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ACCESSIBILITY IN PUBLIC SPACES: Spatial legibility for visually impaired people

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Abstract

According to the 2010 global population estimates of the World Health Organization, more than a billion people live with some form of disability (or approximately 15% of the world's population). There are 45 million visually impaired persons in the world. Architecture discipline must develop approaches that enable visually impaired people to function in social life in spite of their accessibility issues. Vision is the most significant sense that is used to gather environmental information required for orientation and mobility. Therefore, the independent mobility is one of the greatest challenges faced by blind people. Mobility is the act of moving securely. During mobility, vision, sensory stimuli, and environmental factors such as lighting and the presence of various objects impact perception. This study examines how these factors relate to the spatial organisation abilities of visually impaired. Spatial organisation also influenced by location; the characteristic of the structural and the sensory landmarks within the space; and the characteristic of the plan schemes. This paper reports on the result of an experiment examining spatial cognition. This experiment was conducted with 14 visually impaired people (low vision as well as total blindness) in two different shopping malls with very different plans. Their navigation was observed and their narrations and plans sketches were recorded to test their cognitive mapping. Landmarks have always been a significant in the orientation of subjects and as well as the legibility of a place. It was observed that the correct identification of landmarks, depended not only on the characteristic, but also the location of a landmark. The integration and connectivity on the axes of landmarks were examined and demonstrated that they are affiliated. It is also observed that when landmarks are placed appropriately so that they can serve as a reference point for the visually impaired, both the visually impaired and the sighted tend to use the same route. This is consistent with the observations that systems with high integration and high connectivity being highly intelligibility. In conclusion, the legibility of a space for visually impaired calls for inclusion of details that assist in the formation of cognitive maps. Therefore, the criteria identified in this study are important parameters that impact the mapping.

Keywords: *Visually impaired, spatial legibility, landmarks, space syntax, visibility graph analysis.*

Theme: *Spatial Cognition and Behaviours*

1. INTRODUCTION

More than one billion people worldwide have various disabilities, of which 45 million people are visually impaired (World Health Organization 2012). Architects must seek solutions for the accessibility problems that prevent visually impaired people from fully participating in social life.

Vision is the most important manner for gathering environmental knowledge that is required for navigation and movement. Therefore, visual impairment presents a significant problem to **independent movement**. Mobility requires the ability to move around safely. In addition to vision, perceptions from other senses, ambient lighting, nearby objects, and environmental factors influence a person's movement. The aim of this research is to determine whether the design criteria of a space are also among the factors that contribute to the movement of the visually impaired. In this article, the term space design refers to the location, the characteristics of structural and sensory landmarks, and the quality of the schematic design.

1.1. The Research Objectives

A common solution offered for the movement of visually impaired persons is to provide with technological devices that support dynamic navigation. However, these devices often prohibit them from perceiving other sensory inputs, such as environmental sounds. These devices should not distract them from perceiving such sensory input, which can potentially be dangerous. We suggest that solutions that support movement and navigation within a space that rely on using other senses are desirable. Electronic devices that provide audio directions, navigation, and other assistance aim to support safe access for the visually impaired. However, the impact of the principles of spatial design should be considered when accessing the successful perception of spaces. A common approach to dealing with accessibility issues that stem from design and poor structural details is to offering retrofitted and technological solutions. Unfortunately, sufficient time and priority to accessibility issues is not given to the design phase. Instead, solutions are sought only after the construction is finalized. Furthermore, solutions that have further costs, which results in excluding the visually impaired who can afford these solutions.

1.2. Literature Survey

Lynch states that perception of objects are also strongly dependent on senses other that vision, which he refers to as legibility or visibility. According to him, **the more the environment supports envisioning, the more legible it is**. Furthermore, and if a space is legible, it can be visually comprehended by creating a texture of identifiable symbols. Lynch uses legibility as **a reference to easily understand and remember a space** (Lynch 1997). Weisman defines legibility as the ease of the navigation. (Weisman 1981). Similarly, Passini uses the term legibility in relation to navigation, as **an environmental quality which easily opens up and offers comprehensible information** (Passini 1984). According to O'Neill, legibility describes the ability of objects designed to help forming an effective mental image or a cognitive map (O'Neill 1991). In another words **the easier an environment forms a cognitive map in the mind of a visually impaired person, the more accessible it is**.

