A COMPREHENSIVE STUDY OF INTERNAL REPRESENTATIONS OF FLOOR TO FLOOR TRANSITION POINTS IN A LARGE COMPLEX INDOOR ENVIRONMENT

by

Cristina Robles Bahm

BS Management Information Systems, Rochester Institute of Technology, 2007

Master of Information Management, University of Maryland, College Park, 2011

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This dissertation will be presented

by

Cristina Robles Bahm

Stephen Hirtle, PhD, Professor

Hassan Karimi, PhD, Professor

Alexander Klippel, PhD, Associate Professor

Michael Lewis, PhD, Professor

Dissertation Director: Stephen Hirtle, PhD, Professor

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Cristina Robles Bahm, MIM

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Wayfinding in complex indoor environments can be a stressful and disorienting activity. Many factors contribute to this difficulty, one reason being the number of floors paired with many different and often unpredictable ways to get from one floor to another. This dissertation focuses on providing a comprehensive analysis of how the human cognitive system represents the spatial information in floor to floor transition points. In particular, this project will focus on the internal representations formed by people familiar with a particular complex environment. In order to accomplish this, a user study was conducted at the Carnegie Museums of Art and Natural History that drew participants from the Visitor Services Department. Participants were asked to give wayfinding descriptions to and from several landmarks in the museums with the majority of the routes spanning multiple floors. Both verbal descriptions and sketch map descriptions were studied. It was found that floor to floor transition points were often represented as landmarks with two landmarks in particular being represented often as both functional as well as reorientation landmarks. This finding continues the discussion on global landmarks and their representation and salience in large complex indoor environments.

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PREFACE

First and foremost I want to thank Dr. Hirtle my advisor and committee chairperson for his help and support over the years. I have developed into a better writer and critical thinker under his mentorship. I would also like to thank my dissertation committee members: Dr. Lewis, Dr. Karimi, and Dr. Klippel for their comments and encouragement. I also wish to thank my colleagues in the PhD program who have helped me by listening and giving me great feedback. I would like to thank Brandi Belleau, Alka Singh, Marcy Walls, and everyone on the fifth floor for helping me in the final months of my dissertation. Also to my friends Kat and Sarah for listening and giving great encouragement.

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Lastly, I would like to thank my brother and my mother, because I wouldn't be where I am today without them.

1.0 INTRODUCTION

Human beings engage in wayfinding, finding one's way around a space, on a daily basis. If the final destination is somewhere familiar one usually knows where to go, how to get there, and can do so typically without many complications. Conversely, when the environment is difficult it becomes more likely that one will get lost. In a difficult environment it becomes more important to determine why one gets lost and how this can be prevented (Carlson, Hölscher, Shipley, & Dalton, 2010). For this reason, large complex locations become perfect places to study since it is in these locations that wayfinding problems are likely to arise (Hirtle & Bahm, 2015).

One of the tools humans use to successfully wayfind is the cognitive map (Tolman, 1948). This internal representation of spatial information allows engagement with the environment and thus successful completion of wayfinding activities. By comprehensively examining the cognitive maps formed of an environment that is difficult to navigate, one can begin to look at how the human cognitive system represents the spatial information it encounters in difficult spaces (Carlson, Hölscher, Shipley, & Dalton, 2010; Hölscher, Meilinger, Vrachliotis, Brösamle, & Knauff, 2006; Li & Giudice, 2012; Li & Giudice, 2012).

1.1 PROBLEM STATEMENT

Wayfinding in and of itself has a large and diverse body of literature. Of particular interest to this project is the study of cognitive maps, particularly those of people familiar with a large complex indoor environment. Environments such as large museums, large libraries (Li & Klippel, 2012), and large convention centers (Hölscher, Meilinger, Vrachliotis, Brösamle, & Knauff, 2006) present a unique and interesting set of wayfinding difficulties. Many aspects of large complex indoor environments make it difficult to "get ones bearings" when attempting to get from point A to point B (Carlson, Hölscher, Shipley, & Dalton, 2010; Hirtle & Bahm, 2015; Hölscher, Meilinger, Vrachliotis, Brösamle, & Knauff, 2006). One reason it is difficult to navigate in a complex indoor environment according to Hölscher, Meilinger, Vrachliotis, Brösamle, and Knauff (2006), is that staircases, or floor to floor transition points, are often not depicted well on wayfinding aids. The primary goal of this dissertation research is to examine the cognitive maps formed by employees and volunteers who are familiar with the Carnegie Museums and, in particular, the floor to floor transition points. In turn, this research adds to the existing literature by providing comprehensive and extensive insights into the internal representations of floor to floor transition points in complex indoor environments space, specifically in the context of global landmarks.

Building off of one of the first studies (Thorndyke, P. W., & Hayes-Roth, B., 1982), wayfinding in indoor spaces has been gaining more attention in academic as well as commercial environments. A general study on why people get lost in several types of environments found that the structure of the building, the strategies and spatial abilities of individuals, and cognitive maps were the main contributors to getting lost (Carlson, Hölscher, Shipley, & Dalton, 2010). Another study focused on a particular location and conducted a case study in a shopping mall

(Dogu & Erlip, 2000), the focus of the case study being to determine what spatial factors affect wayfinding behaviors. This work found that participants still needed extra wayfinding information even in a location they perceived to be easy to navigate. Another study found that the representation of spatial information on transit maps impacted the decisions participants made in regard to their travel (Guo, 2011). Particular to the study of large complex indoor environments, Hölscher, Meilinger, Vrachliotis, Brösamle, and Knauff (2006) comprehensively studied wayfinding strategies in a large conference location. Another work focused on finding if wayfinding problems could be predicted by conducted a general exploration of a particular environment (Li & Klippel, 2012).

At the same time, work in transitional spaces has also begun (Kray et al., 2011). A transitional space, according to Kray et.al (2011) is a space between two areas that provides a transition between them.

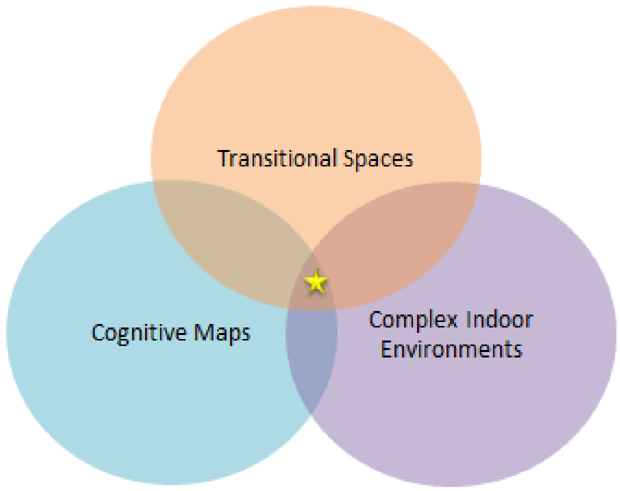


Figure 1. A Visualization of the areas that make up this dissertation

This dissertation blends the idea of complex indoor environments and transitional spaces by examining the way spatial information particular to floor to floor transition points is represented in cognitive maps. Figure 1 shows where this dissertation aims to focus in terms of the three areas mentioned above.

Since this work is focused in an indoor environment, transitional spaces become points where a person goes from one floor to another. That is to say, they are points where a person is neither on one floor or another, but somewhere in between. It is important to study these areas in large complex indoor environments because they are often points where people get lost (Hölscher, Meilinger, Vrachliotis, Brösamle, & Knauff, 2006; Li & Giudice, 2012;). Transitional spaces have been studied in terms of complex indoor environments but mainly from the point of view of cognitive map *formation* (Li & Giudice, 2012). This dissertation builds on, but is distinct from, previous work by taking a step back. Instead of examining how to facilitate the formation of cognitive maps, the focus is on examining the internal spatial representation of a complex indoor environment formed by people who are familiar with a space.

1.2 OVERVIEW OF WORK

This dissertation uses a descriptive approach firmly based in previous research to investigate how floor to floor transition points are represented internally by participants familiar with a large complex indoor environment. A user study was conducted at the Carnegie Museums of Art and Natural History in Pittsburgh, PA, USA. Both museums are housed in the same structure where they intersect and blend together. There are many spaces within the museums where patrons can become disoriented or lost when moving from floor to floor. This aspect of the museums in particular makes it an interesting space to study. In order to complete this analysis, employees and volunteers at the Carnegie Museums were asked to give route descriptions to and from various landmarks in the environment. Participants were asked to give both verbal and sketch map descriptions. All data was then analyzed by using slightly modified but established methods.

1.3 ORGANIZATION OF THIS DISSERTATION

The rest of this dissertation is structured as follows. Chapter 2 outlines related work in the three areas that have contributed to this study. This chapter also provides a description of the data analysis methods that were used in the study. Chapter 3 provides an overview of the research design. Chapter 4 outlines the results of the user study and includes a discussion of the findings. Lastly, Chapter 5 provides a conclusion and specifies future work.

2.0 RELATED WORK

The focus of this dissertation is on comprehensively examining the internal representations of floor to floor transition points in a complex indoor environment. This section also includes a discussion of the literature as well as the previous work that has contributed to the analysis framework applied in this project.

2.1 COGNITIVE MAPS AND THE INTERNAL REPRESENTATIONS OF SPACE

First introduced by Edward Tolman in 1948, the cognitive map is a notion that explains how human beings organize their external environment internally. External objects are organized in the human cognition in terms of their relationships to one another. In order to form these relationships, one must interact with and explore an external environment. Because the cognitive map is an aggregation of ones experience with an environment, it is often not an exact copy of an environment, but instead is a representation of how the environment is represented to the person who possesses the cognitive map (Nadel, 2013).

Over the years the theories of cognitive mapping have undergone many changes and renewals. The cognitive collage (Tversky, 1993) and the cognitive atlas (Hirtle, 2011) are two versions of the cognitive map. Amongst all its forms, one important concept remains: An internal representation of an external space.

In terms of spatial cognition, cognitive maps have been outlined as an internal representation of a spatial environment. From examining the integration of spatial and verbal mental models (Glenberg & McDaniel, 1992) to the study of how cognitive maps could be useful in 3D visualization techniques (Li & Giudice, 2012) the use of cognitive maps in spatial scenarios is well established. Particular to wayfinding, "…cognitive maps provide relevant information about where a goal is located, the routes one can take to get there from the current location, and the landmarks one will observe along the way." (Nadel, 2013, p.160). This makes the cognitive map central to the act of wayfinding and why it is the focus of this dissertation.

Recently, cognitive maps have been studied in regards to getting lost; it has been found that cognitive maps play a role in why people get lost indoors (Carlson, Hölscher, Shipley, & Dalton, 2010). It is the goal of one particular research group to make sure that displays of spatial information facilitate the formation of cognitive maps (Li & Giudice, 2012). It has also been proven that the formation of a cognitive map is particularly difficult in a multi-storied indoor environment (Hölscher, Meilinger, Vrachliotis, Brösamle, & Knauff, 2006; Li & Giudice, 2012). Internal representations also have a history of being considered when studying indoor space (Carlson, Hölscher, Shipley, & Dalton, 2010; Li & Klippel, 2012; Vertesi, 2008).

Taking these past works into account, the focus of this project is on providing a comprehensive examination of the internal representations of people familiar with the Carnegie Museums of Art and Natural History. Using participants familiar with a space allows the examination of a representation for a person who has had several varied interactions with the environment. The rest of this section outlines how wayfinding descriptions have been used in previous work to determine a participant's internal representation of space and which analysis methods were employed by past research.

2.1.1 Wayfinding descriptions

Although wayfinding descriptions have been studied as an area of research in and of themselves, in this dissertation, wayfinding descriptions are used as a data tool. It is outside of the scope of this dissertation to look at the formation and dissemination of route descriptions as the main subject of study. Although several researchers have studied issues in route descriptions (Allen, 1997; Allen, 2000; Ferretti& Cosentino, 2013) modeling spatial knowledge based on route descriptions (Schuldes et al., 2011) and the inclusion of landmarks in route descriptions (Hirtle, 2011). This dissertation is not concerned with the analysis of the structure of the route descriptions themselves, but rather on the internal representations that are communicated through the verbalization of the route descriptions.

2.1.2 Determining a participant's internal representation of a space

Previous work that guides this dissertation is in the areas of linguistic and graphical modeling (Appleyard, 1970; Hayward & Tarr, 1995; Kray et al., 2011; Landau & Jackendoff, 1993; Lohmann, 2011; Passini, 1981, 1984). In order to understand an internal representation of a space it is important to gain a comprehensive view of the space that includes both verbal as well as spatial information (Lohmann, 2011). In addition to applying traditional verbal methods, this dissertation also uses the findings of a verbal method specifically applied to transitional spaces (Kray et al., 2011). Figure 2 shows a general outline for the analysis framework of this study.

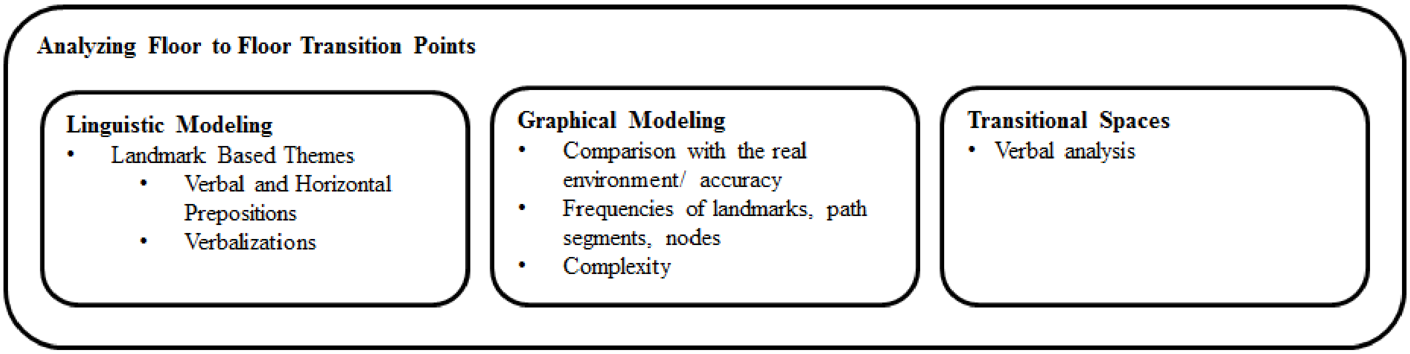


Figure 2. A graphic outlining the analysis framework described in Chapter 3

2.1.2.1 Linguistic modeling

Passini (1981, 1984) was one of the first to use a verbal report protocol to study wayfinding. Since this early work, linguistic analyses have been used by several researchers to define verbal report methods (Hayward & Tarr, 1995; Kray et al., 2011; Landau& Jackendoff, 1993), explore human interactions with environments (Hölscher, Meilinger, Vrachliotis, Brösamle, & Knauff, 2006), and examine the link between language and cognition (Holmes & Wolff, 2013; Spiers & Maguire, 2008).

Landmark Based Themes

Landmarks are an important part of an internal representation of space (Hayward & Tarr, 1995; Hirtle, 2011). This dissertation focuses on the analysis of landmarks in verbal descriptions by examining their placement in speech as a determination of how they relate to one another. For example, a grand staircase might intuitively be represented as a landmark, whereas a small ramp or staircase may not be. However, in this same scenario, the staircase that is used the most might be the smaller staircase. A landmark based theme would show this uneven representation in a participant's cognitive map.

The next sections specifies which verbal landmark based themes were used for this research project. Table 1 at the end of this section gives an overview of which verbal reports were used, which words they focused on, and which seminal paper the analysis method came from.

Vertical and Horizontal Prepositions

In this method, landmarks are related to each other in terms of vertically and horizontally oriented prepositions (Hayward & Tarr, 1995). In order to use this analysis method, one looks for two landmarks related to each other by a vertical or horizontal preposition. 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. Figure 3 illustrates this relationship. This method shows that vertical and horizontal words relate two spatial concepts to one another.

Verbalizations

The verbal modeling method based on verbalizations is a more robust and in-depth analysis of spatial language based on the work of Landau and Jackendoff (1993). This method focuses on a linguistic analysis based on landmarks as: axial parts, prepositions, the relative distance of regions, and paths and trajectories.

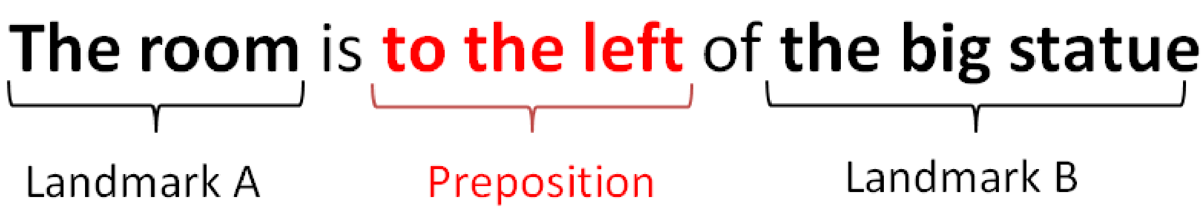


Figure 3. Example of a horizontal preposition

Axial parts: One of the focuses of this method is to examine the naming of spatial parts, namely axial parts, of objects. In terms of investigating landmarks and wayfinding descriptions, it is adequate to look at the axial parts of the complex indoor environment as an object. In the original method, words such as *on top of*, *on the bottom of*, *in front of*, *to the side of*, *ends*, or *behind* were examined because these words denote that the two objects that are being related by these words are parts of a whole. Overall, these words also show a connectedness between the landmarks and often a symmetrical representation of importance for the landmarks on a cognitive map.

Prepositions: 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 (1993):

"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" (Landau & Jackendoff, 1993). This means that the second sentence where the large distinctive immoveable object (the garage) is the figure is not likely to happen in language.

Relative Distance of Regions: This verbalization analysis method focuses on the regions in the dataset in addition to the objects. The distance between two objects as represented on a cognitive map can be concluded by dividing distance into four levels as shown below.

1) Region B is inside of Region A: *in, inside*

2) Region B is outside of Region A, but it is in contact with it: *on, against, along*

3) Region B is located in a Region proximate to Region A: *near*

4) Region B is located at a distance from Region A: *far, beyond*

Paths and Trajectories: This analysis method accounts for the analysis of paths and trajectories. In order to determine if there is a path or a trajectory between two objects it is only necessary to look at the relationship between two objects and how they are being related, likely in terms of their axial structures. Words that were analyzed fall into four classes:

- Axes of the Participant – These words are verbalized by participants in terms of their own horizontal axis. Words include: *forward, backward, sideways*
- Axes of the Earth – These words are verbalized by participants in terms of the axis of the Earth. Words include: *up, down, north, south, east, west*
- Orientation – These words are verbalized in terms of their orientation. Words include: *around, over, left, right*. The word *turn* may also be included in these types of verbalizations.
- Operators as defined by Landau and Jackendoff (1993) – These words are verbalizations that create paths between two objects. In the case of this study, two landmarks. Words include: *via, to, towards, from, away from*

Summary of Linguistic Modeling Analysis Methods

Table 1 below outlines the types of analysis that were conducted as well as the words that were annotated and analyzed and which seminal work the analysis method came from.

Table 1. Table showing the words that will be analyzed in the verbal portion of the project.

Type of Analysis	Sample Words to Look for	Seminal Work Cited
Vertical Prepositions	*Above,below,over, up*	Hayward, W. G., & Tarr, M. J. (1995).
Horizontal Prepositions	*Left, right, beside*	Hayward, W. G., & Tarr, M. J. (1995).
Distance Estimation	*Near,far, diagonal*	Hayward, W. G., & Tarr, M. J. (1995).
Verbalization – Axial Parts	*top, bottom, front, side, end,* or *behind*	Landau, B., & Jackendoff, R. (1993).
Verbalization – Prepositions	All words taking order into account	Landau, B., & Jackendoff, R. (1993).
Verbalization-Relative Distance of Region	*in, inside, on, against, along, near, far, beyond*	Landau, B., & Jackendoff, R. (1993).
Verbalization- Paths and Trajectories	*forward, backward, sideways, around, over, left, right, up, down, north, south, east, west, via, to, towards, from, away*	Landau, B., & Jackendoff, R. (1993).

2.1.2.2 Graphical Modeling

Graphical modeling methods, also known as sketch map methods, give insight into the internal representations of an external environment. From determining the representations people have of urban environments and underground areas (Vertesi, 2008) to using cognitive maps to determine how people visualize areas with vague geographical properties (Anacta, Humayun, Schwering, 2013). The use of sketch maps in order to study internal representations is well established. Although sketch maps usually do not give an exact copy of the environment (Hirtle, 2011; Lohmann, 2011) and do not typically follow map conventions (Lohmann, 2011) they have been used in many ways in geographical research (Agrawala & Stolte, 2001; Anacta, Humayun, Schwering, 2013; Guo, 2011; Vertesi, 2008) and have proven to be a valid tool in the study of cognitive maps.

A note on the reliability of sketch map data: Sketch maps have been studied in order to determine their reliability (Blades, 1990) and also to determine how much sketch maps actually represent the spatial knowledge of a participant (Lohmann, 2011). It has been determined that despite the fact that sketch maps are not an exact copy of an external environment, they provide both a reliable source of data as well as a basis in which to measure spatial knowledge (Lohmann, 2011).

Comparison with the real environment - accuracy

In order to gauge whether or not a sketch map is accurate it is only necessary to look at how well it compares with the real environment. This is a commonly used metric when assessing sketch map data (Lohmann, 2011; Rovine & Weisman, 1989). Although a cognitive map is not an exact replica of a space, accuracy can be measured as a modified metric defined by previous work (Rovine & Weisman, 1989). In order to assess whether the placement of a landmark is accurate only 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.

Frequencies of landmarks, path segments, and nodes

Frequencies of landmarks, path segments, and nodes (Rovine & Weisman, 1989) in the sketch map data 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. Wayfinding descriptions with more path segments and nodes can also be inferred to be more complex as they relate more spatial information.

Complexity of a sketch map

In order to determine the complexity of the sketch map, a metric developed by Appleyard (1970) is a well-used metric. The complexity of a sketch map can begin to be determined by examining the composition of the sketch map as two elements:

1) Sequential elements – essentially paths
2) Spatial elements – individual landmarks or areas.

In addition to the overall category of sequential and spatial elements, the maps were evaluated by observing where they fell into the map categorization developed by Appleyard (1970). The four map types in the categorization of sequentially dominated maps in ascending order by complexity are: 1) Fragment maps 2) Chain maps 3) Branch and Loop maps 4) Network maps. The four map types of spatially dominated maps in ascending order by complexity are: 1) Scattered 2) Mosaic 3) Linked 4) Patterned. Table 2 summarizes the four map types for both sequential and spatial maps. Figure 6 is directly from the literature and shows examples of the eight map types.

Sequential Map - Fragment maps are the most basic type of sketch map possible and, in turn, the least complex. This type of map consists of various paths that are often not connected to each other. An internal representation of a space in a sketch map that is predominately a fragment map will be the least complex representation category.

Sequential Map - Chain maps are the next level of complexity in terms of sketch maps in this analysis. The main difference between a fragment map and a chain map are low level connections between sequential and spatial aspects of the map. Usually in a chain map only major arteries are represented.

Sequential Map - Branch and Loop maps are slightly more developed than chain maps. Usually branch and loop maps contain, "loops and branches as common outcrops from the basic linear system." Although represented on the sketch maps, loops and branches are often drastically simplified versions of the actual environment.

Sequential Map - Network maps are maps that are the most complex. In terms of this dissertation they will include most paths and be the most detail oriented maps classified.

Spatial Map – Scattered maps are the most primitive version of spatial map. Similar to the fragment map type of a sequential map, a scattered map would have landmarks placed in an unconnected manner throughout the sketch. Little or no information about the path will be present. This map is the least complex version possible.

