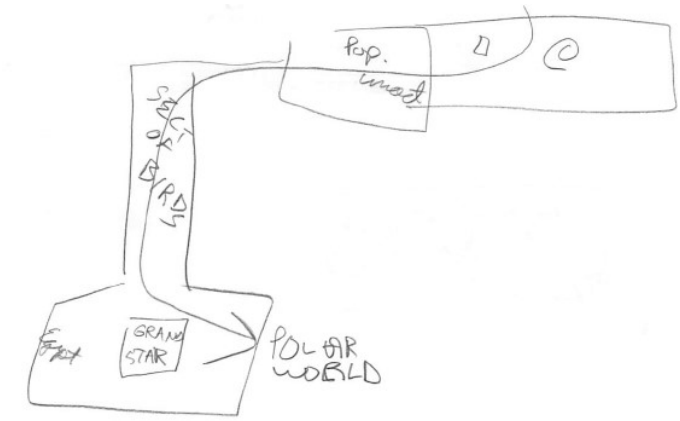

Figure 7 The Grand Staircase ("Grand Stair") as a floor to floor transition point landmark.

the function of going from floor to floor while referring to the Grand Staircase to provide orientation information.

4.3 Where the floor to floor transition points lie structurally in the museums

Where a floor to floor transition point lies in the overarching structure of the museum is important in determining the importance of the floor to floor transition points as a landmark. The literature shows that a landmark is structurally important if it is located somewhere significant in the structure of the space [21]. The three dimensional nature of the museums means that "in order to change floors in a building, for example, it is necessary to move to a location that allows vertical movement such as a staircase" [3]. This vertical movement meant that several of the important landmarks in the cognitive maps of participants were the floor to floor transition points. When applying this definition to the museums, the Grand

Staircase emerges as a particularly important landmark. The Grand Staircase spans all four floors and also sits between the natural history and art museums making it the most important landmark in this case study. Furthermore, while the Grand Staircase was used both for travel and a referent, the Spiral Staircase was used primarily as a referent. The verbal analysis shows that a landmark with the ability to be verbalized as being "down" or "up" from another landmark is of particular importance since these were the most used verbalizations after the word "to."

4.4 Towards a definition of global landmarks

Landmarks, in general, provide a structured knowledge of an environment, usually in terms of an anchor point [5]. Particular to global landmarks, they provide a point of reference for the participant, allowing for orientation and a sort of "compass" effect [22]. One of the difficulties in indoor wayfinding is the fact that it is easy to define landmarks on the local level but not on the global scale [8]. The concept of a local landmark is easily transferred to an indoor environment due to the natural chunking of spatial information in an indoor environment [12]. The unique characteristics of floor to floor transition points make them ideal candidates for global landmarks.

By examining the floor to floor transition points at the Carnegie Museums of Art and Natural History in terms of their ability to be named, their representation as either functional or landmarks, and their location in the structure of the building an idea of a global landmark begins to emerge. The Grand Staircase, the Spiral Staircase, the Gold Elevator all met the first two criteria. However, central location of the Grand Staircase made it the strongest candidate for a global landmark amongst the four.

5 Conclusions

Through the collection of suggested routes by trained staff at a large museum, this study was able to identify floor to floor transitional spaces in large complex indoor environments, which share numerous properties with traditional outdoor/indoor transitional spaces. The study also investigated the possibility of floor to floor transition points as global landmarks in indoor environments.

In addition, the study uncovered some interesting asymmetries between drawings and instructions to be explored in future work. For example, there were several ramps that took patrons to half floors, which were noted in the verbal descriptions, but rarely drawn on the maps as unique features. This difference between the sketch map and verbal descriptions supports the theories that there are differences in how we describe spaces when asked to describe them verbally or spatially [16]. However, in order to fully determine this, a full set of verbal data would need to be taken in conjunction with sketch map data. Finally, the results can give guidance in terms of automatic route generation by determining what elements would constitute the best global landmarks especially as transitioning from one area, or floor, to another in a complex indoor environment.

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