Lynch defines the landmarks as a kind of urban image element (Lynch 1997). He describes landmarks, which he suggests as a point-reference, as physical formations that can easily be identified. According to Lynch, the physical forms that make a city can be grouped into five items: paths, edges, districts, nodes and landmarks (Lynch 1997). Sorrows and Hirtle categorize landmarks into three groups, including **structural landmarks**, which have an important role in the spatial setting (Sorrows and Hirtle 1999). In this case, landmarks refer to those which the visually impaired are engaged with.

Most people with a visual impairment have some partial vision that is useful. A visual residue can cover a large sector from the almost totally blind to the just legally blind person (Passini, Proulx and Ranville 1990). This vision helps them acquire information about surrounding landmarks, hints, and obstacles. For example, visually impaired people can use residual vision[1] to track a vertical or parallel route when following one or multiple navigation lines or move along a straight line. They can also make use of surrounding landmarks through their functioning senses. Besides residual vision, they can gain insight by smelling, hearing, and touching. The announcements accompanying traffic lights, the sound of water, the cashier sound at a supermarket, the smell of bread from the bakery, or the odor of waste bins are all useful landmarks for the visually impaired.

The important thing here is that visually impaired people can identify the static landmarks. Such permanent landmarks, which may be referred to as **sensory landmarks**, constitute important reference points for the visually impaired. Landmarks considered as **unique** and **memorable** (as proposed by Lynch), should be identifiable for visually impaired through senses other than vision.

1.3. Research Question

In the study, the hypothesis **the location and characteristics of structural and sensory landmarks in a spatial setting are important for the navigation of visually impaired people** is examined.

A visually impaired person is engaged with the landmarks in the space that surrounds them. Reliable and static landmarks identified by the person prevent the feeling of being lost. This supports the perception of the space, and consequently the navigation within it.

This work suggests that there is a need to investigate the impact of the space and environment design on the cognitive mapping ability of people with partial or total visual impairment.

2. METHOD

In this study, an experiment was conducted in two shopping malls with significantly different layouts. The shopping malls were identified as public spaces. 14 people with partial or total visual impairment participated in this experiment. Specific routes were identified in the malls. The movements on these routes were monitored. After they completed their routes, they were requested to draw and describe them in order to examine their cognitive mapping.

Furthermore, an axial map analysis of the layout of the space was conducted with space syntax method.

During the evaluation, the subjects drew their perceived space with a special pen on a plastic embossing film that was placed on a geometry mat. In their drawings they were specifically asked to indicate the landmarks on their sketches.

Subsequently, the predicted movement of sighted persons in the same spaces is determined by use of The *Depthmap* software. From the results provided by this software we utilized the

1 Any useful sight of a person who has a severe visual impairment. The person may have a very limited amount of vision, but is often able to make good use of this in everyday situations (RNIB 2013).

connectivity and integration values. The axial map analysis predicts the routes which the sighted people are likely to use. Finally, the routes identified by the subjects in our experiment were compared with the routes predicted by the *Depthmap*.

2.1. Experiment

The trial included 14 adults with visual impairment, including 3 female and 11 male subjects, 4 with partial visual impairment, 4 with congenital and 10 with adventitious impairment. 2 basic criteria were used in selection of subjects:

1. Use of white cane with necessary training

2. Ability to move independently

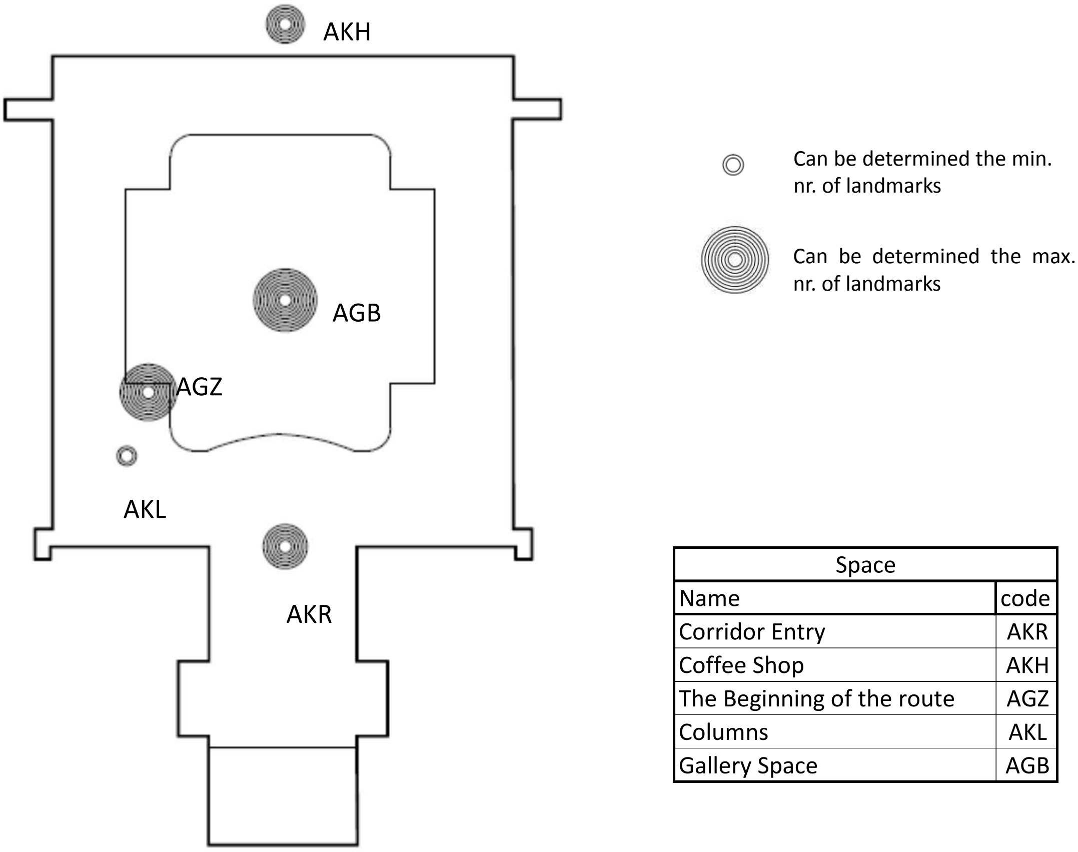
The participants were classified by their degree of vision: 71.4% were totally impaired and 28.6% were partially impaired. All of the partially impaired and some of the totally impaired subjects were adventitiously impaired.

The degree of their vision is based on their own declaration and given as a percentage. Subjects with 10 to 20% and in need of assistance in independent movement (white cane or attendant) were classified as partially impaired. Those with less than 10% vision were classified as totally impaired.

For the trial two shopping malls (SM) with different layouts were selected. The first one has a typical simple and symmetric geometric layout, which we refer to as (A). The second SM has an asymmetrical and non-linear layout, which we refer to as (K). Since, through repetitive processes, people get familiar with their environment and organize the spatial knowledge with mental representations. For this reason, in order to assess the perception of space, subjects who have not previously visited these places were selected. The initial ability to access public spaces are a significant issue for the visually impaired as otherwise they may be excluded or worse disenfranchised. When selecting the trial locations, less known and less accessible SMs targeting were chosen to minimize the use of memories.

3. RESULTS

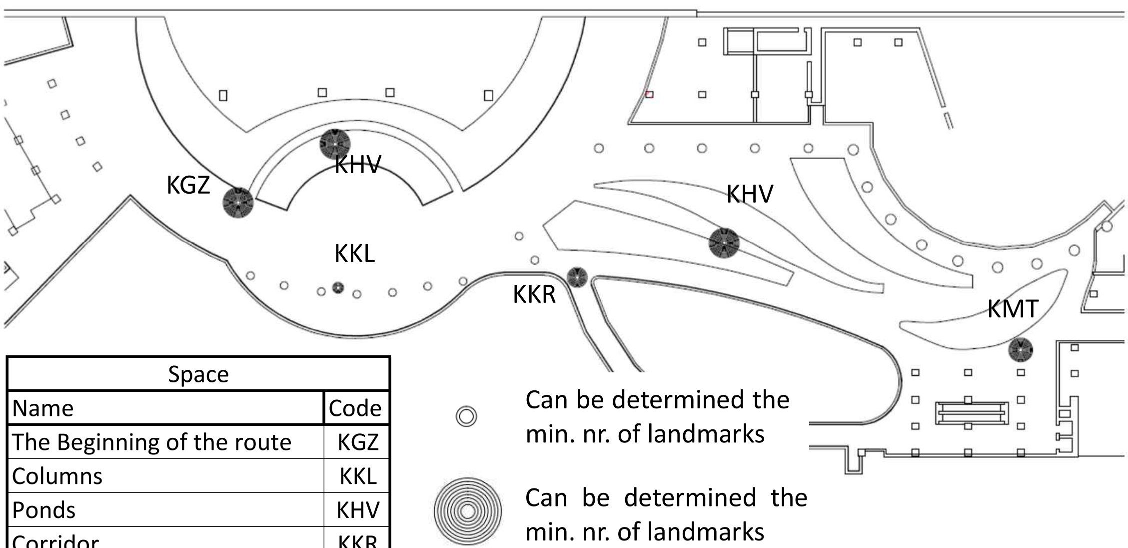
Figure 1 shows the landmarks that were correctly perceived and identified on in the SM (A), where 46% of landmarks were correctly identified.