Spatial Map – Mosaic maps are next in terms of complexity when analyzing spatial sketch maps. This type of map is defined by its capturing areas of the map. For instance, a room of the museums may be circled off from the rest of the map and may be defined as a "zone." Essentially in this type of representation landmarks are being grouped together, but no paths between them are represented.

Spatial Map – Link maps are slightly more sophisticated versions of mosaic maps. In this type of map places and areas represented as landmarks or landmark "zones" are now connected. Although not a sophisticated connection, a link present between these areas is now present.

Spatial Map – Pattern maps are the most complex of the spatial maps. A map is classified as being a pattern map when it highlights the dominant landmarks of the area. These maps are also highly accurate and usually very detail rich.

Table 2 below shows a summary of the map features discussed above as well as examples that define them. The sketch maps produced by participants were grouped into these eight map types.

Table 2. Map types for sketch map categorization based on Appleyard (1970).

Map Type	Complexity	Map Category	Description
Sequential	1	Fragment	Few paths represented. Unconnected.
Sequential	2	Chain	Some major connections present.
Sequential	3	Branch and Loop	More connections present, some minor connections represented.
Sequential	4	Network	Full representation. Most accurate. Detail oriented.
Spatial	1	Scattered	Few landmarks represented.
Spatial	2	Mosaic	More landmarks present. Grouped into areas.
Spatial	3	Link	Links present between landmarks and areas.
Spatial	4	Pattern	Accurate, detail oriented representation. Most landmarks present and connected to each other

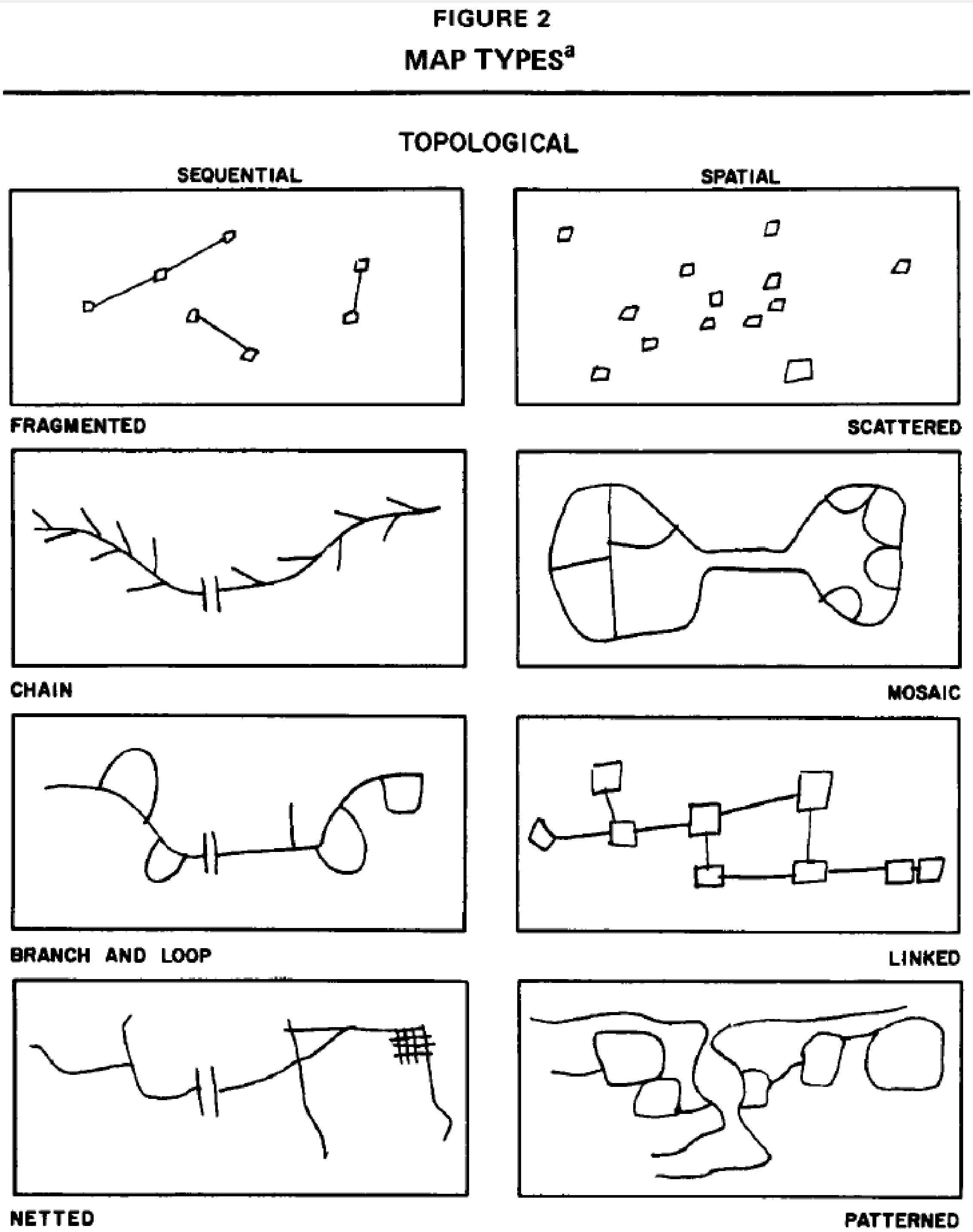


Figure 4. Example directly from Appleyard, 1970 that shows the eight map types

Summary of Graphical Modeling techniques

In conclusion, Table 3 summarizes these graphical modeling methods by providing the name of the analysis method as well as a description and the work which defines it. The first method focuses on the accuracy of the sketch map. The second method focuses on the frequencies of landmarks, path segments, and nodes in the sketch maps. Lastly, the third method focuses on the complexity of the sketch map.

Table 3. Summary of Graphical Modeling Methods

Method	**Description**	**Seminal Work**
Comparison with real environment - accuracy	Does the sketch map fulfill the following two criteria? 1) the landmark appears in the correct sequence 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.	Rovine, M. J., & Weisman, G. D. (1989). Sketch-map variables as predictors of way-finding performance. Journal of Environmental Psychology, 9(3), 217-232.
Frequencies of landmarks, path segments, nodes	Count the frequency in which landmarks, path segments, and nodes are represented on sketch maps.	Rovine, M. J., & Weisman, G. D. (1989). Sketch-map variables as predictors of way-finding performance. Journal of Environmental Psychology, 9(3), 217-232.
Complexity of the sketch map	Determine if sketches are more sequential or spatial data. Determine which of the four levels of complexity the map falls into as described in Chapter 4.4.3.	Appleyard, D. A. (1970). Styles and methods of structuring a city. Environment and behavior, 2, 100-116.

2.1.2.3 Transitional spaces

Researchers found that transitional spaces are verbalized differently usually using words that are specifically transitional in nature to relate objects to one another (Kray et al., 2011). Figure 5 from Kray et al. (2011) shows the words that were found to be transitional in nature as well as their frequencies from the original work.

Words such as "on the left side" were found to be transitional in nature and because of this would still be transitional in an indoor environment. Similar to the preposition analysis methods applied in this work, if two landmarks were related to each other by the word "through" they were coded as being transitional.

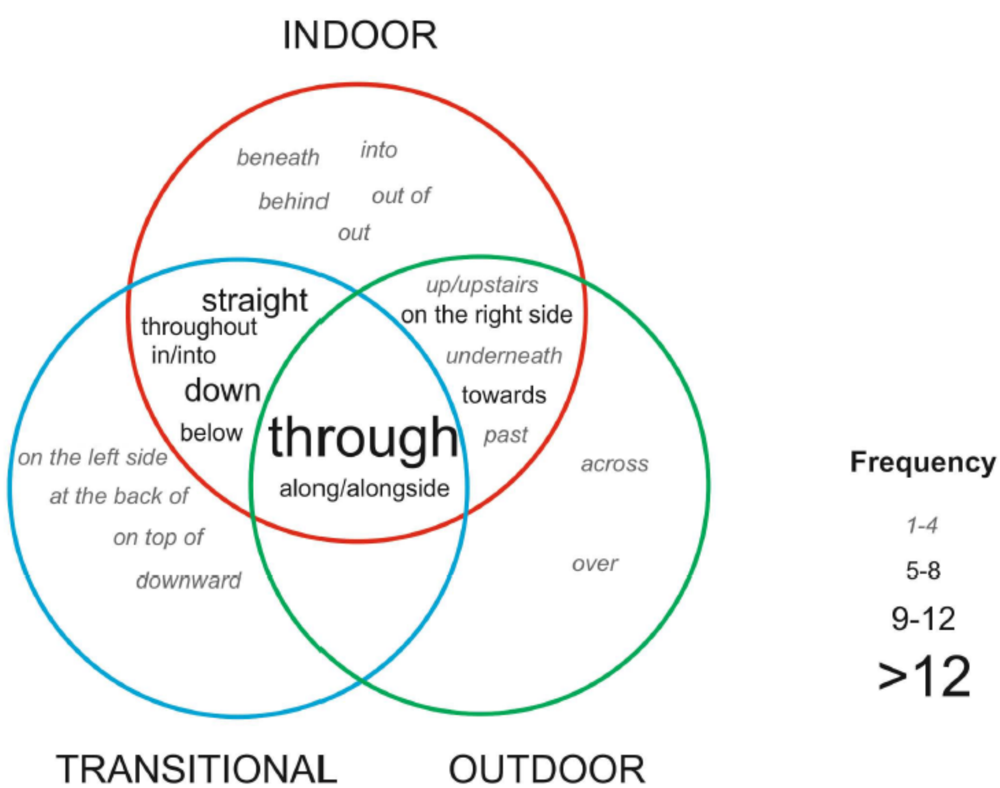


Figure 5. Original image from Kray et al. (2011) showing results of transition spaces analysis

2.2 COMPLEX INDOOR ENVIRONMENTS

In general, indoor environments are well-studied in many fields. From wayfinding strategies in indoor environments (Hölscher, Meilinger, Vrachliotis, Brösamle, & Knauff, 2006) to indoor/outdoor transitional spaces (Kray et al., 2011), to immersion and its effect on cognitive map formation (Li & Giudice, 2013) indoor spaces are a rich and varied area of study. Specific to this project is the study of complex indoor environments also known as multi-storied buildings. Complex indoor environments are of particular interest to the research community because of the depth of problems that arise when traversing them (Carlson, Hölscher, Shipley, & Dalton, 2010; Li & Giudice, 2012).

2.2.1 Multi-storied buildings as three dimensional environments

Multi-storied environments are particularly complex in terms of wayfinding and the formation of a cognitive map. One of the reasons for this is that complex indoor environments are often three dimensional (Hölscher, Meilinger, Vrachliotis, Brösamle, & Knauff, 2006; Li & Giudice, 2012). A three dimensional environment allows for vertical as well as horizontal movement, "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." (Buechner, Hölscher, & Strube, 2007). When thinking of an environment as 3-D it becomes easy to see how one could get lost in this type of environment.

2.2.2 Difficulties in multi-storied buildings

Once one begins thinking about a multi-storied building as a three dimensional environment it is not difficult to see why multi-storied buildings are difficult to navigate. A wide-ranging study on wayfinding strategies in a large complex indoor environment found that there were seven points, deemed "hot spots," in the building that made it difficult for participants to navigate (Hölscher, Meilinger, Vrachliotis, Brösamle, & Knauff, 2006). Of particular interest, it was determined that one of the main reasons for getting lost in the environment was the fact that there was no central stairway that served as a global landmark. There was also a difficulty with the placement of the stairway that most participants used since it was a smaller stairway that appeared out of the way. Because of its architectural unimportance, it was counter-intuitive that the smaller stairway would be the one that was used the most frequently. In addition to their potential difficulty from their placement in the structure of the building, stairways are often cited as a reason for why wayfinding can be difficult because they are disorienting (Li & Giudice, 2012).

In regards to navigation in a multi-storied building, it has been found that people who are familiar to an environment are able to "chunk" the information on each floor and divide the floors into several two dimensional structures that are layered on top of one another. This strategy would be useful for a person who is familiar with the environment to form an internal representation of the space (Hölscher, Meilinger, Vrachliotis, Brösamle, & Knauff, 2006). It has also been found that participants "chunk" landmarks on floors as well (Buechner, Hölscher, & Strube, 2007).

2.3 TRANSITIONAL SPACES

The concept of a transitional space has become increasingly popular in the spatial community. In particular, Kray et al. (2011) described a transitional space as a space in an environment that serves as a way to transition from one area to another. In this context, examples of transitional spaces are: subway tunnels, plazas, passages, footbridges, tunnels, and courtyards. Researchers examined transitional spaces from a linguistic point of view with the goal being to determine how transitional spaces were verbalized by participants. It was determined the words participants used to describe transitional spaces are different.

In relating a cognitive map to a transition space, researchers have done so from the perspective of the facilitation of the formation of cognitive maps where transition points are concerned (Li & Giudice, 2012), the effects of immersion and body-based rotations on leaning multi-level virtual environments (Li & Giudice, 2013), and how they can contribute to someone getting lost in a building (Carlson, Hölscher, Shipley, & Dalton, 2010).

2.4 HOW THIS PROJECT IS DIFFERENT

This dissertation is different from the previous work outlined above because it begins to examine the mental representations of a large complex indoor environment particular to its floor to floor transition points. This project builds on this previous work by providing a thorough descriptive analysis of internal representations, complex indoor environments, and floor to floor transition points.

3.0 RESEARCH DESIGN

In order to comprehensively explore the internal representations of floor to floor transition points in a large complex indoor environment a user study was conducted at the Carnegie Museums of Art and Natural History (Carnegie Museums). The space is a large complex indoor environment that possesses several challenges to wayfinding as outlined in the literature (Carlson, Hölscher, Shipley, & Dalton, 2010; Hirtle & Bahm, 2015; Hölscher, Meilinger, Vrachliotis, Brösamle, & Knauff, 2006). Participants who were familiar with the environment were asked to provide several wayfinding descriptions to and from a variety of locations in the environment.

3.1 STUDY ENVIRONMENT

The environment chosen for the study was the Carnegie Museums of Art and Natural History. Total square footage for the museums is 494,132 square feet. The attendance per year is approximately 330,000 visitors. 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. In addition to the complexities, there are several ways to get from one floor to another, with some floors not connecting to each other in a predictable way. Figures 6 and 7 shows the current map for the environment provided by the museums these maps are shown larger in Appendix A.

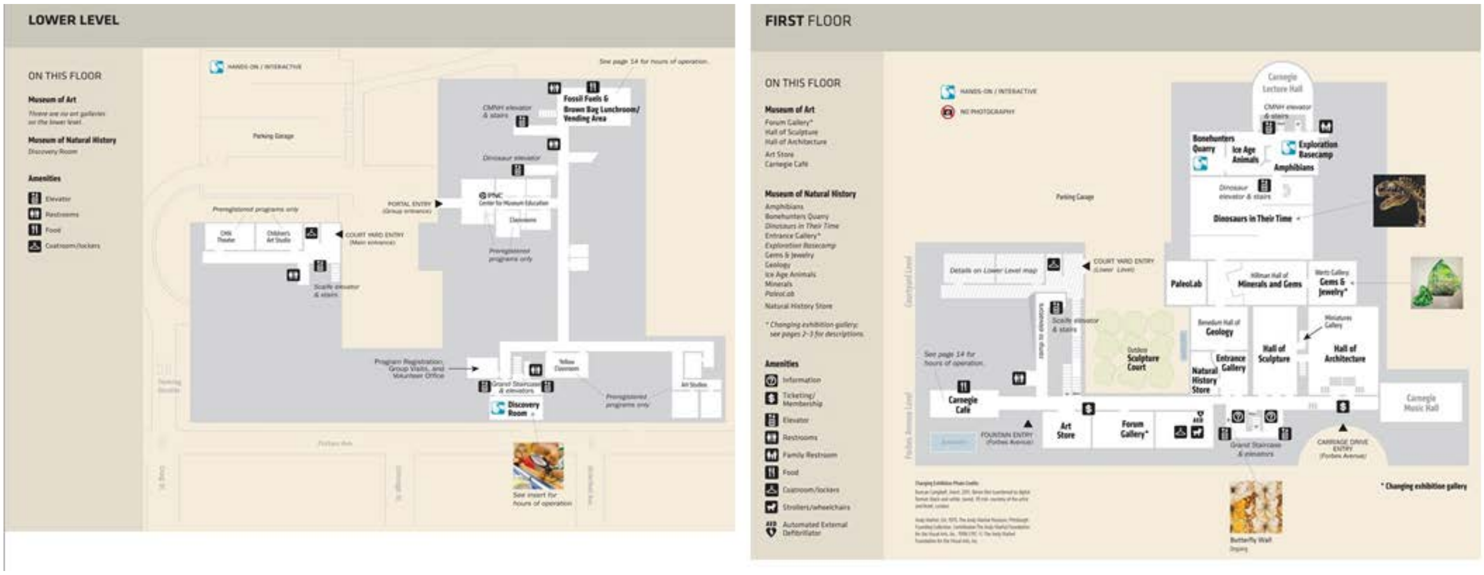


Figure 6. Floor maps for lower level and first floor

The current map displays the floors separate from each other. Floor to floor transition points are represented as icons and can be used by museums patrons to “anchor” themselves on each floor.

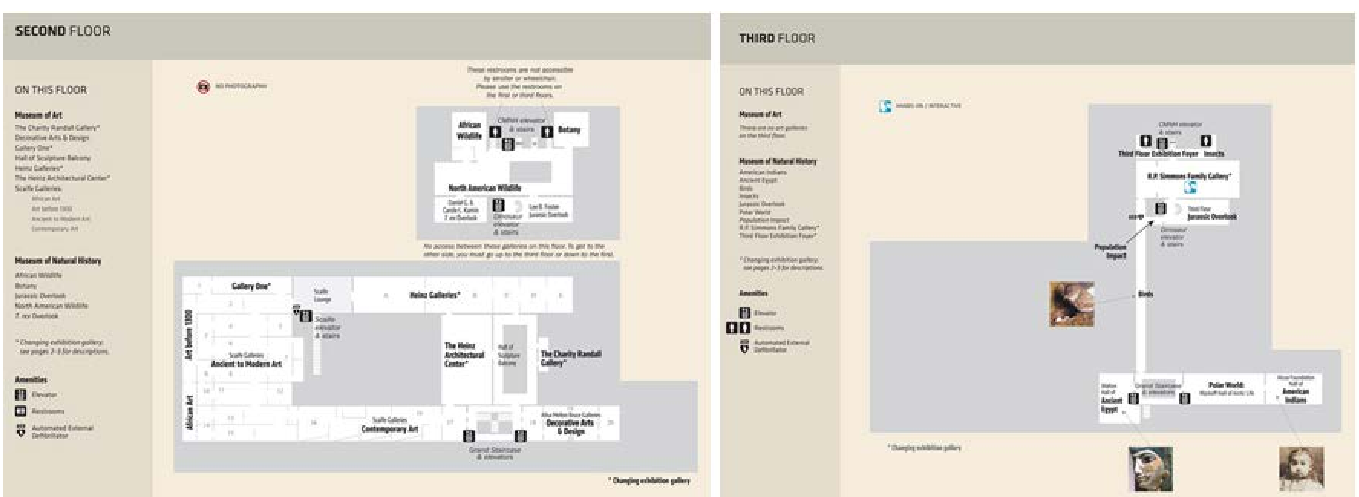


Figure 7. Current maps for second and third floor at the Carnegie Museums.

This building is difficult to navigate for several reasons. According to previous work (Hirtle & Bahm, 2015), this building possesses the following qualities that make it difficult to navigate:

- Lack of visual access
- Navigational aids make wayfinding difficult
- Mental maps are difficult to construct of the space
- The physical environment/the structure of the building is unpredictable

The Head of Visitor Services at the Carnegie Museums of Art and Natural History gave 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: according to the Head of Visitor Services one of the biggest challenges with wayfinding in the museums is the fact that there are several half floors throughout the space. Visitors often enter through the back of the museums because it is the entrance near the parking garage. However, this entrance lies between the lower level and first levels which makes it difficult to represent on wayfinding aids. One of the most visible places in the museums is the gift shop and the café which is on floor one. However to get to this landmark from the back entrance of the museums, one must go up a ramp or up a set of stairs. On the museums maps this entrance is depicted as if it were on the first floor when in reality it is not.

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 is supposed to be a singular one; however, according to the head of visitor services at the museums, people usually come to visit one or the other. This is problematic because the museums are linked physically. For instance, the best way for a person in need of handicapped access to get from the main entrance to the Museum of Natural History is to go through the Museum of Art.

No distinct entrance: One problem that the Head of Visitor Services cited was the fact that the museums are missing a main entrance. Often when people visit the museums they come in through the back entrance. As you can see from the map many people use this entrance because it is the closest to the parking garage. Although this is the entrance that most people use to enter the museum, many people get lost after they enter regardless of signage. Also, because the entrance resides on a half-floor it is, presumably, not easy to place as a landmark.

In addition to the entrance to the museums at the back of the space there is also the entrance for employs and school groups. Often patrons who intend to enter through the back entrance of the museums end up entering through the employee only entrance.

In conclusion, the Carnegie Museums of Art and Natural History provide a rich study space to conduct this dissertation work. Both academically and anecdotally defined as a difficult space, this environment offers several areas of difficulty as well as floor to floor transition points in which to examine. Particularly, the difficult floor plan, multiple “half floors” and the fact that mental map is difficult to construct of the space.

3.2 PARTICIPANTS

Employees and volunteers in the Visitors Services Department of the museums were recruited as participants. This group is familiar with the space and is often tasked with standing at help desks throughout the museums to aid patrons in finding their way around. Because of this, they likely to have a robust internal representation of the environment that has developed naturally over time. More importantly, they are accustomed to giving wayfinding descriptions in ways that visitors to the museums require them and are required to give wayfinding descriptions that include public spaces only. 20 volunteers/employees participated in the study, 10 men and 10 women ranging in age from 19 to 77 years. At the time of the study they had been employed at the museums an average of 31.7 months.

3.3 DATA COLLECTION

After consent was attained, participants were asked to give 22 wayfinding descriptions from 17 origin and destination locations/landmarks. Because the second floor proved to be a particularly difficult area, additional descriptions involving the second floor were added. The entire experiment was videotaped. Participants were sitting while the experiment was taking place. They were instructed to give the description "as if they are giving directions to a patron who is not familiar with the environment." After being given the instructions, participants were free to imagine the direction they were facing and generally used left/right/up/down once they left the initial room. During the time the experiment was conducted a section of the museums was closed to the public. Because of this, participants were instructed to give instructions "as if they were giving the directions today." Participants did not have access to the museum's maps during the experiment. Participants were not corrected if the wayfinding description they gave was not correct or included the closed area. Wayfinding descriptions were asked to be given in verbal and sketch map form. Whether the participant was asked to give the sketch map or the verbal description for a particular route was counterbalanced across participants. They were asked to provide the verbal descriptions first, followed by the sketch map descriptions.

Table 4 gives a detailed outline of the route description, the floor the description starts on as well as the floor it ends on, and which landmarks on each floor the participants are being asked to give the description to and from. Landmarks were either singular landmarks such as the "T. Rex" or commonly visited areas of the museums for instance "African Wildlife."