Space	
Name	code
Corridor Entry	AKR
Coffee Shop	AKH
The Beginning of the route	AGZ
Columns	AKL
Gallery Space	AGB

Figure 1: (A) SM - the landmarks that were correctly perceived and identified on in the SM (A)

Figure 2 shows similar information for SM (K). In this case the percentage of correct identification is higher at 67%.



Space	
Name	Code
The Beginning of the route	KGZ
Columns	KKL
Ponds	KHV
Corridor	KKR
Subway Exit	KMT

Figure 2: the landmarks that were correctly perceived and identified on in the SM (K)

A comparison of the landmarks that were accurately perceived during navigation as well as drawn (or described) later is shown in Table 1. As can be understood from this table, some landmarks that were perceived during navigation, were not be accurately depicted in the drawings or descriptions.

Table 1: (A) – (K) SM Landmarks Perception / Determine

Shopping Mall	Landmarks	nr of Perception (a)	nr of determine (b)	ratio of determine (b/a)
(A)	AGB Gallery Space	9	9	100%
	AKR Corridor Entry	9	8	89%
	AGZ The Begenning of the route	9	7	78%
	AKH Coffee Shop	9	6	67%
	AKL Columns	2	2	100%
(K)	KHV Ponds	13	13	100%
	KGZ The Begenning of the route	13	13	100%
	KMT Subway Exit	10	9	90%
	KKR Corridor	8	7	88%
	KKL Columns	6	5	83%

The subjects were more successful in SM (K) in terms of accurately perceiving and identifying landmarks.

The axial maps of the relevant floors of the SMs were drawn on *Depthmap* software to study the **impact of physical characteristics** of SMs on **human movement** and the density of their use. The maps created with the software (All-line Map, VGA Map) and numeric data as described in the following paragraph. The software uses colors for the values, which are blue for low integration or connectivity and red for higher integration or connectivity.

In the connectivity analysis of the SM (A), the axe coded 179, which has the lowest number of connections, connects to 32 points, and the axe coded 145, which has the highest number of connections, connects to 187 points. The average connectivity value was calculated as 109.79. The axes with the highest and lowest number of connections according the results of connectivity analysis for SM (A) are shown in Figure 3. On this layout, the axes shown in red, which have high connectivity values (axes 145, 97, 146, 135, and 114) are the lines which have the densest circulation on the relevant floor and which are mandatory routes. The axes with the lowest number of connectivity (axes 179, 210, 173, 177, and 69) are the most deep districts and do not lead to any subsequent space. Therefore, the lowest numbers of connection points in SM (A) are less frequently used, while the axes with the highest number of connection points are used more frequently.

In the connectivity analysis of SM (K), the axe coded 92, which has the lowest number of connections, connects to 23 points, and the axe coded 178, which has the highest number of connections, connects to 1285 points. The average connectivity value was calculated as 569.02. The axes with the highest and lowest number of connections according the results of connectivity analysis for SM (K) are shown in Figure 4. In this layout, the axes shown in red, which have high connectivity values (axes 178, 451, 452, 31, and 30) are those which are located on uninterrupted routes. The axes in dark blue the lowest number of connectivity (axes 92, 141, 572, 562, and 98) are non-mandatory axes. Thus, the population within and the use of districts where these axes are located is small. The axes with the lowest number of connection points in SM (K) are used less by people, while the axes with the highest number of connection points are used more frequently.