Table 4. Detailed view of routes chosen for user study

Description	Starting Floor	Ending Floor	Starting Landmark to Ending Landmark
1	Basement	Basement	Rental Lockers to Fossil Fuels
2	Basement	1	Fossil Fuels to T. Rex
3	Basement	2	Fossil Fuels to African Wildlife
4	Basement	2	Fossil Fuels to Walking Man
5	Basement	3	Fossil Fuels to Polar World
6	1	Basement	Exploration Basecamp to Fossil Fuels
7	1	1	T. Rex to Hall of Architecture
8	1	2	Exploration Basecamp to Walking Man
9	1	2	Exploration Basecamp to Botany
10	1	3	T. Rex to Hall of Birds
11	2	Basement	Walking Man to Fossil Fuels
12	2	Basement	North American Wildlife to Fossil Fuels
13	2	1	Heinz Galleries to PaleoLab
14	2	1	Botany to PaleoLab
15	2	2	Walking Man to North American Wildlife
16	2	3	African Wildlife to Polar World
17	2	3	Modern Art to Polar World
18	3	Basement	Ancient Egypt to Fossil Fuels
19	3	1	American Indians to T. Rex
20	3	2	Hall of Birds to African Wildlife
21	3	2	Hall of Birds to Heinz Galleries
22	3	3	Jurassic Overlook, Ancient Egypt

Verbal data was transcribed and coded by the researcher according to the methods outlined in the related works section. The frequencies of prepositions and landmarks as well as their relationships to one another were coded and analyzed. Axial parts, distance of regions, and paths and trajectories were also assessed. Analysis methods were applied to all landmarks mentioned, not just floor to floor transition points. Sketch map data was coded by the researcher and analyzed using the methods outlined in the Related Works section. Each map was examined and a determination was made about its accuracy. It was then given a complexity level. Landmarks, path segments, and nodes were counted. Routes that contained floor to floor transition points were examined more closely in order to determine how those floor to floor transition points were represented. Floor to floor transition points were also coded as being functional floor to floor transition points or landmark floor to floor transition points. Participants were then asked to complete the Santa Barbara Sense of Direction Scale (Hegarty, Richardson, Montello, Lovelace, & Subbiah, 2002). The purpose of which was to measure their individual spatial ability. Lastly, participants completed a map placement activity. During this activity they were given a copy of the current maps for the museums with the labels of all the landmarks removed. Figure 8 shows the label removal for one of the floors.

Participants were asked to place 17 landmarks on the blank map. The landmarks chosen were those that were the beginning and ending landmarks in the wayfinding descriptions. The purpose of this activity was to gauge how well they knew the museum.

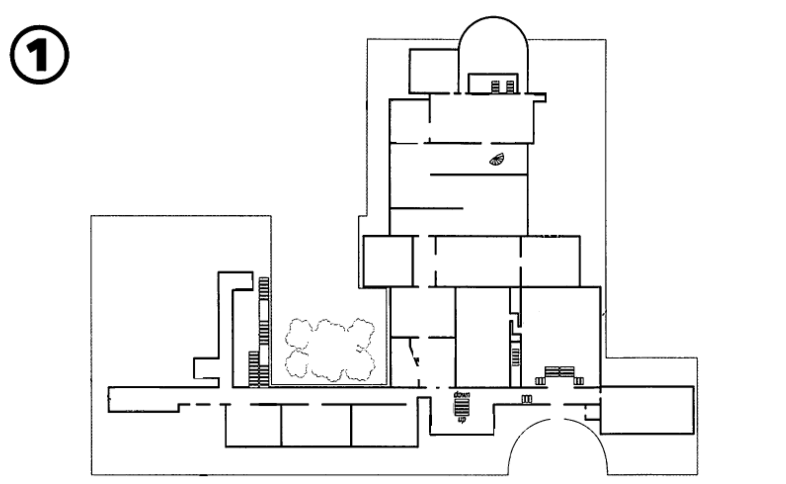


Figure 6. Floor 1 of the museums with labels removed for map placement activity.

4.0 RESULTS

This chapter is organized as follows: Section 4.1 describes the participants by demographics. Section 4.2 presents the results from the map placement activity. Section 4.3 presents the results from the verbal analysis. Section 4.4 describes the outcome of the sketch map analysis. Section 4.5 shows the results from the transitional spaces analysis. Section 4.6 provides a discussion of the results.

4.1 DESCRIPITION OF PARTICIPANTS

The gender of the participants was split evenly with 10 men and 10 women taking part in the study. They ranged in age from 19 to 77 years. The average was 32.7 years with a standard deviation of 15.55 years. Table 5 displays the number of participants in each age range.

Table 5. Table showing age range of participants

Age Range	Number of Participants
18-28	12
29-39	5
40-50	0
51-61	1
62+	2

At the time the study was conducted, participants had been employed at the museums an average of 31.7 months with the minimum being one month, the max 180 months, and the standard deviation being 42.41 months. All of these data are self-reported. Table 6 shows the data for the number of months worked at the museums per participant.

Table 6. Number of years participants had worked at the museums

Months Range	Number of Participants
<1	7
1-2	6
3-4	3
5+	4

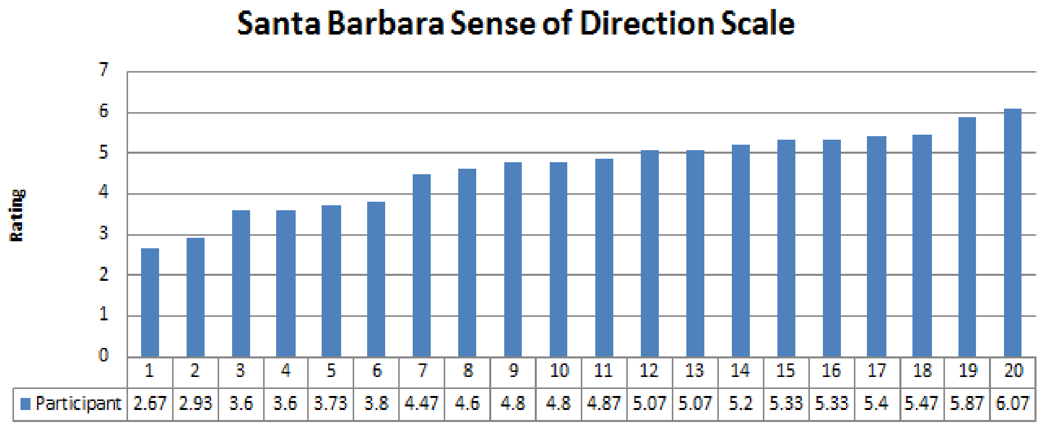


Figure 7. Results from the Santa Barbara Sense of Direction Scale per participant

Participants took a Santa Barbara Sense of Direction Scale (Hegarty, Richardson, Montello, Lovelace, & Subbiah, 2002). The results from the Santa Barbara Sense of Direction (SBSOD) Scale showed an average score of 4.63 with a minimum of 2.67 a maximum of 6.07 and a standard deviation of .95. A score of 4.7 suggests an "average" sense of direction (Hegarty, Richardson, Montello, Lovelace, & Subbiah, 2002). This indicates that participants in this study, as a whole, had a relatively characteristic sense of direction. Figure 7 shows the results from the Santa Barbara Sense of Direction Scale by participant in ascending order.

The results from the Santa Barbara Sense of Direction Scale were then further examined by comparing the results with the participant data. The data was first examined by gender. The average score for women was 4.79 with a standard deviation of .84. For men the average score was 4.81 with a standard deviation of .98. Table 7 below shows the results from this comparison.

Table 7. Comparison between Santa Barbara Sense of Direction and Gender

Gender	Santa Barbara Sense of Direction Score
Female	4.8
Female	5.33
Female	5.87
Female	5.47
Female	3.8
Female	4.47
Female	5.2
Female	4.6
Female	5.4
Female	2.93
Male	3.6
Male	5.07
Male	2.67
Male	3.6
Male	4.8
Male	5.07
Male	3.73
Male	6.07
Male	5.33
Male	4.87

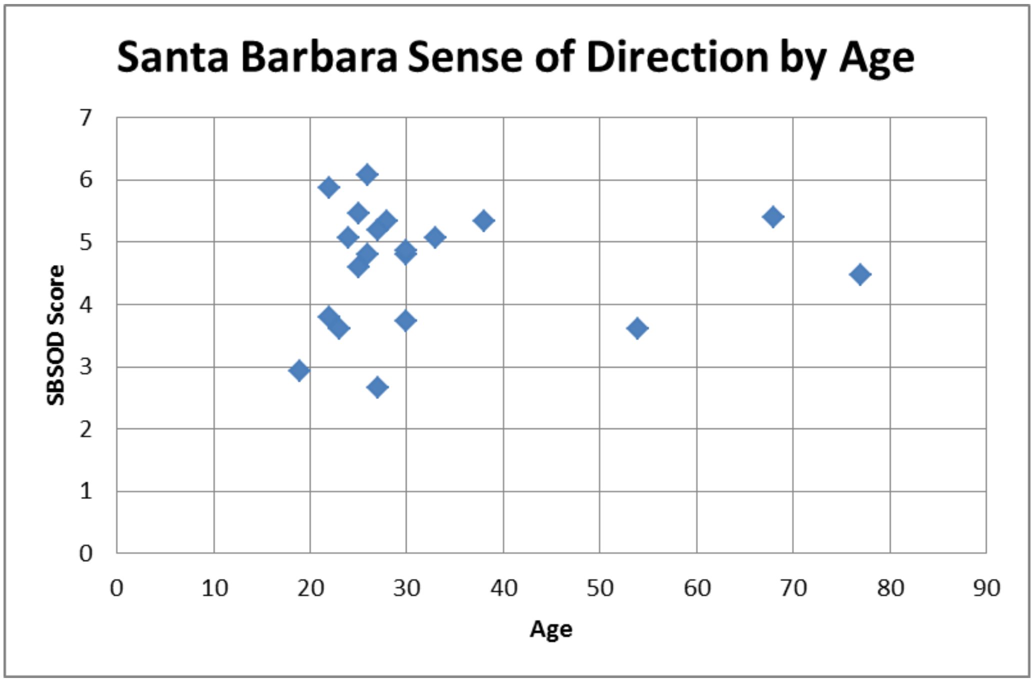


Figure 9. Santa Barbara Sense of Direction score by age.

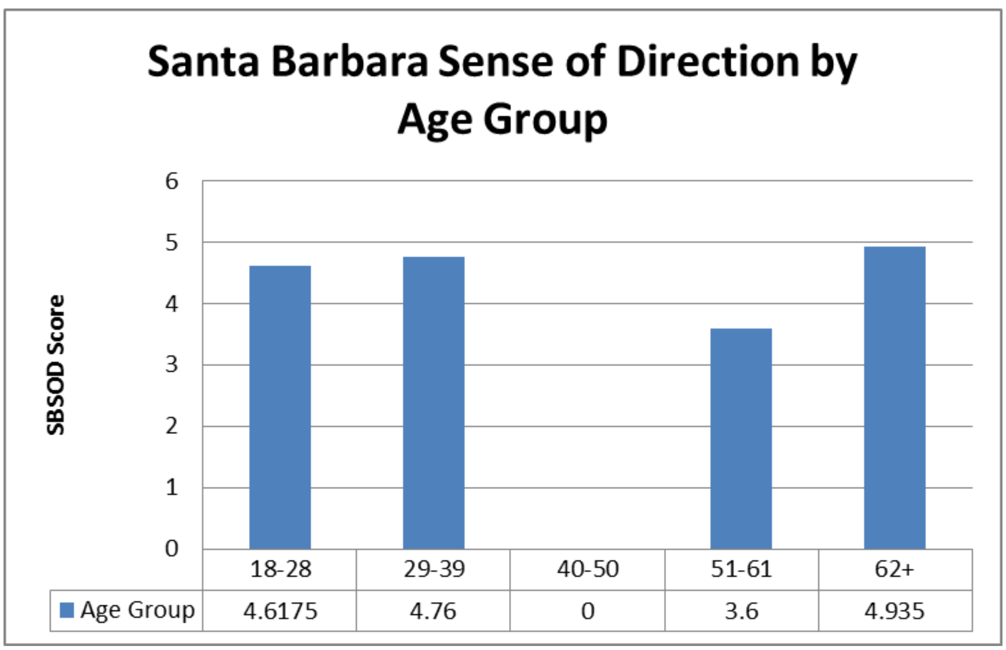


Figure 8. Santa Barbara Sense of Direction score by age group.

The Santa Barbara Sense of Direction scores were also examined in terms of age by looking at the average across age groups. These data are presented below in Figure 9. Lastly, the data was examined by comparing the scores from the SBSOD scale with the number of months participants had worked at the museums. Figure 10 shows the relationship between these variables.

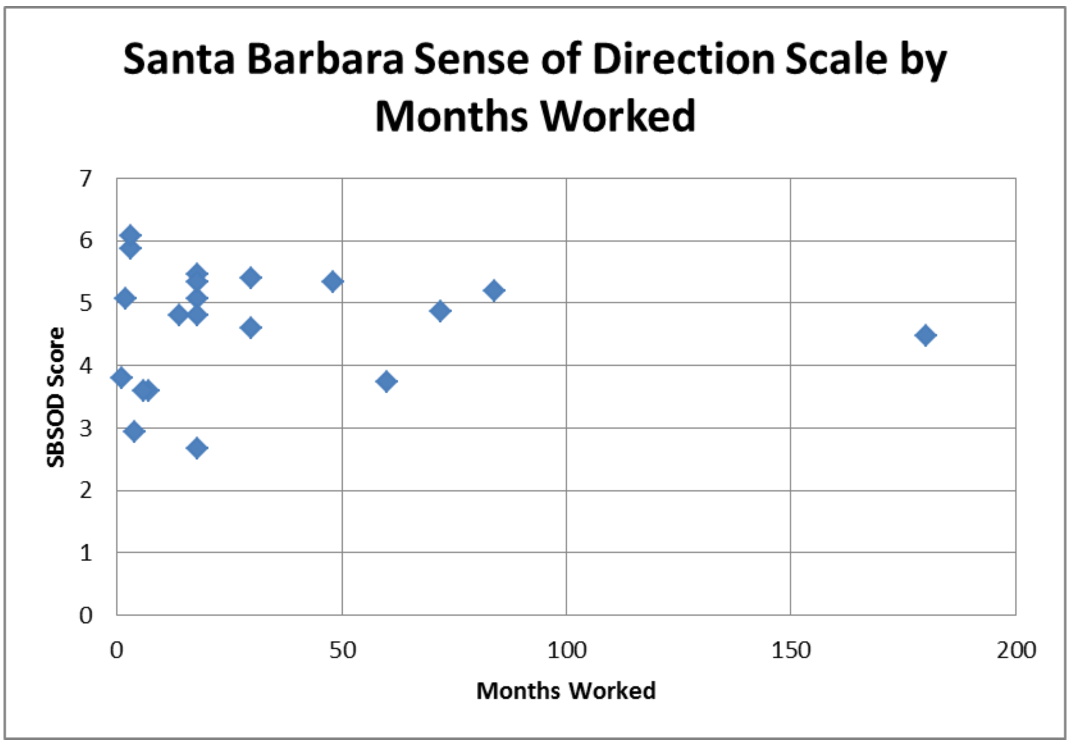


Figure 10. Santa Barbara Sense of Direction scale score by number of months worked at the museums.

4.2 MAP PLACEMENT ACTIVITY

The objects to be placed on the blank maps were either landmarks (for example: the T. Rex) or, more often, regions (for example: Modern Art). The map placement activity was analyzed in two ways: First, by determining if the object or region was placed on the correct floor, then by determining if the object was placed in the correct location. Determining whether the object was placed on the correct floor is self-explanatory. Landmark objects were marked in the correct location if they were placed in the correct region on the correct floor. While regions were marked as being in the correct location if the region indicated by the participant on the map was correct. A region is defined as the room or confined area within the museums where that area resides. Each region had clear boundaries on the blank maps as shown in the following figures.

Figure 11 shows an example of several regions that were marked as being correct while Figure 12 shows an example of the same floor with the landmarks being marked as incorrect. Several participants placed regions incorrectly did so because of a misunderstanding of the map itself. In these cases regions were placed outside of the boundaries of the museum. Figure 12 shows an example of this with American Indians being placed in a region of the map that is not part of the museum.

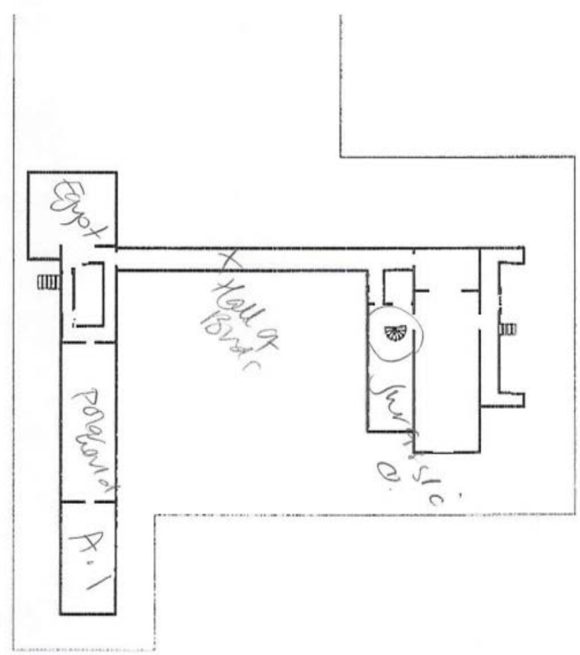


Figure 11. Regions that were marked correctly during the map placement activity

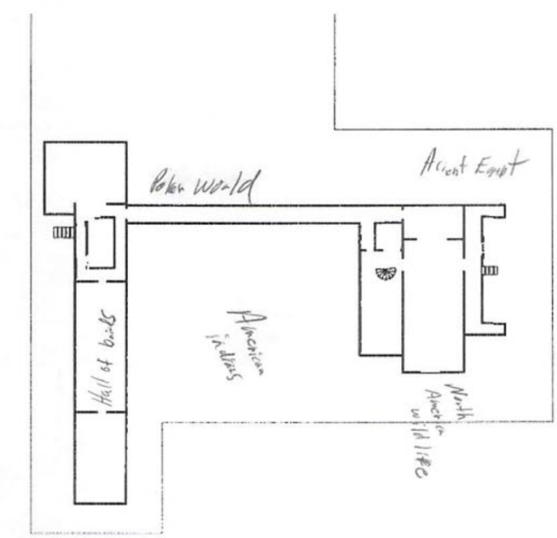


Figure 12. Regions that were marked as incorrect in the map placement activity

Table 8 shows the average number of landmarks that participants placed correctly. The maximum possible is 20 since there were 20 participants in the study.

Table 8 Average number of landmarks that were placed on floors and in the correct locations

Analysis	Average	Minimum	Maximum	Standard Deviation
Floor	18.05	5	20	3.32
Correct Location	13.11	3	18	3.98

The participant with the minimum number of correctly placed landmarks was included in the study for two reasons. First, the participant confused the art portion with the natural history portion of the museums causing them to confuse where the landmarks went even though they had them on the correct floor. Secondly, because this study focused on the information in the cognitive maps of participants it is important to appreciate that cognitive maps are not always exact, or correct, representations of an environment. The participant that couldn't find most of the landmarks in the map placement activity was still able to give wayfinding descriptions correctly.

In order to further analyze the map placement activity, the number of correct placements of the landmark per participant was examined. Since there were 20 participants, a landmark with a frequency of 20 indicates that all participants placed it correctly on the map. Table 9 shows these data.

Table 9 Number of participants who placed landmarks on the correct floor and correct location

Landmark	**Floor**	**Correct Location**
Hall of Birds	20	18
PaleoLab	20	16
Heinz Galleries	19	16
American Indians	19	16
Polar World	19	16
Fossil Fuels	19	15
Botany	19	14
Rental Lockers	19	12
Walking Man	19	11
Ancient Egypt	19	11
African Wildlife	19	10
Modern Art	19	5
T. Rex	18	16
Exploration Basecamp	18	16
Hall of Architecture	18	15
North American Wildlife	18	13
Jurassic Overlook	5	3

Most landmarks were placed on the correct floor, but often not in the correct region. The hall of birds was a landmark that was often placed correctly. This is likely because the hall of birds is easy to find on a map since it is a long easily identifiable hallway on the third floor. The Jurassic Overlook was a landmark of particular interest because it was often misplaced. Several participants confused the Jurassic Overlook with the Lee Foster Overlook which was directly above the intended overlook. This is likely why most participants totally misplaced this landmark.

Another region that participants had difficulty placing was Modern Art. This is likely because of the confusion about which areas in the art galleries comprised of modern art. Several participants made the comment that modern art and contemporary art are similar and they weren't sure which area they were being asked to place, regardless of the specification on the currently existing maps.

The activity was then analyzed by participant. Table 10 shows the percentage of landmarks each participant correctly placed sorted by months worked at the museums. Although participant six only placed 6% of the landmarks in the correct location, they were still able to give wayfinding descriptions correctly. This is likely because of the map orientation error described above. Bolded numbers show the percentages that are greater than the global average.

Table 10. Percentage of landmarks correctly placed by participants sorted by years worked at museums[1]

Participant Number	Years Worked At Museums	Santa Barbara Scale Rating	Correct Floor Placement Percentage	Correct Location Placement Percentage
12	< 1	6.07	0.88	**0.88**
1	< 1	3.6	**0.94**	**0.88**
7	< 1	5.87	0.88	**0.82**
13	< 1	3.8	**0.94**	0.65
9	< 1	5.07	**0.94**	0.59
18	< 1	2.93	0.88	0.47
6	< 1	3.6	0.71	0.06
8	2-4	4.8	**1**	**1**
4	2-4	5.07	**0.94**	**0.88**
2	2-4	4.8	**0.94**	**0.82**
10	2-4	5.47	0.88	**0.82**
5	2-4	2.67	**0.94**	0.71
17	2-4	5.4	**0.94**	0.59
19	2-4	5.33	**0.94**	0.35
16	2-4	4.6	0.65	0.24
3	2-4	5.33	**1**	**0.94**
11	5+	3.73	**0.94**	**0.94**
15	5+	5.2	**0.94**	**0.88**
20	5+	4.87	0.88	**0.82**
14	5+	4.47	0.88	**0.76**

This data was then further explored. To begin this exploration, the data was examined by looking at the data above in more detail. To begin, the results of the map placement activity were examined by gender. Table 11 below shows the correct placement of landmarks both by floor and in the correct location by gender. Overall females had an average of .89 landmarks placed on the correct floor with a standard deviation of .09 and an average of .67 landmarks placed in the correct location with a standard deviation of .23. Males had an average of .91

[1] Bolded numbers show an average that is higher than the global average

landmarks placed on the correct floor with a standard deviation of .07 and an average of .71 landmarks placed in the correct spot with a standard deviation of .28.

Table 11. Correct map placement percentages by floor and correct location examined by gender

Gender	Correct Floor Placement Percentage	Correct Location Placement Percentage
Female	1	0.94
Female	0.94	0.82
Female	0.94	0.35
Female	0.94	0.88
Female	0.94	0.59
Female	0.88	0.82
Female	0.88	0.82
Female	0.88	0.76
Female	0.88	0.47
Female	0.65	0.24
Male	1	1
Male	0.94	0.88
Male	0.94	0.88
Male	0.94	0.71
Male	0.94	0.59
Male	0.94	0.94
Male	0.94	0.35
Male	0.88	0.88
Male	0.88	0.82
Male	0.71	0.06

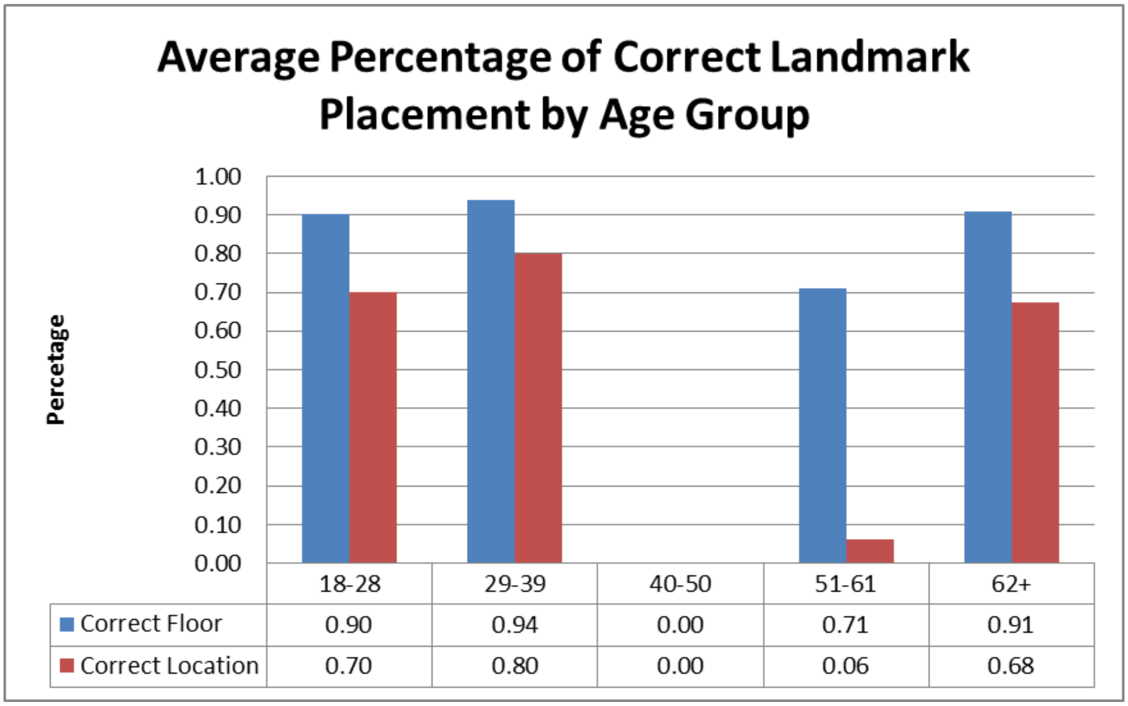


Figure 14. Percentage of correctly placed landmarks by floor and location in terms of age

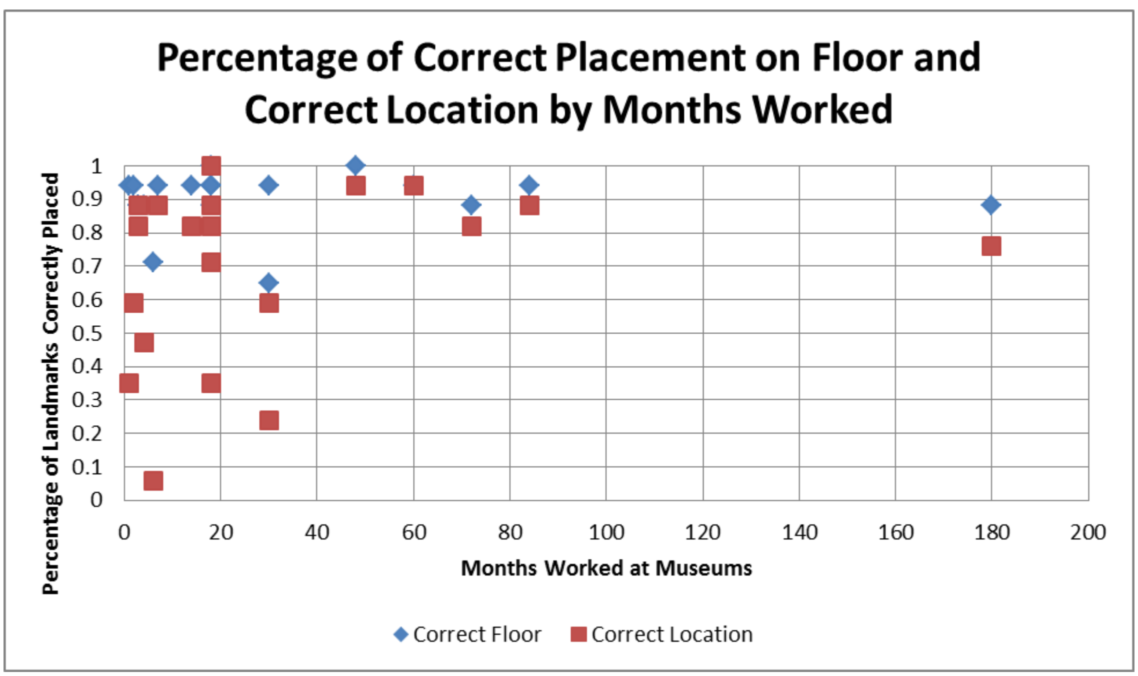


Figure 13. Percentage of correctly placed landmarks by number of months worked

The data was then explored by the amount of time participants had been working at the landmarks was then examined by looking at the raw counts of landmarks participants placed on the correct floor as well as in the correct location. First, this data was examined by the number of months the participant had worked at the museums. The guiding question here was whether or not there was a correlation between the number of months a participant had worked at the museums and the number of landmarks they placed on the correct floor as well as in the correct location. A Pearson correlation coefficient was calculated for both the correct floor placement as well as the correct location. Table 12 shows this data.

Table 12. Pearson correlation coefficients for floor placements and correct location placements

	Number of Correct Floor Placements	***Number of Correct Locations***
Number of months worked at the museums	.02	.22

The data for the placement of landmarks in the correct location and the number of months worked at the museums was further examined by conducting a Student-T Test and a Wilcoxon Two Sample Test. Table 13 below shows these data.

Table 13. Results from Student-T and Wilcoxon tests on number of months worked and correct locations

Test	**p-value**
Student-T Test	.046**
Wilcoxon Two Sample Test	.098*

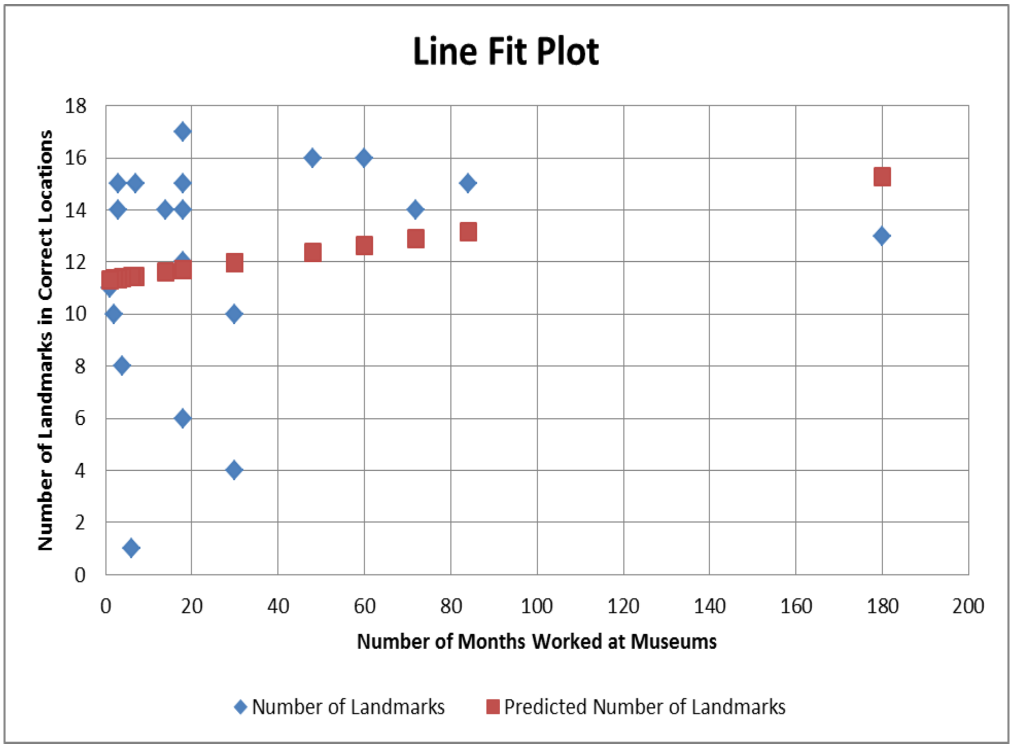


Figure 15. Line fit plot for number of landmarks placed correctly and the predicted values

This shows that there exists a relationship between the number of months worked at the museums and the ability to place landmarks in the correct locations. A linear regression was also performed on this data, however the fit of the line was not very good. A line fit plot between the observed and predicted number of landmarks correctly placed is shown below in Figure 15.

The ability to place a landmark correctly on the map was then examined in terms of the Santa Barbara Sense of Direction Scale. Table 14 outlines this data by looking at the Santa Barbara Sense of Direction Scale score in descending order.

Table 14. Santa Barbara Sense of Direction score and correct landmark placement

Santa Barbara Sense of Direction Scale Score	Correct Floor	Correct Location
6.07	15	15
5.87	15	14
5.47	15	14
5.4	16	10
5.33	17	16
5.33	16	6
5.2	16	15
5.07	16	15
5.07	16	10
4.87	15	14
4.8	16	14
4.8	17	17
4.6	11	4
4.47	15	13
3.8	16	11
3.73	16	16
3.6	16	15
3.6	12	1
2.93	15	8
2.67	16	12

A Pearson Correlation Coefficient was determined for these data as well. The results of this analysis are shown below in Table 15.

Table 15. Pearson Correlation Coefficients for SBSOD Rating and landmark placement.

	Number of Correct Floor Placements	***Number of Correct Locations***
Santa Barbara Sense of Direction Rating	.125	.278

A Student-T as well as a Wilcoxon test were both performed on this data as well. There were no significant or even near significant results for either one of the categories being tested. Figure 16 shows a scatter plot of the data which shows that there is no shape to the ratings and the correct landmarks and correct floor placements. The correct placement of landmarks was also examined by looking at the floor in which the landmark was located. The guiding question here was whether or not there were floors with a higher percentage of correctly placed

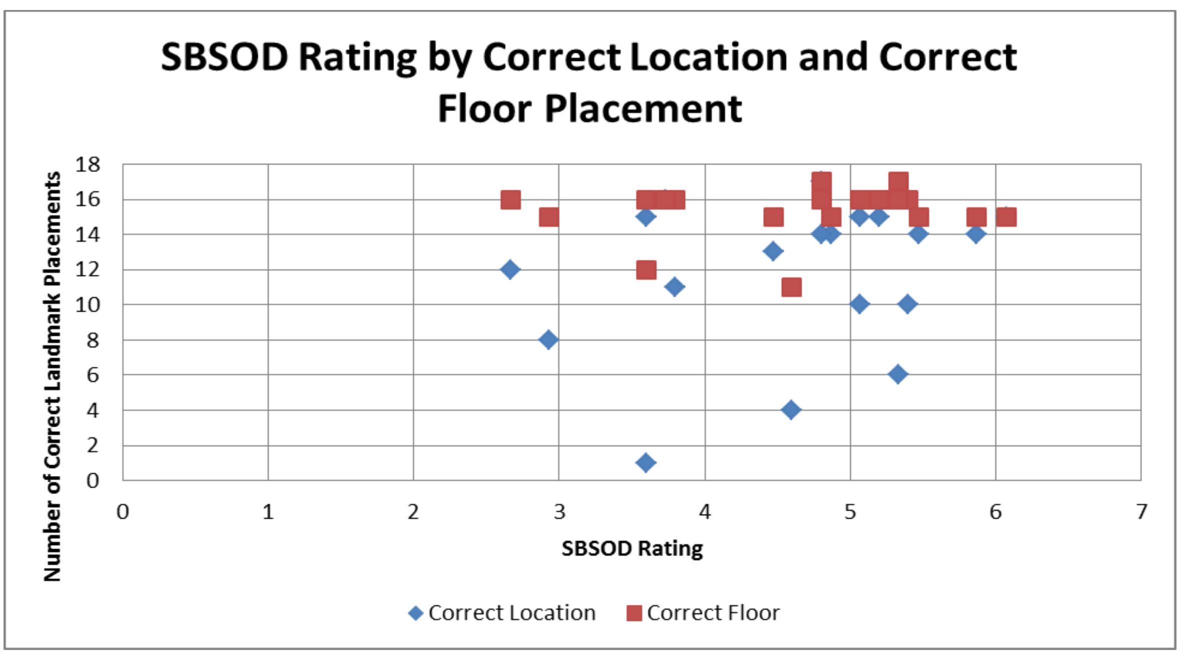


Figure 16. SBSOD Rating by correct location and correct floor.

landmarks. Table 16 outlines the results from this data.

Table 16. Percentage of landmarks placed correctly by floor

Floor	N Landmarks	Floor	Detail
L	2	.95	.68
1	4	.93	.79
2	6	.94	.56
3	5	.82	.64

In conclusion, participants were able to place most landmarks on the correct floor with the exception of the Jurassic Overlook. Participants that were unable to place landmarks in the correct location usually did so because they were unable to orient themselves on the map placing landmarks in areas of the map that did not represent part of the building. The second floor in particular caused a lot of problems with participants. Often, participants were not able to determine which side was which in the provided map.

4.3 VERBAL ANALYSIS

Each of the 20 participants gave verbal wayfinding descriptions for 11 routes making the total number of descriptions collected 220. Due to technical difficulties the verbal data from six participants as well as an additional two routes was not able to be analyzed. This made the total number of descriptions available for analysis 152. The verbal analysis as outlined in Section 2.1.2.1 and Section 3.3 of this dissertation was conducted on all available descriptions. Since participants were instructed to give wayfinding descriptions as if they are giving them to another person, several of the descriptions make reference to the person they are giving the description to by using the word "you". These descriptions were kept in the analysis and the reference to "you" was treated as a reference to the hypothetical traveler the participant is speaking to.

4.3.1 Word Frequency Analysis

To begin the verbal analysis, all wayfinding descriptions across all routes were examined cumulatively. This was done by concatenating all given descriptions into documents by route. There were 22 documents available for analysis, one for each route. The documents were then examined as a whole. The average number of words per route was 519.32 with a minimum of 257 a maximum of 1171 and a standard deviation of 228.25. Figure 17 shows the cumulative number of words per route.

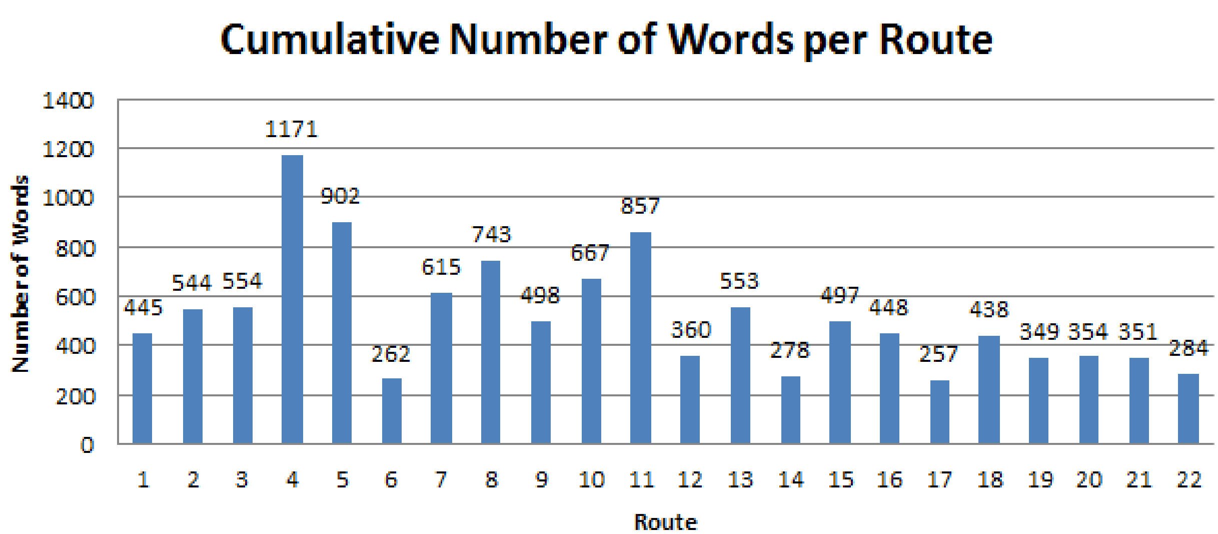


Figure 17. Cumulative number of words per route

The data was then examined by the average number of words across all descriptions by the difference in the beginning floor and the ending floor of each route. Table 17 shows the results for this data.

Table 17. Number of words across all routes by floor difference

Floor Difference	Average Number of Words
0	460.25
1	428.80
2	659.67
3	670

The cumulative number of words per route was then examined by participant, specifically in terms of their Santa Barbara Sense of Direction (SBSOD) scale rating and the number of months they had been working at the museums. Figure 18 shows a scatter plot of the data comparing the results from the SBSOD Scale Rating analysis. No significant relationship was found between these two variables.

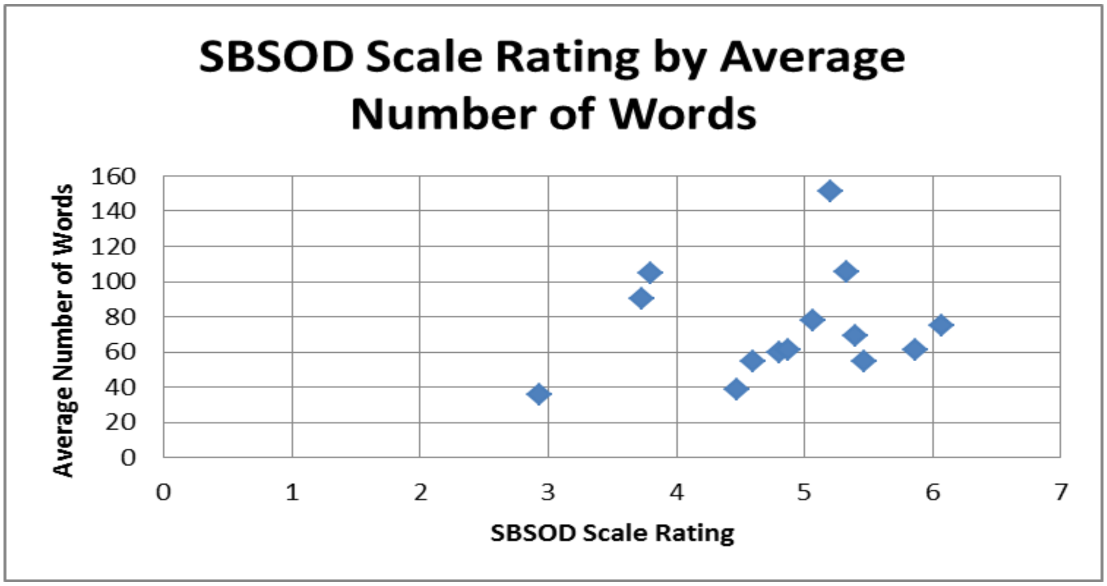


Figure 18. SBSOD scale rating by average number of words used by participants

Figure 19 shows the results from the analysis of the number of months worked at the museums and the average number of words used by the participant.

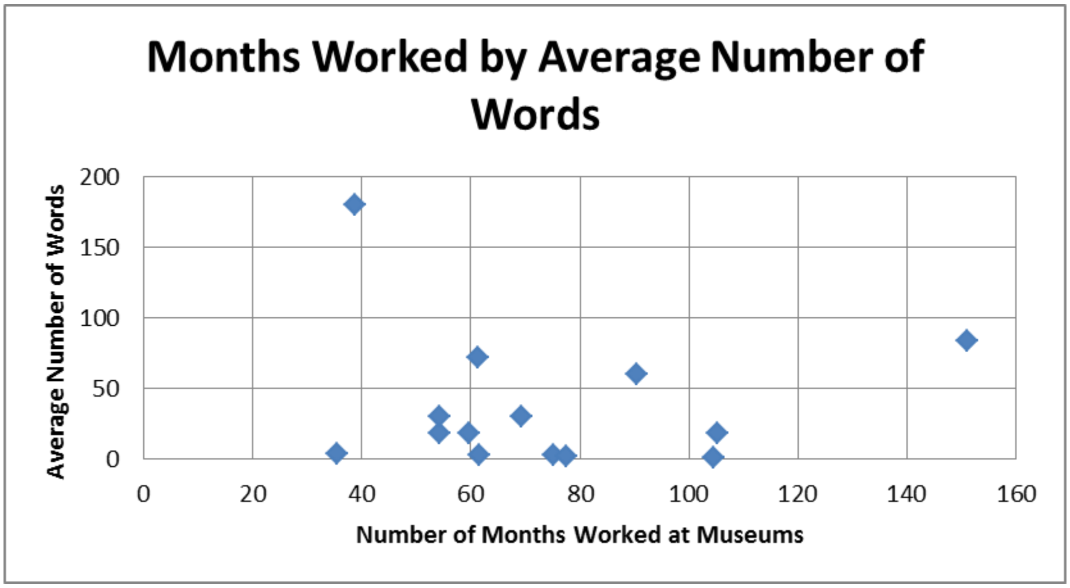


Figure 19. Number of months worked by the average number of words used in wayfinding descriptions

A Pearson Correlation coefficient between the number of months worked and the average number of words across all routes by participant showed a correlation of -.04. Both a Student-T Test and a Wilcoxon Two Sample Test were conducted, the results of which are shown in Table 18.

Table 18. Student-T and Wilcoxon two sample test results

Statistical Test	P-Value
Student-T Test	.02**
Wilcoxon Two Sample Test	.005**

The rest of the verbal analysis results will not be examining the wayfinding descriptions per route as a whole, but will take each individual description. The analysis continues by examining the words in the following categories as outlined in Section 2.1.2.1 and Section 3.3 of this dissertation with examples of landmark pairs and a joining preposition:

- Vertical Prepositions: Landmark 1 *is above* Landmark 2
- Horizontal Prepositions: Landmark 1 *is to the left of* Landmark 2
- Verbalizations – Axial Parts: Landmark 1 *is on the bottom of* Landmark 2
- Verbalizations – Relative Distance of Regions: Landmark 1 *is far from* Landmark 2
- Verbalizations – Paths and Trajectories: Landmark 1 *is up from* Landmark 2

Table 19 shows the frequency in which the verbalizations from the categories above were found across all verbal wayfinding descriptions. The average frequency for a word across all descriptions was 47.77 with a minimum of 1 a maximum of 281 and a standard deviation of 62.84.

The lines bolded represent words whose frequencies are higher than the global average. Words that were removed from the analysis because they had zero frequency were: Below, Beside, Near, Diagonal, Inside, Against, Far, Beyond, Forward, Sideways, North, South, East, West, Via.

Table 19. Frequency of verbalizations in each category[2]

Word	Word Type	Frequency
Above	Vertical Preposition	2
Over	Vertical Preposition	2
Up	**Vertical Preposition**	**115**
Left	**Horizontal Preposition**	**92**
Right	**Horizontal Preposition**	**72**
Top	Verbalization – Axial Parts	11
Bottom	Verbalization – Axial Parts	7
Front	Verbalization – Axial Parts	12
Side	Verbalization – Axial Parts	5
End	Verbalization – Axial Parts	21
Behind	Verbalization – Axial Parts	6
In	**Verbalization-Relative Distance of Region**	**71**
On	Verbalization-Relative Distance of Region	33
Along	Verbalization-Relative Distance of Region	3
Far	Verbalization-Relative Distance of Region	2
Backward	Verbalization- Paths and Trajectories	1
Around	Verbalization- Paths and Trajectories	17
Over	Verbalization- Paths and Trajectories	2
Left	**Verbalization- Paths and Trajectories**	**92**
Right	**Verbalization- Paths and Trajectories**	**72**
Up	**Verbalization- Paths and Trajectories**	**115**
Down	**Verbalization- Paths and Trajectories**	**133**
To	**Verbalization- Paths and Trajectories**	**281**
Towards	Verbalization- Paths and Trajectories	10
From	**Verbalization- Paths and Trajectories**	**64**
Away	Verbalization- Paths and Trajectories	1
	Total	**1243**

[2] Lines bolded represent frequencies higher than the global average

The average frequencies for each category of word are as follows:

- Vertical Prepositions – 39.67
- Horizontal Prepositions - 82
- Distance Estimation - 2
- Verbalizations – Axial Parts – 10.33
- Verbalizations – Relative Distance of Regions – 35.67
- Verbalizations – Paths and Trajectories – 71.63

The following sections break down each category of word by examining the words in each section separately.