For the integration analysis of both of the SMs, the global Rn analysis, which evaluates the relationship of each axe to all other axes was applied. This approach helps identifying the integrated and dissociated areas of spaces. Here, the most integrated part of a system is the core of the system.

According to the results of the global integration (Rn) analysis for SM (A), the lowest integration value was 3.69 for the axe code 226, and the highest integration value was 15.09 for axe 148, which is the core of the system. The average Rn (global) integration value was 8.09.

According to the results of global integration (Rn) analysis for SM (K), the lowest integration value was 3.21 with for 447, and the highest integration value was 18.90 for axe 178, which is the core of the system. The average value was 8.86. The axes with high integration values were located in the same part as the axes with high connectivity values. The axes with the lowest integration value were in the same location as the axes with the lowest connectivity values, and were not mandatory passages to access any destination.

The results for connectivity and integration analyses created by the software from the axial map analyses for SMs (A) and (K) are presented in Table 2.

Table 2: Connectivity and integration values

	Connectivity			Integration		
	max.	min.	average	min.	max.	average
(A) SM	32.00	187.00	109.79	3.69	15.09	8.09
(K) SM	23.00	1285.00	569.02	3.21	18.90	8.86

According to the results of integration analyses, the lowest integration value in SM (A) was 3.69, which corresponds to two areas in layout: (1) the corridor area shown on the top of the plan (where a coffee shop is located) and (2) the area at the bottom, which is the end of a corridor. The axes with the highest Rn (global) integration are the points at the gallery space, which is near the start point. These axes are near the escalator, which descends from the floor above the trial floor. The start points of the escalators which ascend from the trial floor to the upper floor, and the gallery space in the center. Furthermore, they are close to the connection points to the corridor. According to the analysis results, the axes with the highest connectivity values are of the gallery space and near the start point of the route. The axes with the lowest connectivity values are small corridors located in corners and the areas at the end of the corridor. The axes with the highest global integration value are located in the same district as the axes with the highest connectivity value. Therefore, these districts are preferred and more frequently used.

In SM (K), the axes with the lowest integration value are located in an area outside the specified route, which were not traversed by subjects[2] as well. The other one was located in the back side of the pool near the starting point of the route. The area with the highest integration value was the route. The area with the highest integration value in SM (K) is an axe that is extensively

[2] Note that a subject may wander outside of the route specified by the experiment.

utilized to guide the customers to the shops, and it is considered to be commercially successful.

Finally, we independently superimposed the layout of correctly identified landmark with the connectivity and the integration maps for SM (A) and SM (K). This reveals the relation between the successfully identified landmarks and the axes with the highest and lowest values (Figure 3, Figure 4, Figure 5, and Figure 6).