4.3.2 Vertical Prepositions

Table 20 outlines the vertical prepositions to be further analyzed in this section as well as their frequency across all wayfinding descriptions and routes. A common use of vertical prepositions includes statements such as *you're going to take the elevator or stairwell UP to the second floor* or *you'll see the yellow classroom make a right UP that hallway*.

Table 20. Table showing vertical prepositions included in analysis

Word	Word Type	Frequency
Above	Vertical Preposition	2
Over	Vertical Preposition	2
Up	**Vertical Preposition**	**115**

The preposition "Up" accounted for 9.34% (115/1243) of all analyzed words. 81.82% of routes contained the preposition "up" and all participants uttered the word at least once. The routes that did not mention the word "up" were

- Exploration Basecamp (Floor 1) to Fossil Fuels (Basement Level)
- North American Wildlife (Floor 1) to Fossil Fuels (Basement Level)
- Ancient Egypt(Floor 3) to Fossil Fuels(Basement Level)
- American Indians(Floor 3) to T. Rex(Floor 1)

These routes likely did not include the preposition "Up" because they are primarily downward; however there were five routes which were primarily downward but still contained the word "up" in at least one verbal description. These routes were as follows:

- Walking Man (Floor 2) to Fossil Fuels (Basement Level)
- Heinz Galleries (Floor 2) to Fossil Fuels (Basement Level)
- Botany (Floor 2) to PaleoLab (Floor 2)
- Hall of Birds (Floor 3) to African Wildlife (Floor 2)
- Hall of Birds (Floor 3) to Heinz Galleries (Floor 2)

These routes likely contained the word "Up" in a downward route because they had the second floor as a starting or ending point. The second floor of the museums does not connect the art and the natural history sides of the museums. Because of this, participants often chunked the information on both sides of the museums into two separate areas. This meant that in order to get from one side of the museums to the other it was necessary to go down a set of stairs then back up another set of stairs to reach the other half of the museum.

Next, the data was analyzed by examining the routes in particular. Table 21 outlines these results in more detail by showing more information on the routes that contained the preposition “Up.” The average number of verbalizations of the word “Up” per route was 6.22 with a minimum of 1 a maximum of 18 and a standard deviation of 4.81. Rows bolded show frequencies that were above the global average.

Table 21. Detailed description of routes containing the word “Up”[3]

Route Number	Starting From	Ending At	Beginning Floor	Ending Floor	Floor Difference	Direction	Frequency
5	**Fossil Fuels**	**Polar World**	**B**	**3**	**3**	**Up**	**18**
4	**Fossil Fuels**	**Walking Man**	**B**	**2**	**2**	**Up**	**15**
3	**Fossil Fuels**	**African Wildlife**	**B**	**2**	**2**	**Up**	**11**
9	**Exploration Basecamp**	**Botany**	**1**	**2**	**1**	**Up**	**11**
2	**Fossil Fuels**	**T. Rex**	**B**	**1**	**1**	**Up**	**9**
16	**African Wildlife**	**Polar World**	**2**	**3**	**1**	**Up**	**8**
15	**Walking Man**	**North American Wildlife**	**2**	**2**	**0**	**Same**	**7**
10	T. Rex	Hall of Birds	1	3	2	Up	6
8	Exploration Basecamp	Walking Man	1	2	1	Up	5
22	Jurassic Overlook	Ancient Egypt	3	3	0	Same	5
17	Modern Art	Polar World	2	3	1	Up	4
13	Heinz Galleries	PaleoLab	2	1	1	Down	3
1	Rental Lockers	Fossil Fuels	B	B	0	Same	2

[3] Bolded lines represent frequencies that are higher than the global average

Table 21 (continued)

7	T. Rex	Hall of Architecture	1	1	0	Same	2
11	Walking Man	Fossil Fuels	2	B	2	Down	2
20	Hall of Birds	African Wildlife	3	2	1	Down	2
14	Botany	PaleoLab	2	1	1	Down	1
21	Hall of Birds	Heinz Galleries	3	2	1	Down	1

The word "Up" was then analyzed by examining the landmarks on either side of the word (Hayward & Tarr, 1995) with a focus on floor to floor transition points (FTF). 112 of the 115 instances in which the word "Up" was used was in reference to a floor to floor transition point. A note on the verbalization of the word "Up": In 120 wayfinding descriptions FTF were the ground objects (Landau & Jackendoff, 1993). However in 63 of these descriptions the floor to floor transition points were paired with another landmark "up the ____ to [the] _____." This made it difficult to analyze the landmarks on both sides of the prepositions as pairs or landmarks related by a verbalization.

In order to keep with the analysis of one landmark as a reference and not two these paired references have been removed from the remainder of the analysis. FTF that were related by the word "Up" are shown in Table 22. The first column shows the number of times the landmark was the first landmark in the verbalization while the third column shows the number of times the landmark was the second landmark. For example, the landmark Elevator was referenced as "Elevator Up _____" four times, and "______ Up Elevator" zero times.

Table 22. Landmarks that are related to a floor to floor transition point by the word "Up"

N Landmark 1	Landmark	N Landmark 2
4	Elevator	0
4	Gold Elevator	0
3	Grand Staircase	0
5	Ramp	4
6	Stairs	10
2	Stairwell	0

The three verbalizations in the dataset that contained the word "Up" but did not reference a FTF were:

- Route 5, Participant 7: *so you'd have to go UP through through the dinosaurs in our time*
- Route 5, Participant 15: *you'll see the yellow classroom make a right UP that hallway*
- Route 2, Participant 13: *I would recommend making a right UP by the discovery area*

The other prepositions included in the analysis were "Above" and "Over." They accounted for .3% of the total frequency of analyzed words present in the dataset. The following landmarks were those that were related by the words "Above" and "Over"

- Crow's Nest ABOVE Foster Overlook
- First Floor ABOVE Third Floor
- Elevator OVER Art Balcony
- Elevator OVER Balcony

Two of these were in reference to floor to floor transition points and were verbalized by the same participant in reference to the same balcony.

4.3.3 Horizontal Prepositions

Table 23 shows the horizontal prepositions analyzed in this section as well as their frequencies across all wayfinding descriptions and all routes. A common use of horizontal prepositions in the study includes statements such as *on the LEFT hand side go through the contemporary art work glass doors* and *you're actually at an overlook make the RIGHT around the corner*.

Table 23. Table showing horizontal prepositions included in analysis

Word	**Word Type**	**Frequency**
Left	**Horizontal Preposition**	**92**
Right	**Horizontal Preposition**	**72**

The preposition "Left" accounted for 7.4% of all analyzed words in the dataset while "Right" accounted for 5.8% of analyzed words. 81.82% of participants used the word "Left" in at least one description while 95% of verbal descriptions contained the word "Right". In regard to descriptions that mentioned a floor to floor transition point (FTF), 45.65% of verbal wayfinding descriptions referenced a FTF as being to the "Left" of another landmark while 40.3% referenced a FTF as being to the "Right". The data was analyzed by looking at landmarks that were referenced as being "Left" or "Right" of another landmark more than once. Since a horizontal preposition is used to relate two landmarks to each other by examining them in terms of the preposition the tables below are organized by showing the landmark and how often it was the first landmark or the second landmark. For example: if N Landmark 1 for Doors is three then

"Doors LEFT ____" was observed three times in the dataset. Table 24 and Table 25 below show the landmarks that were mentioned more than once "Left" and "Right."

Table 24. Landmark pairs with one word being a FTF related by the word "Left"

N Landmark 1	Landmark	N Landmark 2
0	Alcove	2
0	Botany	6
3	Doors	2
4	Elevator	4
0	Fossil Fuels	3
4	Galleries	0
4	Gallery	0
0	Geology	2
2	Gift Shop	0
4	Glass Doors	0
2	Grand Staircase	3
0	Hall of Birds	3
5	Hallway	8
14	Hypothetical Traveler	11
0	Jane	2
0	PaleoLab	2
0	Polar World	2
7	Ramp	4
2	Scaife Gallery	0
0	Second Floor	2
6	Stairs	8
0	T. Rex	2
0	Walking Man	6
2	Yellow Railing	0

Table 25. Landmark pairs with one word being a FTF related by the word "Right"

N Landmark 1	Landmark	N Landmark 2
0	African Wildlife	3
0	African American Wildlife	2
2	Botany	0
3	Elevator	0
2	Fossil Fuels	2
3	Hall	0
2	Hall of Egypt	0
3	Hall of Sculpture	0
3	Hallway	3
2	Lockers	2
15	Hypothetical Traveler	17
0	Polar World	3
5	Ramp	8
0	Scaife Gallery	3
5	Stairs	3
2	T. Rex	2

4.3.4 Verbalizations – Axial Parts

Table 26 shows the words to be further analyzed as verbalizations of axial parts (Landau & Jackendoff, 1993) in this section as well as their frequencies across all wayfinding descriptions. A common use of verbalizations of axial parts in the study includes statements such as *then once you get to the TOP of the stairs* and *down to the END of the ramp*.

Table 26. Frequencies of words denoting a relationship as axial parts between landmarks

Word	Word Type	Frequency
Top	Verbalization – Axial Parts	11
Bottom	Verbalization – Axial Parts	7
Front	Verbalization – Axial Parts	12
Side	Verbalization – Axial Parts	5
End	Verbalization – Axial Parts	21
Behind	Verbalization – Axial Parts	6

None of the verbalizations were greater than the global average of analyzed words found in the dataset. Because of this, the verbal analysis for this portion of the data will be looked at cumulatively. All words show a connectedness between landmarks and often represent a symmetrical representation of importance for landmarks connected by using these words on a cognitive map (Landau & Jackendoff, 1993). In total, all verbalizations showing a relationship between landmarks as axial parts accounted for 4.99% of the total analyzed words used across all wayfinding descriptions given. Total, 21 out of the 22 routes examined across all participants contained at least one mention of a word of this type. The route that did not have one of these words was the following route:

- Ancient Egypt (Third Floor) to Fossil Fuels (Basement)

In particular to floor to floor transition points 50% of these verbalizations related a FTF to another landmark. Table 27 shows all landmark pairs containing a FTF for each of the verbalizations denoting a relationship as axial parts in the entirety of the dataset broken down by landmark 1 the verbalization that relates them and landmark 2. These data comes from the participant verbalizations themselves. Each line represents one verbalization.

Table 27. Data showing floor to floor transition points separated by verbalizations

Landmark1	Preposition	Landmark2
Stairs	Behind	North American Wildlife
Silver Elevator	Behind	Staircase
Admissions Desk	Behind	Steps
Staircase	Behind	Grand Staircase
Stairs	Bottom	Hypothetical Traveler
Ramp	Bottom	Yellow Classroom
Stairs	Bottom	Paleolab
Stairwell	Bottom	Doors
Fossil Fuels	Bottom	Steps
Grand Staircase	Bottom	Hypothetical Traveler
Ramp	Bottom	Hypothetical Traveler
Grand Staircase	End	Scaife Galleries
Gift Shop	End	Grand Staircase
Hallway	End	Ramp
Exploration Basecamp	End	Stairs
Gallery 17	End	Elevator
Hallway	End	Ramp
Bird Hall	End	Grand Staircase
Elevator	End	Contemporary Galleries
Bird Hall	End	Grand Staircase
Ramp	End	Fossil Fuels
Gallery	Front	Stairs
Grand Staircase	Front	Hall of Birds
Art	Front	Stairs
Elevator	Front	Polar World
Doors	Side	Grand Staircase
Hypothetical Traveler	Top	Top
Hypothetical Traveler	Top	Stairs
Grand Staircase	Top	Hypothetical Traveler
Hypothetical Traveler	Top	Ramp
Stairs	Top	Botany
Hypothetical Traveler	Top	Stairs
Steps	Top	Hypothetical Traveler
Silver Elevator	Top	Hypothetical Traveler
Rand Staircase	Top	Polar World
Sign	Top	Stairs

In order to further examine the floor to floor transition points verbalized as axial parts a count of the landmarks themselves was conducted. The results of this are shown below in Table 28 and are further broken down by showing the number of times the FTF was the first or second landmark in the verbalization.

Table 28. Table showing the frequency of the landmark as the first or second landmark

N Landmark 1	Floor to Floor Transition Point	N Landmark 2
2	Elevator	1
5	Grand Staircase	5
3	Ramp	3
1	Staircase	1
4	Stairs	6
1	Steps	2
2	Silver elevator	0
1	Stairwell	0

4.3.5 Verbalizations – Prepositions

In order to apply the verbalization analysis of Landau and Jackendoff (1993) in particular to preposition the vertical and horizontal prepositions from Section 4.3.2 and Section 4.3.3 were revisited. Table 29 below shows the prepositions analyzed in this section:

Table 29. Prepositions analyzed in this portion of the results section

Word	Word Type	Frequency
Above	Vertical Preposition	2
Over	Vertical Preposition	2
Up	**Vertical Preposition**	**115**
Left	**Horizontal Preposition**	**92**
Right	**Horizontal Preposition**	**72**

This portion of the results focused on determining which landmarks are considered figure and ground according to Landau and Jackendoff (1993) and because of this the order in which the landmarks were verbalized is important. In 40.10% of the instances in which one of these prepositions was used in a wayfinding description across all routes, the floor to floor transition points (FTF) was the figure object. This shows that FTF appeared to be both figure and ground objects and were not verbalized in any one way. Table 30 and Table 31 show the frequency of FTF when they were figure and ground objects.

Table 30. The preposition associated with a FTF transition point when it is the figure object

Preposition	Frequency
Left	24
Over	2
Right	16
Up	31
Total	73

Table 31. The preposition associated with a FTF transition point when it is the ground object

Preposition	Frequency
Left	23
Right	16
Up	81
Total	120

The analysis continued by examining the frequency of FTF as figure objects. Table 32 below outlines this data.

Table 32. Frequencies of landmarks as figure objects

Landmark	Frequency
Back Elevator	1
Back Stairs	1
Elevator	12
Gold Elevator	6
Grand Staircase	5
Grand Staircase Area	1
Main Staircase	1
Ramp	17
Scaife Stairs	3
Silver Elevator	2
Staircase	2
Stairs	17
Stairway	1
Stairwell	2
Steps	2

In 120 wayfinding descriptions FTF were ground objects. However in 63 of these descriptions, all with the preposition "Up," floor to floor transition points as ground objects were usually paired with another landmark "up the ____ to [the] _____" In order to keep with the analysis of one landmark as a single ground object these pairings have been removed from the remainder of the analysis. Table 33 shows the landmarks that were singular ground objects.

Table 33. Landmarks and their frequencies that were singular ground objects

Landmark	Frequency
Elevator	5
Gold Elevator	1
Grand Staircase	3
Main Staircase	1
Ramp	16
Silver Elevator	1
Slope	1
Spiral Staircase	1
Spiral Stairs	2
Stairs	24
Stairway	1
Top of Steps	1

4.3.6 Verbalizations – Relative Distance of Regions

Table 34 shows the verbalizations denoting the relative distance of regions (Landau & Jackendoff, 1993) in this section as well as their frequencies across all wayfinding descriptions. A common use of verbalizations that indicated a relative distance between regions in the study includes statements such as *from fossil fuels café to the walking man IN the art museum* and *then start following the signs ON the ceiling.*

Table 34. Frequency of Relative Distance of Region Verbalizations

Word	Word Type	Frequency
In	**Verbalization-Relative Distance of Region**	**71**
On	Verbalization-Relative Distance of Region	33
Along	Verbalization-Relative Distance of Region	3
Far	Verbalization-Relative Distance of Region	2

In total, 8.8% (109/1243) of all words in this analysis were verbalizations denoting the relative distance of regions. 21 of the words used were in reference to a floor to floor transition point. Table 35 shows the data from these descriptions as well as the word that related the two landmarks. These data comes from the participant verbalizations themselves. Each line represents one verbalization.

Table 35. Words with the prepositions Along, In, or On that reference a floor to floor transition point

Landmark 1	Preposition	Landmark 2
Stairway	Along	Back Wall
Staircases	In	Basecamp
Stairs	In	Glass Doors
Elevator	In	Fossil Fuels
Elevator	In	African Wildlife
Stairs	In	Scaife Galleries
Steps	In	Gallery
Elevator	In	Polar World
Elevator	In	Third Floor
Level 1	In	Silver Elevator
Stairs	In	Discovery Basecamp
Stairs	In	Basecamp
Stairs	In	Art Museum
Grand Staircase	In	Hypothetical Traveler
Elevator	In	Basement
Hall of Birds	On	Grand Staircase
Elevator	On	Level
Steps	On	Back Wall
Elevator	On	First Floor
Hypothetical Traveler	On	Elevator
Stairs	On	Second Floor

In most cases, 85.7% (18/21) the FTF was the first landmark in the given wayfinding description.

Within these 18 descriptions, the ones that had more than one reference were as follows:

- three of them referenced the staircase IN Discovery basecamp
- two of them referenced the back stairs ALONG or ON the back wall
- three of them referenced the stairs or elevator IN the Scaife Galleries

4.3.7 Verbalizations – Paths and Trajectories

Table 36 shows the wayfinding descriptions that denoted a path or trajectory. This group of verbalizations had, by far, the most number of words associated. Although this analysis method included verbalizations that were included in other portions of the analysis, they will be revisited in this section as it applies a different analysis framework. A common use of verbalizations that indicated a path or trajectory in the study includes statements such as *go UP the ramp to fossil fuels* and *go up the ramp TO fossil fuels.*

Table 36. Verbalizations denoting Paths and Trajectories to be included

Word	Word Type	Frequency
Backward	Verbalization- Paths and Trajectories	1
Around	Verbalization- Paths and Trajectories	17
Over	Verbalization- Paths and Trajectories	2
Left	**Verbalization- Paths and Trajectories**	**92**
Right	**Verbalization- Paths and Trajectories**	**72**
Up	**Verbalization- Paths and Trajectories**	**115**
Down	**Verbalization- Paths and Trajectories**	**133**
To	**Verbalization- Paths and Trajectories**	**281**
Towards	Verbalization- Paths and Trajectories	10
From	**Verbalization- Paths and Trajectories**	**64**
Away	Verbalization- Paths and Trajectories	1

In total, all words denoting a path or trajectory between landmarks made up 63.34% (788/1243) of the words in the analyzed word list. The words that were verbalized three or less times across all descriptions and routes were examined first. These included “Backward,” “Over,” and “Away.” Table 37 shows the route, participant, and word from these data.

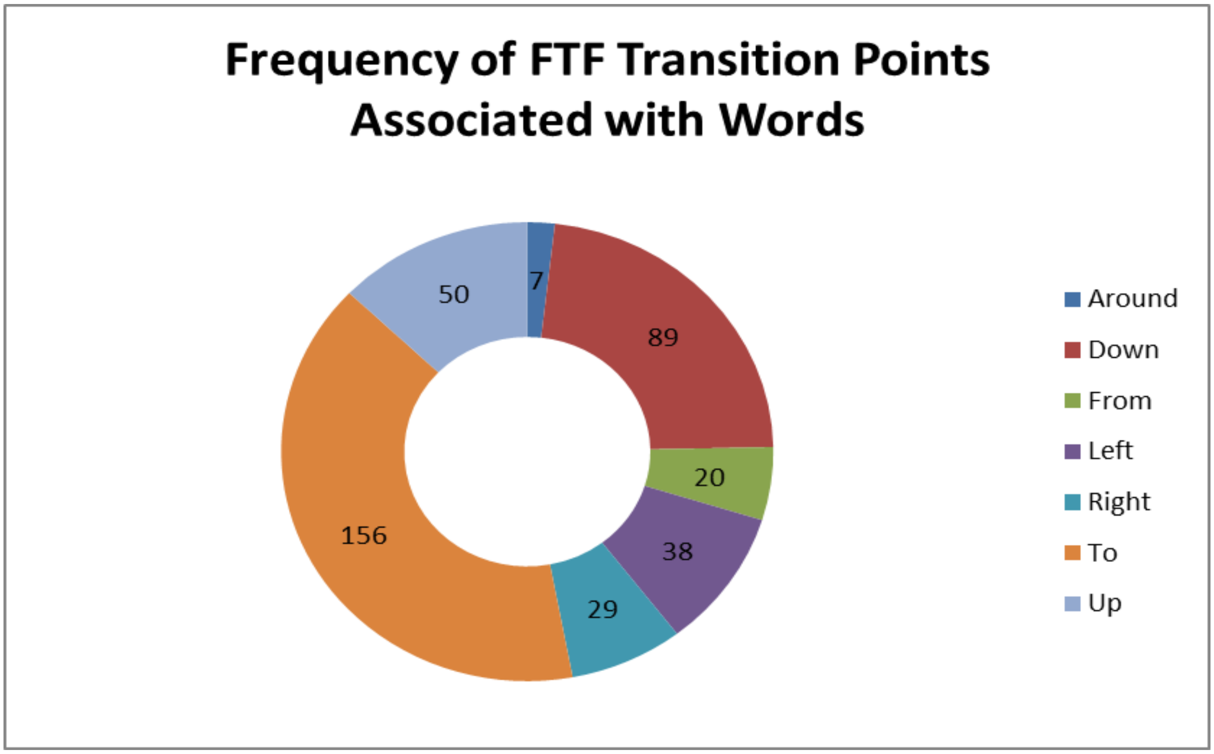


Figure 20. Frequency of floor to floor transition points associated with words

Table 37. Words that were verbalized three or less times across all descriptions and routes

Route	Participant	Landmark 1	Word	Landmark 2
11	19	Hypothetical Traveler	Away	Walking Man
7	9	Hypothetical Traveler	Backward	Dinosaurs
20	14	Elevator	Over	Art Balcony
20	14	Elevator	Over	Balcony

Of the remaining 784 verbalizations, 455 of them contained a FTF as either the first or second landmark. Please note, the descriptions where floor to floor transition points were paired with other landmarks were removed from the analysis. Figure 20 shows the distribution of the remaining words that denote paths and trajectories.

The results were analyzed by looking at the words that are verbalized in terms of their orientation. This includes the words, “Around”, “Left”, and “Right.” 74 of the wayfinding descriptions given by participants across all routes included one of these words in reference to a FTF. Table 38 below shows the floor to floor transition points that were either landmark 1 or 2 in the wayfinding descriptions containing these words.

Table 38. Number of words that were verbalized with a landmark using “Around” “Left” or “Right.

N Landmark 1	Landmark	N Landmark 2
7	Elevator	6
2	Gold Elevator	1
4	Grand Staircase	6
1	Main Staircase	0
12	Ramp	12
2	Scaife Stairs	0
1	Staircase	0
12	Stairs	11
1	Steps	0
0	Silver Elevator	1
0	Slope	1
0	Spiral Staircase	1
0	Stairway	1

Next, the results were analyzed by examining verbalizations in terms of the axes of the Earth. Verbalizations that included floor to floor transition points were “up” and “down.” In total 139 wayfinding descriptions given by participants across all routes contained these two words. Section 4.3.2 includes a more in depth analysis of the verbalization “Up.” Similar to

“Up,” “Down” also contained words that were paired with other landmarks, these were removed from the analysis making the total number of instances of the word “Down” 89. This makes the total percentage of the verbalization “Down” in the entire dataset 7.16%. The word “Down” was then examined by looking at the route number. Table 39 below outlines these results.

Table 39. Prepositions by route number

Route Number	Start	End	Beg. Floor	End Floor	Floor Difference	Direction	Frequency	Preposition
1	Rental Lockers	Fossil Fuels	B	B	0	Same	4	Down
3	Fossil Fuels	African Wildlife	B	2	2	Up	1	Down
4	Fossil Fuels	Walking Man	B	2	2	Up	2	Down
5	Fossil Fuels	Polar World	B	3	3	Up	1	Down
6	Exploration Basecamp	Fossil Fuels	1	B	1	Down	8	Down
7	T. Rex	Hall of Architecture	1	1	0	Same	4	Down
8	Exploration Basecamp	Walking Man	1	2	1	Up	3	Down
9	Exploration Basecamp	Botany	1	2	1	Up	1	Down
11	Walking Man	Fossil Fuels	2	B	2	Down	12	Down
12	North American Wildlife	Fossil Fuels	2	B	2	Down	7	Down
13	Heinz Galleries	PaleoLab	2	1	1	Down	6	Down
14	Botany	PaleoLab	2	1	1	Down	4	Down
15	Walking Man	North American Wildlife	2	2	0	Same	3	Down
16	African Wildlife	Polar World	2	3	1	Up	1	Down
17	Modern Art	Polar World	2	3	1	Up	3	Down

Table 39 (continued)

18	Ancient Egypt	Fossil Fuels	3	B	3	Down	10	Down
19	American Indians	T. Rex	3	1	2	Down	8	Down
20	Hall of Birds	African Wildlife	3	2	1	Down	4	Down
21	Hall of Birds	Heinz Galleries	3	2	1	Down	7	Down

The largest list of words in the analysis of paths and trajectories included the operators as defined by Landau and Jackendoff (1993). These words create paths between two objects and include the words "To" and "From." Total, 176 instances of these words were present wayfinding descriptions across all routes. In regard to FTF, these words were present between a landmark and a FTF in wayfinding descriptions across all routes. Table 40 below shows the frequency in which a FTF was paired with an instance of one of these words.

Table 40. Frequency in which a FTF was paired with a verbalization showing path and trajectory

N Landmark 1	Landmark	N Landmark 2
50	Elevator	6
1	Elevators	1
1	Gold Elevator	0
0	Front Stairs	1
7	Grand Staircase	17
1	Main Staircase	0
6	Ramp	3
1	Scaife Stairs	2
1	Silver Elevator	0
2	Spiral Staircase	2
8	Staircase	1
2	Staircases	0
37	Stairs	14
1	Stairway	0
4	Stairwell	0
6	Steps	1
0	Top of Stairs	1

4.3.8 Conclusion

The coarseness of the spatial information communicated by participants linguistically can be compared to the coarseness the information in their representations of space (Heidorn & Hirtle, 1993). This makes the linguistic methods employed by this dissertation appropriate. The verbal analysis showed that floor to floor transition points were an important part of the environment since they were verbalized and often related to other landmarks in the environment. The words "Up," "Down," and "To" were of particular importance in the verbalizations of participants. "Up" and "Down" are particularly relevant to gaining insight into the cognitive maps of participants because they specify vertical movement in the cognitive maps of participants. This vertical movement in a complex indoor environment is of particular interest since it denotes a three dimensional representation.

The word "Up" was primarily used in reference to floor to floor transition points, but was often paired with a different landmark. For example the phrase *Go UP the stairs to the third floor*. This verbalization shows the word up pairing the hypothetical traveler with the stairs as well as the third floor.

The lack of verbalizations denoting axial parts is also curious because of the fact that "Up", "Down", "Left", and "Right" were particularly important in the environment. Taken together as important one would assume that these verbalizations would make it more likely that a relationship of landmarks as axial parts would emerge at the Carnegie Museums but this is not the case. Verbalizations denoting axial parts show a symmetrical importance in the environment. This shows that landmarks in the environment were not of symmetrical importance and that some were of more importance than others.

An analysis of verbal prepositions focused on determining figure and ground objects showed that floor to floor transition points were verbalized as ground objects, but the differences between the two types of references were very slight. This is of particular interest since ground objects usually have, "properties that facilitate search" and "in many contexts, they should be large, stable, and distinctive."(Landau & Jackendoff, 1993).

In conclusion, floor to floor transition points were revealed to be important in terms of the vertical preposition, horizontal prepositions, and paths and trajectories in the cognitive maps of participants. Of particular importance is the fact that floor to floor transition points were often verbalized as ground objects which made them of particular importance in the verbalizations of wayfinding descriptions.

4.4 SKETCH MAP ANALYSIS

Each of the 20 participants drew sketch maps for 11 routes. In total 220 sketch maps were available for analysis, 10 for each route. The sketch maps were measured for accuracy against the real environment (Rovine & Weisman, 1989) and only sketch maps that met both requirements for accuracy were further analyzed making the total dataset a total of 168 sketch maps. The requirements were does:

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.

4.4.1 Nodes and Segments

Each sketch map was analyzed by counting the frequency of path segments and nodes present in the sketch map (Rovine & Weisman, 1989). Table 41 shows the results of this analysis.

Table 41 Node and Path Segment analysis

Type	**Average**	**Minimum**	**Maximum**	**Standard Deviation**
Nodes	9.34	2	30	5.46
Path Segments	6.55	1	21	4.02

The number of nodes, path segments, and were then further analyzed by route number in order to determine which routes had the most data associated with them. The differences in notes and path segment data can easily be seen by comparing a route with several nodes and path segments to one with few. Figure 21 shows a sketch map from route one while Figure 22 shows a sketch map from route 18. It is clear when looking at the sketch maps of these two routes that route 18 is far more complicated than route one.

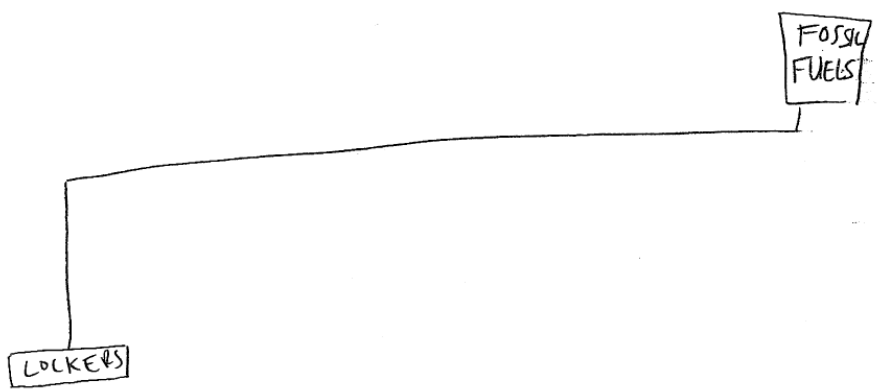


Figure 21. Sketch map from route one showing a less complex route

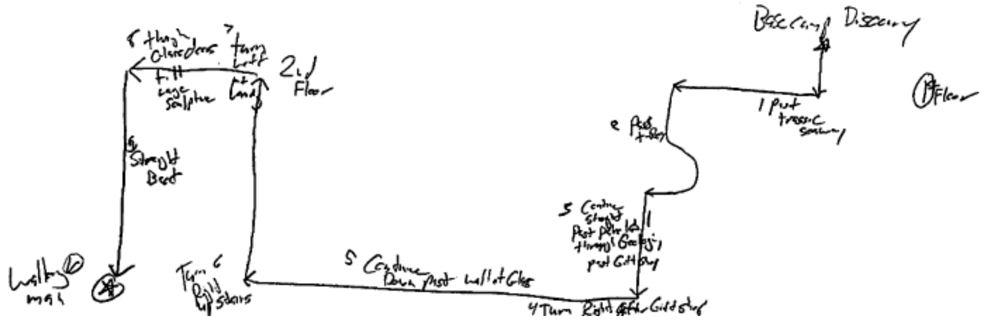


Figure 22. Sketch map from Route 18 showing a more complex route

Table 42 shows a summary of the results comparing nodes and path segments by route number ordered by node average in descending order. Bolded numbers are those that are above the global average.

Table 42 Number of nodes and path segments by route number[4]

Route Number	Nodes				Path Segments			
	Average	Min	Max	St.Dev.	Average	Min	Max	St.Dev.
15	**16.88**	10	28	7.36	**12.63**	5	21	5.58
4	**16.00**	10	28	6.87	**11.88**	6	20	4.7
11	**13.50**	6	30	7.71	**8.50**	4	15	3.38
18	**12.43**	7	22	5.41	**8.86**	5	16	4.14
16	**11.63**	5	17	4.21	**8.63**	4	13	3.07
19	**11.38**	5	20	4.98	**8.5**	4	15	3.85
14	**10.86**	6	19	4.63	**8.29**	3	19	5.35
8	**10.38**	4	24	6.59	**6.88**	2	13	3.8
20	**9.63**	4	16	4.24	**6.88**	3	11	3.18
5	**9.43**	5	16	3.82	6	3	10 .00	2.24
21	8.71	0	14	5.22	**6.86**	0	13	4.78
17	8.5	4	12	3.34	5.63	3	10	2.45
22	7.5	5	10	3.54	5.5	4	7	2.12
10	7.44	2	12	3.4	4.67	1	8	2.35
7	7.33	3	17	4.27	5.22	2	10	2.59
13	7.25	4	13	3.37	5	3	9	1.85
2	7.11	3	13	2.98	4.67	2	10	2.55
9	6.75	4	11	2.6	4.13	2	9	2.17
12	5.78	0	10	3.46	4.22	0	8	2.82
6	5.63	2	11	3.5	3.88	1	8	2.64
1	5.38	4	10	2.2	3.75	3	6	1.16
3	5.33	2	10	3.01	3.33	1	7	2.25

[4] Bolded numbers show averages that are higher than the global average

4.4.2 Sketch Map Complexity Analysis

Each sketch map was classified and sorted into one of the sketch map complexity types as specified by Appleyard (1970). The number of sketch maps that met the criteria for each classification of map is shown in Table 43.

Table 43. Number of maps rated as the 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	Patterned	4	29

In terms of the specific maps produced by participants, Figure 23 shows examples of all map types from the data.

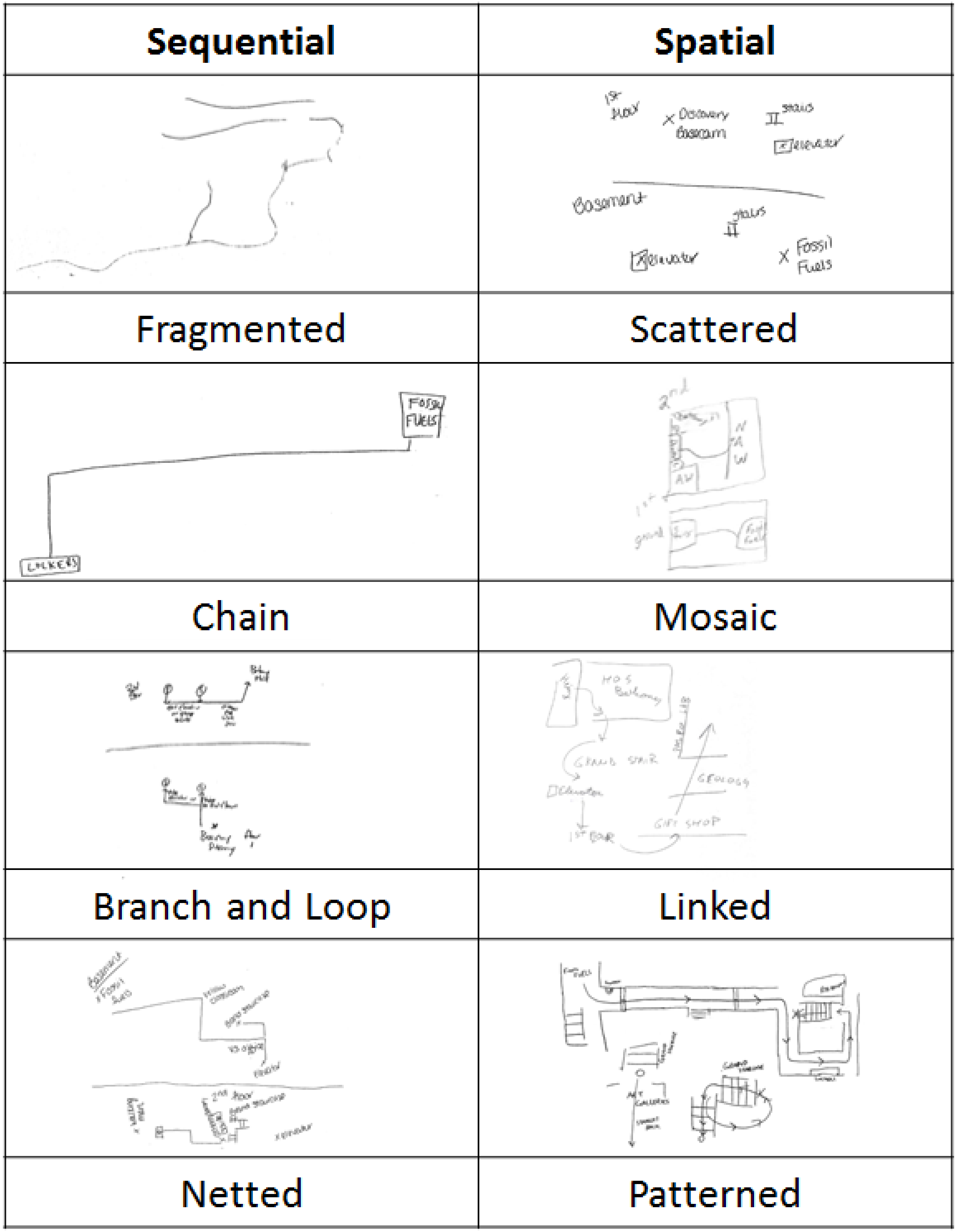


Figure 23. Examples of all types of maps similar to Appleyard (1970)

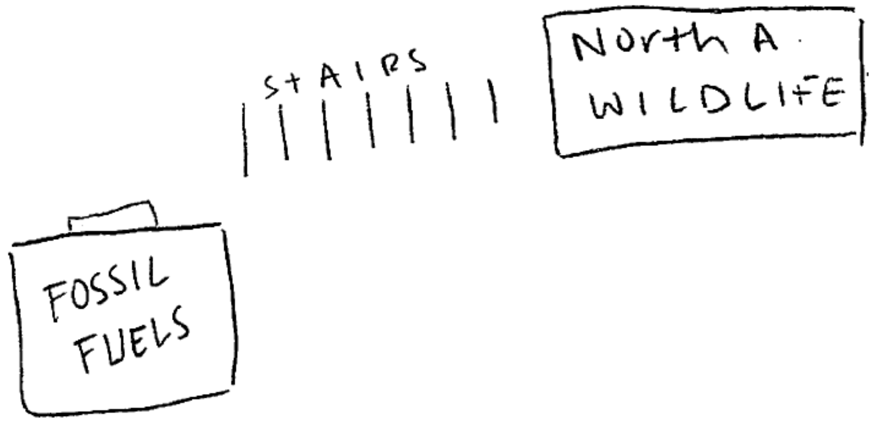


Figure 24. Example of a functional FTF

The results were then analyzed by looking at the map type and participant in order to examine whether participants tended towards drawing the same type of map regardless of the route. No participant used one map type and because of this the data was too large to put into a table. Overall participants employed a variety of map types to show their routes.

4.4.3 Floor to floor transition points

Each sketch map was analyzed by totaling the floor to floor transition points (FTF) in two ways. First, the FTF represented on the map was coded as being either a functional FTF or a landmark FTF. A functional FTF was one whose representation on the sketch map served as a way to move from floor to floor. To formalize this, a FTF was determined to be function if the information on both sides of it was on a different floor. Figure 24 shows an example of a sketch map where the FTF was classified as functional.

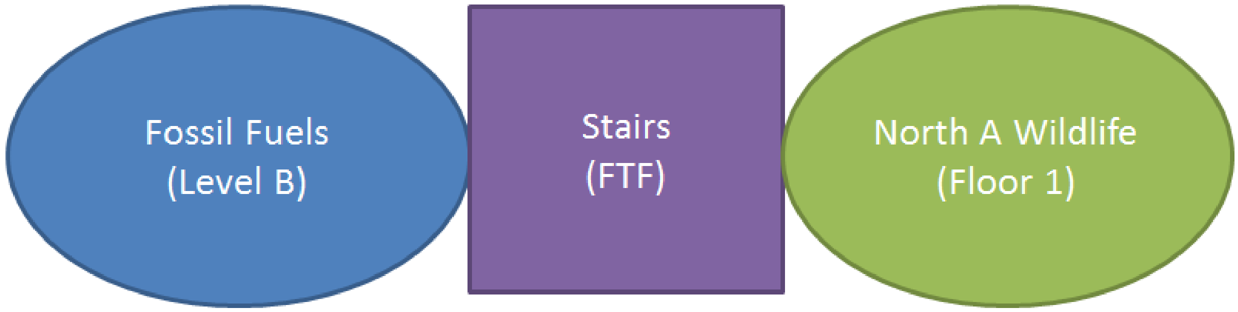


Figure 25. Formalization of information from Figure 17. Shows a functional FTF.

Figure 25 shows the formalization behind the classification of the stairs in Figure 24 as functional. The circles represent spatial information in the sketch map and the square represents the floor to floor transition point. The circles are different colors because they show a difference in the floors of the information on both sides of the FTF.

In contrast, a landmark FTF had information on both sides that was from the same floor. Figure 26 shows an example of a FTF that was determined to be a landmark FTF. Figure 27 shows the formalization behind the classification of the spiral staircase in Figure 26 as a landmark. The circles represent spatial information in the sketch map and the square represents the floor to floor transition point. The circles are the same color because they show that the spatial elements on both sides of the FTF are the same. Please note there are more coded floor to floor transition points than those that are present in the environment because the sketch maps represent the cognitive maps of participants. If the participant labeled an elevator as "Elevator by VS Lockers" and another participant labeled the same elevator in the building as "Gold elevator" that elevator was marked as being two separate elevators regardless of the fact that these were the same elevator in the actual physical space.

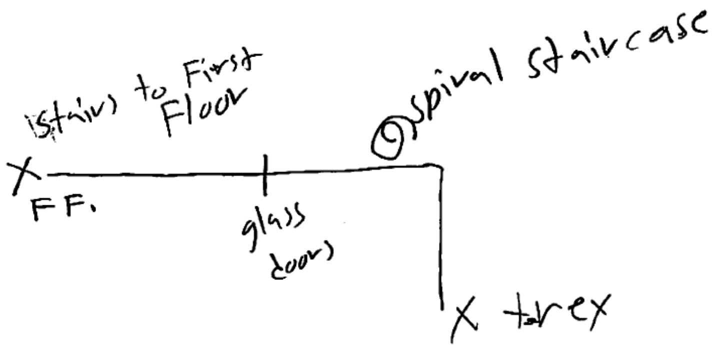


Figure 27. Example of a landmark FTF

To begin, the numbers of floor to floor transition points across all sketch maps were examined. On average sketch maps contained 1.58 floor to floor transition points with the minimum being 0, the maximum being 6, and a standard deviation of .94. Floor to floor transition points were then examined by looking at the average of floor to floor transition points

Figure 26. Formalization of information from Figure 19. Shows a landmark FTF.

per route. Table 44 shows the results from this analysis bolded rows show routes where the average is greater than the global average.

Table 44. Table showing average of floor to floor transition points by route number[5]

Route Number	Start	End	Start Floor	End Floor	Floor Difference	Direction	Average
18	**Ancient Egypt**	**Fossil Fuels**	**3**	**B**	**3**	**Down**	**2.86**
15	**Walking Man**	**North American Wildlife**	**2**	**2**	**0**	**Same**	**2.375**
4	**Fossil Fuels**	**Walking Man**	**B**	**2**	**2**	**Up**	**2**
5	**Fossil Fuels**	**Polar World**	**B**	**3**	**3**	**Up**	**2**
11	**Walking Man**	**Fossil Fuels**	**2**	**B**	**2**	**Down**	**2**
16	**African Wildlife**	**Polar World**	**2**	**3**	**1**	**Up**	**2**
17	**Modern Art**	**Polar World**	**2**	**3**	**1**	**Up**	**2**
19	**American Indians**	**T. Rex**	**3**	**1**	**2**	**Down**	**2**
21	**Hall of Birds**	**Heinz Galleries**	**3**	**2**	**1**	**Down**	**1.71**
9	**Discovery Basecamp**	**Botany**	**1**	**2**	**1**	**Up**	**1.63**
20	**Hall of Birds**	**African Wildlife**	**3**	**2**	**1**	**Down**	**1.63**
3	Fossil Fuels	African Wildlife	B	2	2	Up	1 .5
6	Exploration Basecamp	Fossil Fuels	1	B	1	Down	1.5
2	Fossil Fuels	T. Rex	B	1	1	Up	1.44
10	T. Rex	Hall of Birds	1	3	2	Up	1.44
13	Heinz Galleries	PaleoLab	2	1	1	Down	1.38
12	North American Wildlife	Fossil Fuels	2	B	2	Down	1.33
14	Botany	PaleoLab	2	1	1	Down	1.29
8	Exploration Basecamp	Walking Man	1	2	1	Up	1
22	Jurrasic Overlook	Ancient Egypt	3	3	0	Same	0.5
7	T. Rex	Hall of Architecture	1	1	0	Same	0.44
1	Rental Lockers	Fossil Fuels	B	B	0	Same	0.38

[5] Bolded rows show averages above the global average

Floor to floor transition points were also examined by looking them in terms of participants. Table 45 shows the results of this analysis bolded rows and show routes where the average is greater than the global average.

Table 45. Results of floor to floor transition points by participants[6]

Participant Number	Years Worked at Museums	Santa Barbara Scale	Average
1	**<1**	**3.6**	**2.3**
19	**2-4**	**5.4**	**2.1**
11	**2-4**	**5.47**	**1.9**
15	**5+**	**4.47**	**1.8**
2	**2-4**	**4.8**	**1.73**
3	**2-4**	**5.33**	**1.73**
13	**<1**	**6.07**	**1.7**
7	**<1**	**3.6**	**1.67**
14	**<1**	**3.8**	**1.64**
10	<1	5.07	1.56
4	2-4	5.07	1.55
9	2-4	4.8	1.44
20	<1	2.93	1.44
12	5+	3.73	1.3
8	<1	5.87	1.14
6	2-4	2.67	1
18	2-4	4.6	0.91
17	5+	5.2	0

Floor to floor transition points were then inspected by looking at the points themselves. The total frequency in which they were portrayed on the sketch maps as both a functional FTF and a landmark FTF are shown in Table 46.

[6] Bolded rows show routes where the average is greater than the global average

Table 46. 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

Next, floor to floor transition points represented on sketch maps as landmark FTF were examined. It is important to note here how the frequencies of FTF were counted. If there were four FTF represented on the sketch map and two of them were landmark FTF, the count would be: four functional FTF, two landmark FTF. By this count we can see that 50% of the FTF that were represented were landmark FTF.

In total 266 floor to floor transition points were represented on the maps, 44 of which were represented as landmarks. This makes the total percentage of landmark FTF 16.54%. On average .26 landmark FTF were represented on sketch maps with a minimum of 0 a maximum of 3 and a standard deviation of .55. The number of FTF that were represented on the sketch maps as landmarks were also examined by participant. Table 47 shows the total sum of landmark FTF by participant ordered by number of landmark FTF.

Table 47. Number of landmark FTF by participant. Ordered by N landmark FTF descending

Participant Number	Years Worked at Museums	Santa Barbara Scale	N landmark FTF
2	2-4	4.8	5
3	2-4	5.33	5
4	2-4	5.07	5
20	5+	4.87	5
1	<1	3.6	5
19	2-4	5.33	4
14	5+	4.47	4
12	<1	6.07	4
11	5+	3.73	3
7	<1	5.87	3
13	<1	3.8	2
6	<1	3.6	2
8	2-4	4.8	2
9	<1	5.07	1
15	5+	5.2	1
17	2-4	5.4	0
18	<1	2.93	0
10	2-4	5.47	0

The sum of floor to floor transition points as landmarks were also looked at in terms of routes. Table 48 shows the total sum of landmark FTF by participant ordered by number of landmark FTF.

Table 48. Landmark FTF by route

Route Number	Start	End	Start Floor	End Floor	Floor Difference	Direction	N landmark FTF
18	Ancient Egypt	Fossil Fuels	3	B	3	Down	7
4	Fossil Fuels	Walking Man	B	2	2	Up	6
5	Fossil Fuels	Polar World	B	3	3	Up	6
21	Hall of Birds	Heinz Galleries	3	2	1	Down	5
2	Fossil Fuels	T. Rex	B	1	1	Up	3
9	Exploration Basecamp	Botany	1	2	1	Up	3
16	African Wildlife	Polar World	2	3	1	Up	3
1	Rental Lockers	Fossil Fuels	B	B	0	Same	2
3	Fossil Fuels	African Wildlife	B	2	2	Up	2
6	Exploration Basecamp	Fossil Fuels	1	B	1	Down	2
10	T. Rex	Hall of Birds	1	3	2	Up	2
19	American Indians	T. Rex	3	1	2	Down	2
20	Hall of Birds	African Wildlife	3	2	1	Down	2
11	Walking Man	Fossil Fuels	2	B	2	Down	1
13	Heinz Galleries	PaleoLab	2	1	1	Down	1
16	African Wildlife	Polar World	2	3	1	Up	3
17	Modern Art	Polar World	2	3	1	Up	1

Table 48 (continued)

18	Ancient Egypt	Fossil Fuels	3	B	3	Down	7
19	American Indians	T. Rex	3	1	2	Down	2
20	Hall of Birds	African Wildlife	3	2	1	Down	2
21	Hall of Birds	Heinz Galleries	3	2	1	Down	5
22	Jurrasic Overlook	Ancient Egypt	3	3	0	Same	1

Because over half of the landmark FTF came from routes 2, 4, 5, 16, and 18 those routes were further examined. These routes were examined by looking at the count of landmark FTF and the number of participants that contributed to that count. A landmark FTF/Participant Number of 1 means that each landmark FTF came from a separate person. Table 49 shows these results.

Table 49. Routes with high landmark FTF examined by participants

Route	Count of landmark FTF	N Participants	Landmark FTF/N Participants
2	3	3	1
4	6	5	1.2
5	4	2	2
16	3	3	1
18	7	4	1.75

These routes were also examined by the number of floors between the start and end points of the route. The results of this analysis are shown below in Table 50.

Table 50. Routes with high landmark FTF examined by difference in starting floor and ending floor

Route	Count of landmark FTF	Starting Floor	Ending Floor	Difference in floors	Direction
2	3	B	1	1	Up
4	6	B	2	2	Up
5	4	B	3	3	Up
16	3	2	3	1	Up
18	7	3	B	3	Down

4.4.4 Conclusion

In general, participants used a variety of complexity levels to portray a wayfinding description to a hypothetical traveler. Although participants tended to use the same complexity level for most of their maps, not one participant used the exact same level for each map. Node and path segment analysis showed that route 15 was most complex in the dataset. It is interesting that route 15 was complex because this route is from a landmark on the second floor in the art half of the museums to a landmark in the natural history side of the museum.

Of particular interest to this study is the result of functional FTF and landmark FTF. Although the majority of floor to floor transition points were functional, 16.54% of floor to floor transition points were non-functional landmarks. The main purpose of putting these landmark FTF in the graphical representations was to serving as a way for participants to reorient the hypothetical traveler they were providing directions for. As would be expected, most floor to floor transition points were in upward or downward routes with the most frequently represented point, by far, in terms of a landmark FTF being the grand staircase.

4.5 TRANDITIONAL SPACE ANALYSIS

A verbal analysis based on the verbalizations found to be indicative of a transitional space introduced by Kray et al. (2011) was conducted. In this analysis, the following words were examined by looking at their frequency in the verbal descriptions. Similar to the other verbal analysis methods conducted in this study, some of the original verbalizations have been modified due to the instructional nature of participants giving route descriptions. For example: the word "left" instead of the phrase "to the left of".

- Through
- Throughout
- Down
- Left
- Straight
- Top
- Along
- In
- Below
- Back
- Into

The frequency of each word as it appeared across all wayfinding descriptions is shown in Figure 28. On average words indicating a transitional space were spoken 88.5 times with a minimum of 3 a maximum of 232 and a standard deviation of 67.89. Please note that the words "below" and "throughout" were removed from the analysis as they were never verbalized by participants.

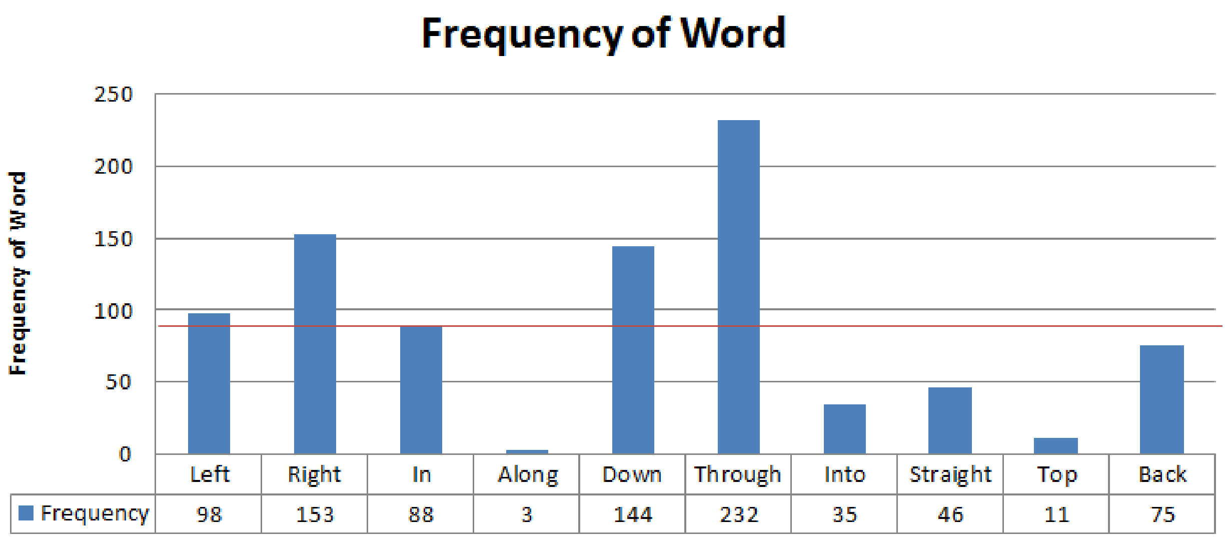


Figure 28. Frequency of transitional spaces words in all verbal accounts.

Next the transitional words were examined by route. The purpose of this analysis was to explore if certain routes contained higher numbers of transitional words Figure 29 shows the results of this analysis.

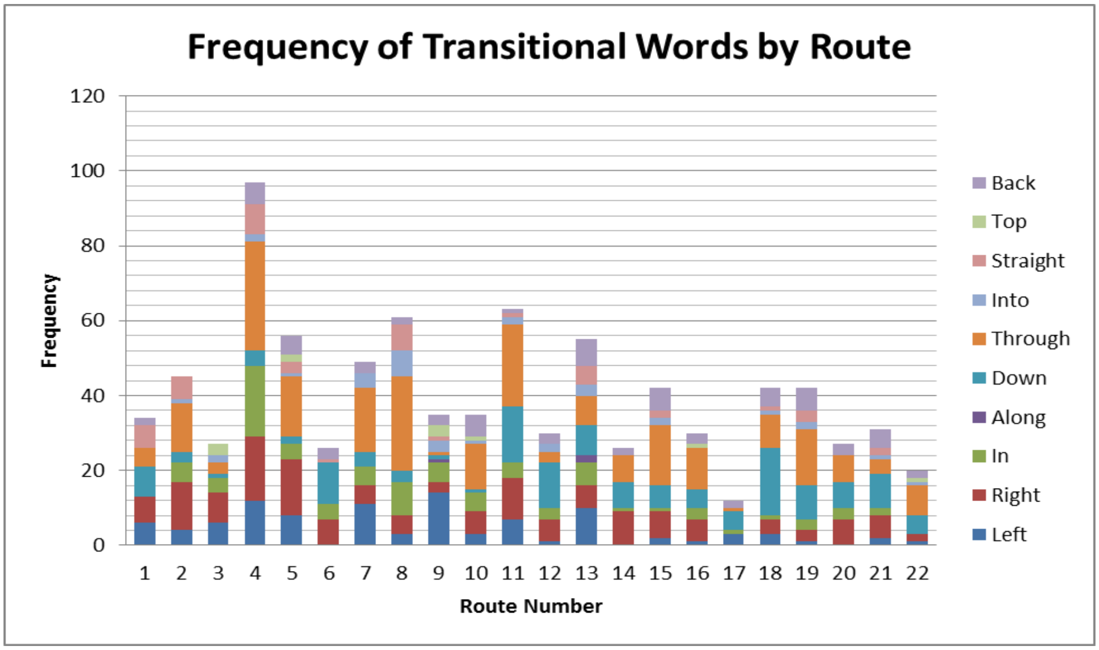


Figure 29. Transitional words by route

Table 51 shows a detailed view of the frequencies of transitional words spoken by route. Bolded rows show a transitional word average that is higher than the global average of 4.02. The minimum was 2 with a maximum of 9.7 and a standard deviation of 1.80.

Table 51. Average frequency of transitional word usage by route[7]

Route Number	Start	End	Beginning Floor	Ending Floor	Floor Difference	Direction	Transitional Word Average
4	**Fossil Fuels**	**Walking Man**	**B**	**2**	**2**	**Up**	**9.7**
11	**Walking Man**	**Fossil Fuels**	**2**	**B**	**2**	**Down**	**6.3**
8	**Exploration Basecamp**	**Walking Man**	**1**	**2**	**1**	**Up**	**6.1**
5	**Fossil Fuels**	**Polar World**	**B**	**3**	**3**	**Up**	**5.6**
13	**Heinz Galleries**	**PaleoLab**	**2**	**1**	**1**	**Down**	**5.5**
7	**T. Rex**	**Hall of Architecture**	**1**	**1**	**0**	**Same**	**4.9**
2	**Fossil Fuels**	**T. Rex**	**B**	**1**	**1**	**Up**	**4.5**
15	**Walking Man**	**North American Wildlife**	**2**	**2**	**0**	**Same**	**4.2**
18	**Ancient Egypt**	**Fossil Fuels**	**3**	**B**	**3**	**Down**	**4.2**
19	**American Indians**	**T. Rex**	**3**	**1**	**2**	**Down**	**4.2**
9	Exploration Basecamp	Botany	1	2	1	Up	3.5
10	T. Rex	Hall of Birds	1	3	2	Up	3.5
1	Rental Lockers	Fossil Fuels	B	B	0	Same	3.4
21	Hall of Birds	Heinz Galleries	3	2	1	Down	3.1
12	North American Wildlife	Fossil Fuels	2	B	2	Down	3
16	African Wildlife	Polar World	2	3	1	Up	3
3	Fossil Fuels	African Wildlife	B	2	2	Up	2.7
20	Hall of Birds	African Wildlife	3	2	1	Down	2.7

[7] Bolded rows show a transitional word average that is higher than the global average

Table 51 (continued)

6	Exploration Basecamp	Fossil Fuels	1	B	1	Down	2.6
14	Botany	PaleoLab	2	1	1	Down	2.6
22	Jurassic Overlook	Ancient Egypt	3	3	0	Same	2
17	Modern Art	Polar World	2	3	1	Up	1.2

Afterward, the transitional words were examined by looking at them in terms of the participants that said them. Figure 30 shows an overview of these data.

Table 52 shows the average number of transition words they used across all descriptions and routes. Bolded rows show a transitional word average that is higher than the global average of 6.32. The minimum was 4 with a maximum of 12.5. and a standard deviation of 2.23.

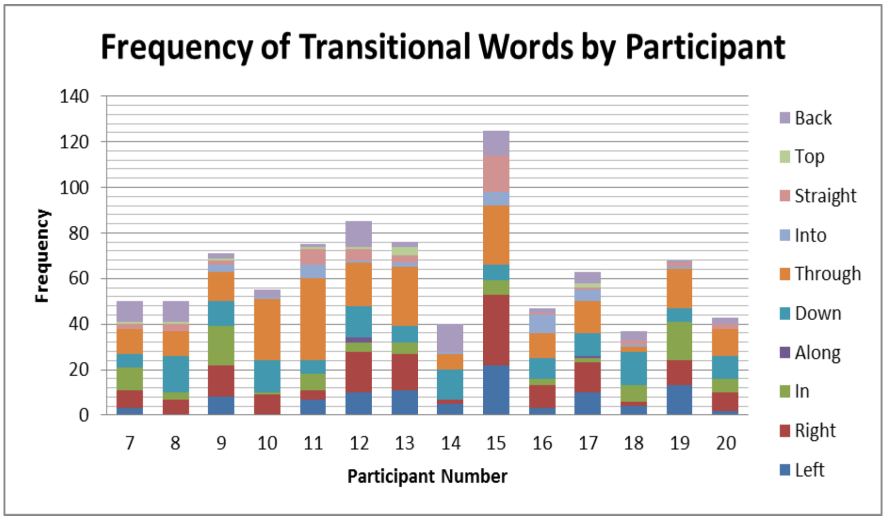


Figure 30. Frequency of transitional words examined by participant

Table 52. Average number of transitional words used by participant[8]

Participant Number	Years Worked at Museums	Santa Barbara Scale	Transitional Word Average
12	**<1**	**6.07**	**8.5**
13	**<1**	**3.8**	**7.6**
11	**5+**	**3.73**	**7.5**
9	**<1**	**5.07**	**7.1**
19	**2-4**	**5.33**	**6.8**
15	**5+**	**5.2**	**12.5**
17	2-4	5.4	6.3
10	2-4	5.47	5.5
7	<1	5.87	5
8	2-4	4.8	5
16	2-4	4.6	4.7
20	6+	4.87	4.3
14	5+	4.47	4
18	<1	2.93	3.7

In conclusion, the transitional space analysis showed that the word “through” was verbalized the most out of all the transition words found in Kray et al. (2011). Route four had the most verbalizations of transitional words. Although this analysis provided an interesting verbal analysis of words that were transitional in nature, a more robust analysis method would need to be employed to find anything of particular interest. Perhaps future work can devise a method that combines the verbal analysis methods and the transitional words for the context of a complex indoor environment.

[8] Bolded rows show a transitional word average higher than the global average

4.6 DISCUSSION OF RESULTS

In order to provide a lens in which to view the results, floor to floor transition points (FTF) will be discussed in terms of global landmarks in indoor environments. In line with the literature, FTF at the Carnegie Museum of Art and Natural History were important landmarks in the cognitive maps of participants in both sketch map and verbal tasks (Denis, 1997). By defining a landmark as anything that stands out from a scene (Presson & Montello, 1988) this discussion explores the characteristics of FTF representations that allowed them to "stand out" by examining them in three ways:

1) FTF that were descriptively named wayfinding descriptions
2) FTF that were represented as both functional and landmarks
3) Where the FTF lies structurally in the museums

By taking these three criteria into account, the importance of FTFs in the museums can be better discussed. The case for the use of global landmarks at the Carnegie Museums begins to emerge with the grand staircase being the best candidate for a global landmark across most participants and with the elevators and ramps serving as a global landmark for only a few participants. Even the Grand Staircase failed to be used consistently by all participants, despite its overall importance in structuring the space.

4.6.1 Explicit naming of FTF in wayfinding descriptions

The guiding idea here is that floor to floor transition points (FTF) that were more important were referred to by name. As with landmarks in any context, FTF were represented in varying degrees of importance in the cognitive maps of participants (Michon & Denis, 2001; Tenbrink & Winter, 2009). Most wayfinding descriptions used generic FTF such as “the stairs” or “the elevator” instead of descriptive words such as “the gold elevator”. 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* showed a generic, unnamed, communication of FTF. Sketch map data also showed that most FTF were thought of generically. Figure 31 shows the generic representation of a stairway as well as an elevator.

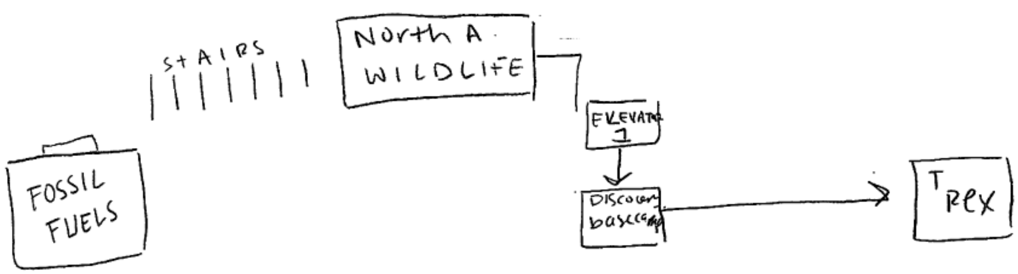


Figure 31. Example of generic unnamed stairway and elevator

Although most FTF were mentioned generically, some were explicitly named. The grand staircase, the spiral staircase, the silver elevator, and the gold elevator were referred to by name in several of the verbal and sketch map descriptions. It is interesting to note that when specifically naming these FTF participants always used these names. This communicates a global understanding of what these landmarks were, thus strengthening their importance. An interesting observation is that these FTF in particular are visually distinguishable from the rest of

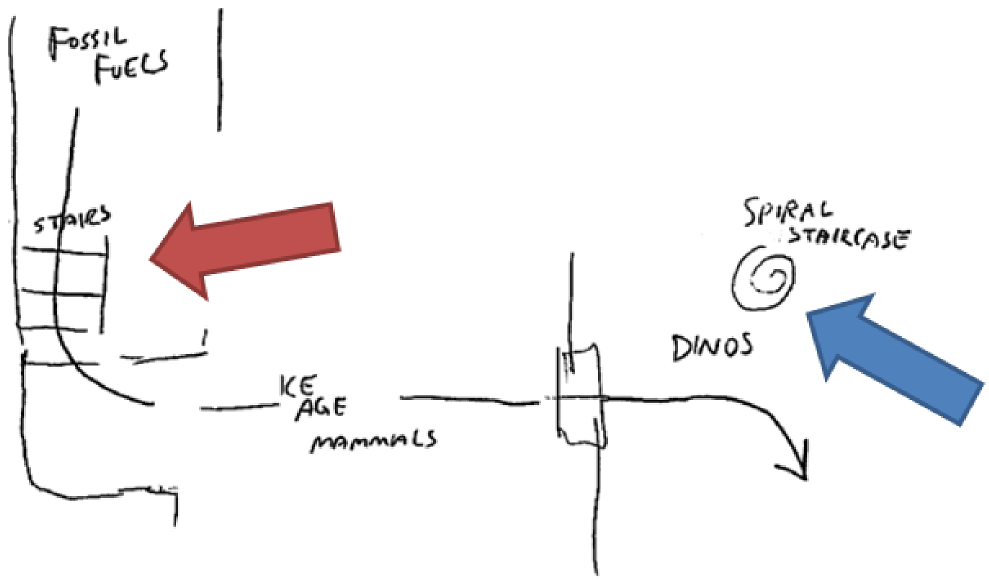


Figure 32. Figure showing functional FTF (red arrow) as well as landmark FTF (blue arrow)

the museums. This makes a case for why they were important landmarks to begin with (Lynch, 1960; Sorrows & Hirtle, 1999). It is likely this distinguishability that makes the grand staircase, the spiral staircase, the silver elevator, and the gold elevator important landmarks in the environment. Giving these landmarks specific names showed their importance by specifying and separating them in comparison to the rest of the cognitive map.

4.6.2 Floor to floor transition points as functional versus landmarks

The guiding idea here is that floor to floor transition points (FTF) that were more important were represented as both functional and landmarks. A functional representation of a FTF meant that its purpose in the wayfinding description was to provide a means to get from one floor to another. A landmark representation meant that a FTF was there as a landmark and did not serve as a way to move vertically through the environment. All FTF were represented as being functional in at least one description. However; some FTF that were represented as landmarks as well. Figure 32 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 from Figure 32 is that the landmark FTF is named while the functional FTF is generic.

One of the FTF in the Carnegie Museums of Art and Natural History that was often represented as functional as well as a landmark in both verbal and sketch map descriptions is the grand staircase. Figure 33 shows an example of the grand staircase being portrayed as a functional FTF, while Figure 34 shows the grand staircase as a landmark FTF.

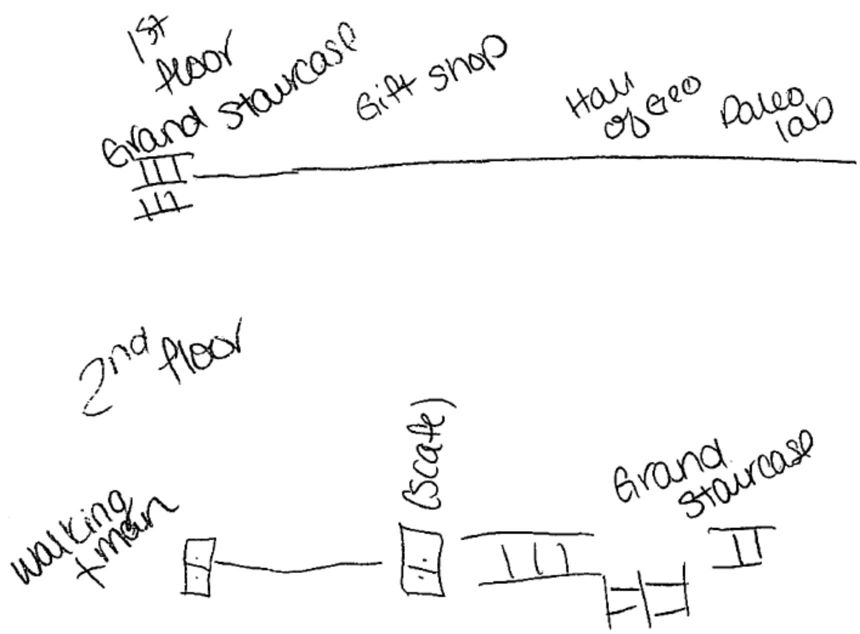


Figure 33. The grand staircase as a named function landmark

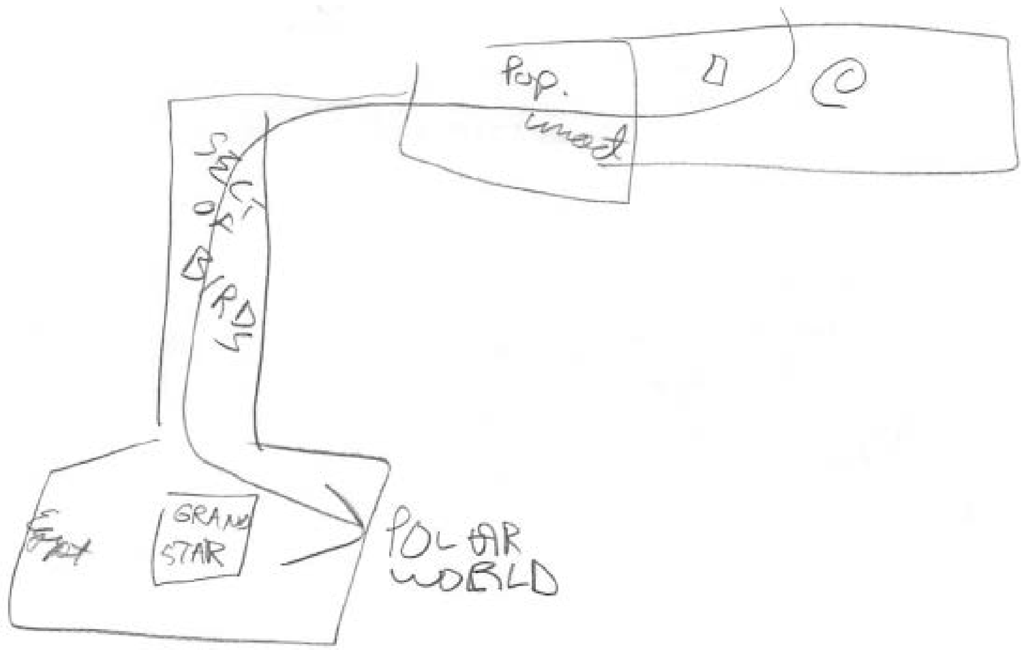


Figure 34. The grand staircase as a landmark FTF

The distinction of a functional versus a landmark FTF provides an interesting duality to specific landmarks that frames the rest of the discussion, in particular, the beginning of a discussion on global landmarks in a complex indoor environment. A FTF that is referred to as a landmark is, not surprisingly, an important FTF in the museums. At the museums, FTF that were often referred to as landmarks were: the grand staircase, the spiral staircase, the silver elevator, and the gold elevator. An interesting utterance 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 name as a landmark, but then the participants is telling the addressee to use the elevator to go down to two. This verbalization shows a deliberate instruction to use the elevator to complete the function of going from floor to floor while referring to the grand staircase to provide orientation information.

4.6.3 Building structure and global landmarks

Where a floor to floor transition point (FTF) lies in the overarching structure of the museums is important in determining the importance of the FTF as a landmark. The literature shows that a landmark is structurally important if it is located somewhere important in the structure of the space (Sorrows & Hirtle, 1999). 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." (Buechner, Hölscher, & Strube, 2007). 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 general.

4.6.4 Towards a definition of global landmarks

Landmarks, in general, provide a structured knowledge of an environment, usually in terms of an anchor point (Couclelis, Golledge, Tobler, 1987). Particular to global landmarks, they provide a point of reference for the participant, allowing for orientation and a sort of "compass" effect (Steck & Mallot, 2000). 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 (Giudice, Walton, & Worboys, 2010). 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 (Hölscher, Meilinger, Vrachliotis, Brösamle, & Knauff, 2006).

By examining the floor to floor transition points (FTF) 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 silver elevator, and the gold elevator all met the first two criteria. However, central location of the grand staircase made it the best candidate for a global landmark amongst the two.

4.6.5 Limitations

The study was not without its limitations. To begin, there was a technical problem which meant that the verbal analysis of six participants could not be analyzed, which means that the data from a third of the participants was not able to be analyzed. This also meant that the dataset was limited and any findings were partial. Another limitation was that a formal analysis of the space wasn’t conducted. Having formalized data about the environment itself would be useful because it would give more data in which to conduct an analysis and draw conclusions about the nature of the landmarks that were found to be of a global nature in the environment.

5.0 CONCLUSION

This chapter presents the conclusion of this dissertation by examining the contributions and implications of this work. It also includes a discussion and direction of future work.

5.1 CONTRIBUTIONS AND IMPLICATIONS

This dissertation focuses on the space between cognitive maps, transitional spaces, and large complex indoor environments in terms of floor to floor transition points (FTF). A user study was conducted at the Carnegie Museums of Art and Natural History that included a verbal as well as a sketch map analysis. Overall, the data collected from participants in this environment was rich and varied. In addition to the sketch map and verbal data collected demographic information was also collected. This allowed the comparison between sketch maps and verbal reports from participants who had various years of experience in a space.

5.1.1 The issue of global landmarks in indoor environments

One of the contributions of this work is the examination of floor to floor transition points as global landmarks. Global landmarks are critical for indoor navigation (Giudice, Walton, & Worboys, 2010; Li & Giudice,2012). This study examined an indoor environment in which the grand staircase became a universal global landmark for orientation and navigation. The findings of this experiment make a case for the grand staircase to be a global landmark at the Carnegie Museums of Art and Natural History. The criteria outlined for this determination is that it:

1. Is often explicitly named in the cognitive maps of participants
2. Is dually represented as functional as well as a landmark
3. Lies structurally in an area that would allow for maximum connection globally

5.1.2 The building of cognitive maps over time

One of the interesting results of this study was the relationship between the number of months a participant had been employed at the museums and the results of the data. In particular, Table 13 presents a statistically significant relationship between the number of landmarks a participant was able to place in the correct location during the map placement activity and the number of months they had worked the museums. A positive correlation shows that the longer a participant had been employed at the museums, the more landmarks they were able to place in the correct location. This result supports the claim that cognitive maps are formed over time as outlined in the current body of research (Nadel, 2013).

A significant relationship with a negative correlation was found between the numbers of words a participant used on average in their wayfinding descriptions and the number of months they had been employed at the museums. The implication here is that participants become better, or perhaps more efficient, at verbalizing route directions over time. This result is particularly interesting because it shows that not only does our cognitive map change over time, but also how we communicate it verbally.

5.1.3 Sketch map versus verbal data in terms of ramps

When examining the differences between the sketch map and verbal descriptions from this study, one of the main differences was in the way inclines or ramps were portrayed by participants. When examining the sketch map descriptions ramps were hardly depicted. Conversely, in the verbal descriptions ramps were mentioned several times. Particularly in the basement level of the museum, the hallway that was also an inclined was described as being so by several participants in the verbal descriptions. This same ramp was hardly depicted as being an incline in the sketch maps.

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 (Lohmann, 2011). It also emphasizes the importance of employing both verbal and graphical modeling methods when studying cognitive maps.

5.1.4 Modified methods

Another contribution of this work is in the modification of existing methods in order to apply them to indoor wayfinding studies. As noted in Chapter 4.0 several methods were modified in order to apply them to an indoor environment appropriately. These methods were modified in order to include any language or sketch map conventions that were particular to an indoor environment. An example of a modification of a method is the modification of the preposition from "on the left" to "left." The modifications were made in order to ensure that the most data possible would be collected in order to conduct the analysis. These modifications were necessary because people appear to verbalize indoor spaces differently than outdoor spaces. This was not tested extensively and is perhaps an area that future work could focus on.

5.2 FUTURE WORK

There are many directions in which future work could build off of this project. Particular to this project, conducting the same study in a new environment would be a natural next step. Another step would be the examination of the word "Through" specifically. Kray et al. (2011) found this word to be important in the transitional spaces analysis they conducted. It was also an important verbalization in this project, however there wasn't enough data to draw conclusions from these verbalizations. Another step could be the examination of gestures in addition to a verbal and sketch map analysis. Perhaps gestures would give insight into the global nature of landmarks.

In terms of the field as a whole, a project focused on the development of cognitive maps over time would be a probable direction for future work to go in. As outlined in Section 5.1 the results of this project supported the overall theory that cognitive maps are formed over time (Nadel, 2013), however a comprehensive examination on the exact differences between these maps would need to be conducted in order to formalize these findings.

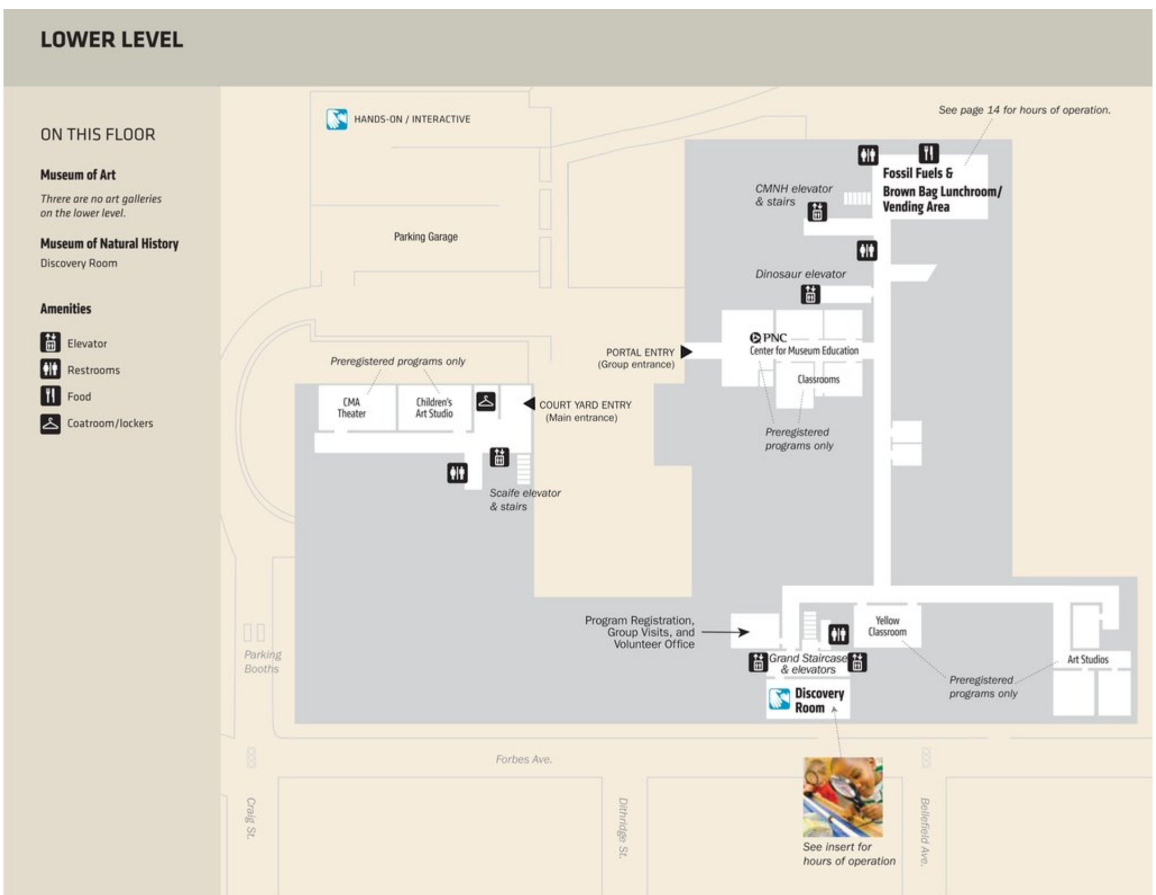
Since existing methods were modified in order to be appropriately applied to wayfinding in indoor spaces, future work should be conducted on formalizing and adequately describing these methods in a peer-reviewed setting. Particular to the analysis of transitional spaces based on the results of Kray et al. (2011) a formalized methodology needs to be developed to describe transitional spaces particular to indoor wayfinding.

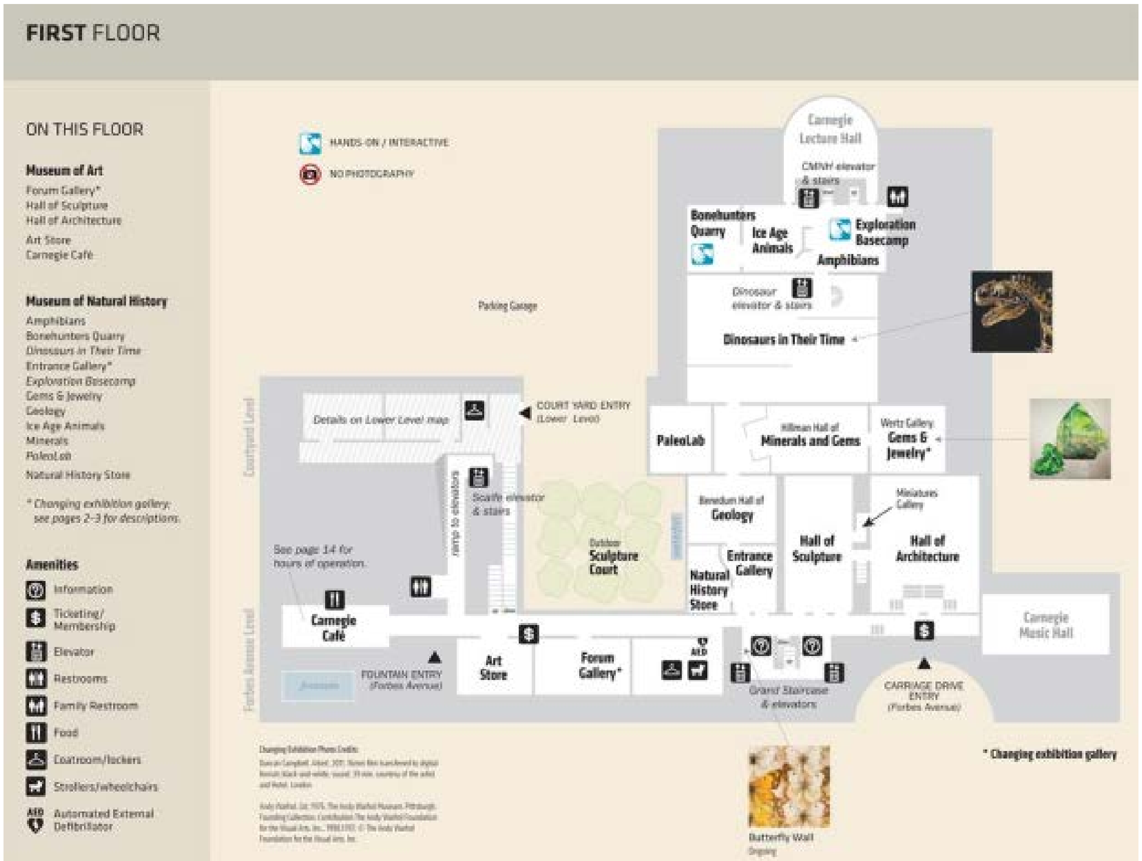
Lastly, another direction entirely could focus on looking at the data in terms of automatic route generation would be an interesting direction. If candidates for global landmarks are able to be determined by looking at the properties of a landmark, that begs the question, “Are we able to determine a global landmark and adequately differentiate it from other landmarks in an automatic context?”. Specifically applying methods such as those employed by Klippel and Winter (2005) and Duckham, Winter, and Robinson (2010) would be great candidates for future work blending these works.

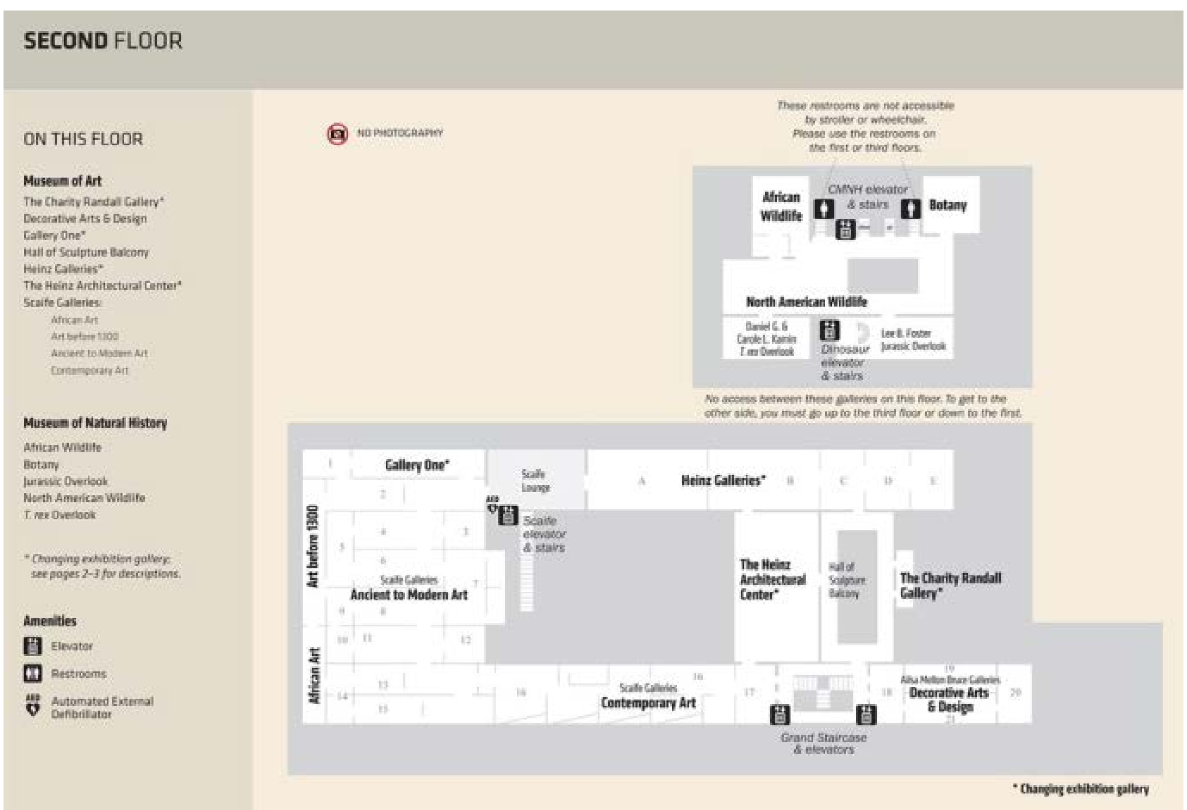
APPENDIX A

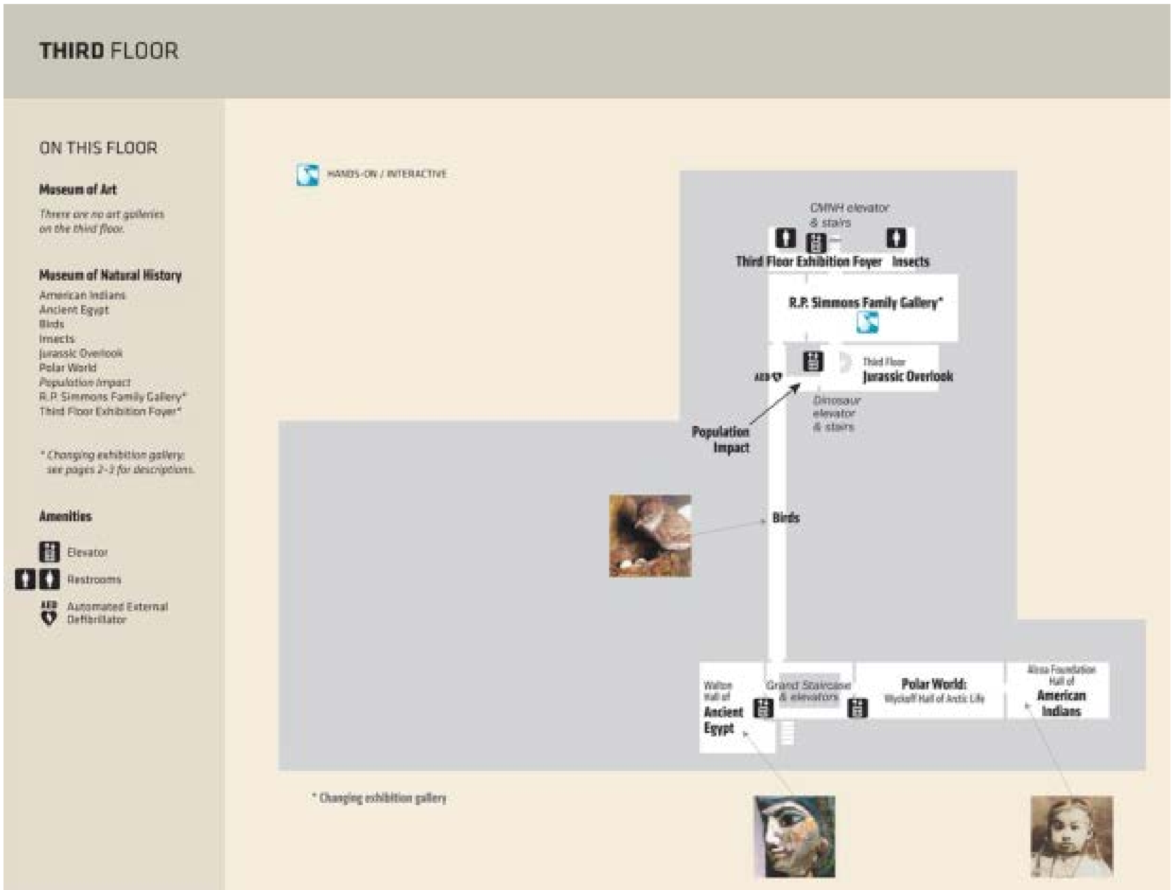
CURRENT MAPS AT THE CARNEGIE MUSEUMS OF ART AND NATURAL HISTORY

Below are the current maps for the Carnegie Museums of Art and Natural History. These maps are larger than the maps presented in the body of this dissertation.




FIRST FLOOR
ON THIS FLOOR
Museum of Art
Forum Gallery*
Hall of Sculpture
Hall of Architecture
Art Store
Carnegie Café
Museum of Natural History
Amphibians
Bonehunters Quarry
Dinosaurs in Their Time
Entrance Gallery*
Exploration Basecamp
Gems & Jewelry
Geology
Ice Age Animals
Minerals
PaleoLab
Natural History Store
* Changing exhibition gallery; see pages 2–3 for descriptions.
Amenities
Information
Ticketing/Membership
Elevator
Restrooms
Family Restroom
Food
Coatroom/lockers
Strollers/wheelchairs
Automated External Defibrillator
HANDS-ON / INTERACTIVE
NO PHOTOGRAPHY
Carnegie Lecture Hall
CMNH elevator & stairs
Bonehunters Quarry
Ice Age Animals
Exploration Basecamp
Amphibians
Parking Garage
Dinosaur elevator & stairs
Dinosaurs in Their Time
Details on Lower Level map
COURT YARD ENTRY (Lower Level)
PaleoLab
Hillman Hall of Minerals and Gems
Wertz Gallery Gems & Jewelry*
Scaife elevator & stairs
ramp to elevators
Benedum Hall of Geology
Miniatures Gallery
See page 14 for hours of operation.
Outdoor Sculpture Court
Natural History Store
Entrance Gallery
Hall of Sculpture
Hall of Architecture
Carnegie Café
Carnegie Music Hall
FOUNTAIN ENTRY (Forbes Avenue)
Art Store
Forum Gallery*
Grand Staircase & elevators
CARRIAGE DRIVE ENTRY (Forbes Avenue)
Courtyard Level
Forbes Avenue Level
Butterfly Wall
* Changing exhibition gallery


SECOND FLOOR
ON THIS FLOOR
Museum of Art
The Charity Randall Gallery*
Decorative Arts & Design
Gallery One*
Hall of Sculpture Balcony
Heinz Galleries*
The Heinz Architectural Center*
Scaife Galleries:
African Art
Art before 1300
Ancient to Modern Art
Contemporary Art
Museum of Natural History
African Wildlife
Botany
Jurassic Overlook
North American Wildlife
T. rex Overlook
* Changing exhibition gallery; see pages 2–3 for descriptions.
Amenities
Elevator
Restrooms
Automated External Defibrillator
NO PHOTOGRAPHY
These restrooms are not accessible by stroller or wheelchair. Please use the restrooms on the first or third floors.
African Wildlife
CMNH elevator & stairs
Botany
North American Wildlife
Daniel G. & Carole L. Kamin T. rex Overlook
Dinosaur elevator & stairs
Lee B. Foster Jurassic Overlook
No access between these galleries on this floor. To get to the other side, you must go up to the third floor or down to the first.
Gallery One*
Scaife Lounge
Heinz Galleries*
Scaife elevator & stairs
Art before 1300
Scaife Galleries Ancient to Modern Art
The Heinz Architectural Center*
Hall of Sculpture Balcony
The Charity Randall Gallery*
African Art
Scaife Galleries Contemporary Art
Ailsa Mellon Bruce Galleries Decorative Arts & Design
Grand Staircase & elevators
* Changing exhibition gallery


THIRD FLOOR
ON THIS FLOOR
Museum of Art
There are no art galleries on the third floor.
Museum of Natural History
American Indians
Ancient Egypt
Birds
Insects
Jurassic Overlook
Polar World
Population Impact
R.P. Simmons Family Gallery*
Third Floor Exhibition Foyer*
* Changing exhibition gallery; see pages 2–3 for descriptions.
Amenities
Elevator
Restrooms
Automated External Defibrillator
HANDS-ON / INTERACTIVE
CMNH elevator & stairs
Third Floor Exhibition Foyer
Insects
R.P. Simmons Family Gallery*
Third Floor
Jurassic Overlook
AED
Dinosaur elevator & stairs
Population Impact
Birds
Walton Hall of
Ancient Egypt
Grand Staircase & elevators
Polar World:
Wyckoff Hall of Arctic Life
Alcoa Foundation Hall of
American Indians
* Changing exhibition gallery

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