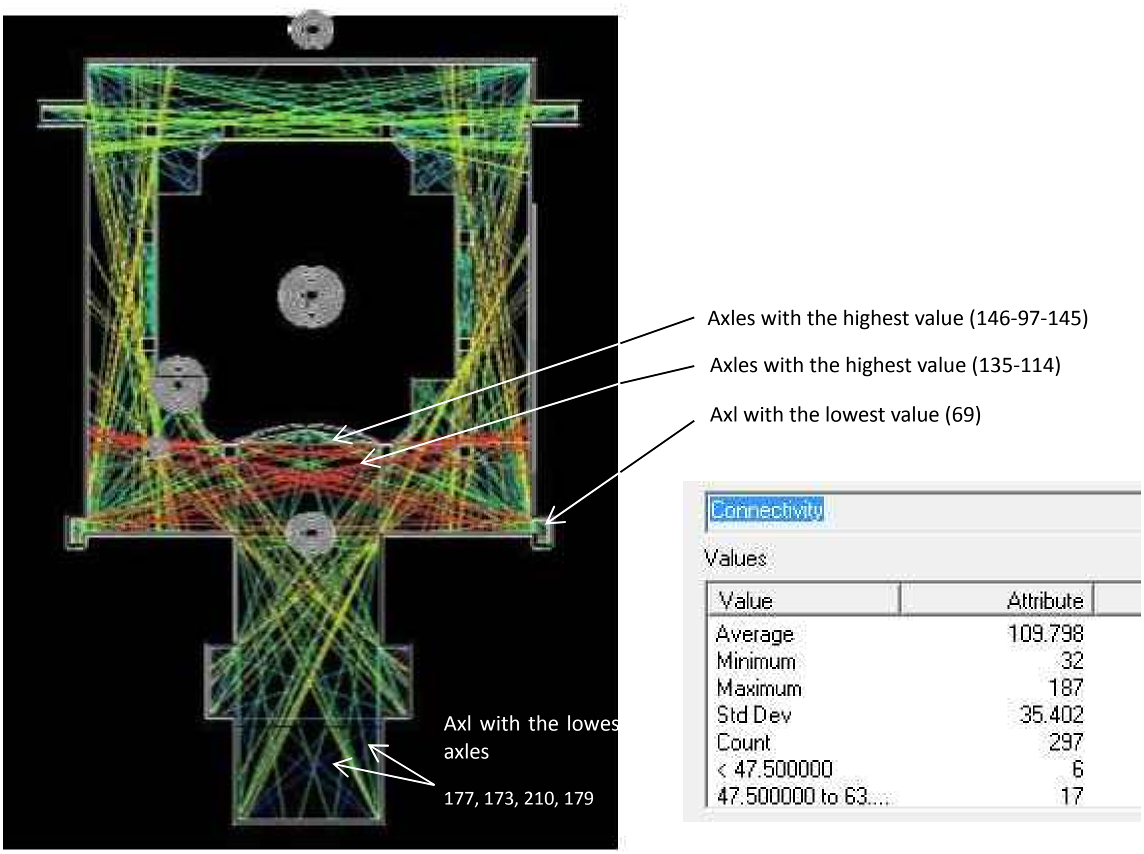


Figure 3: (A) SM Connectivity analysis and marking the landmarks

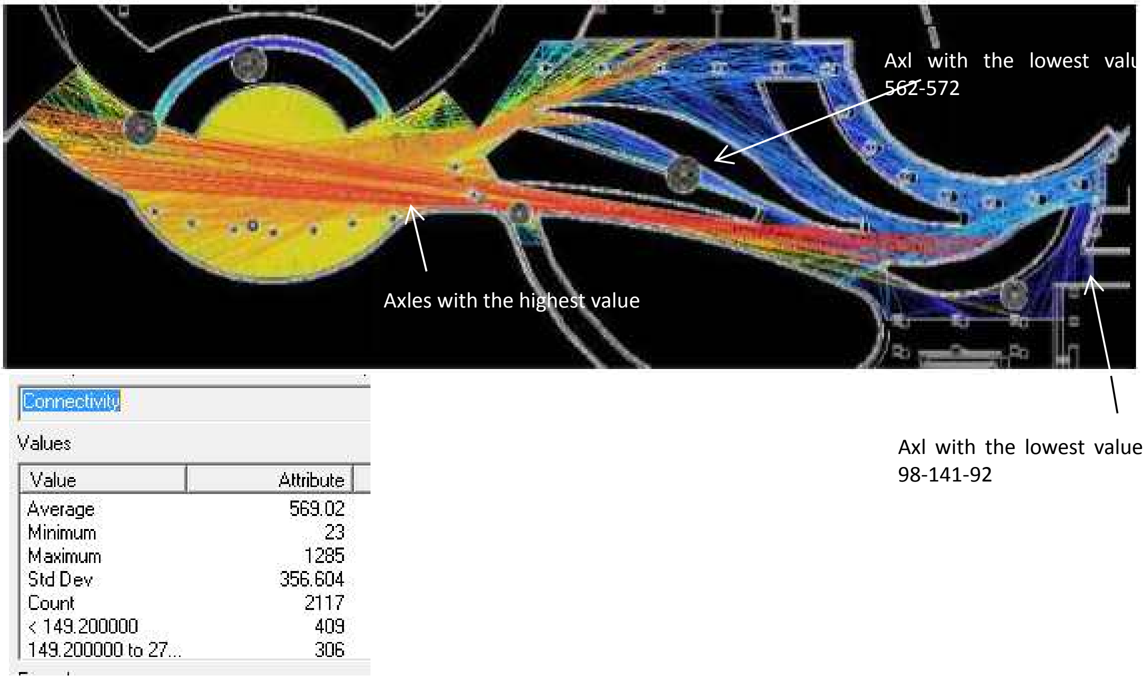


Figure 4: (K) SM Connectivity analysis and marking the landmarks

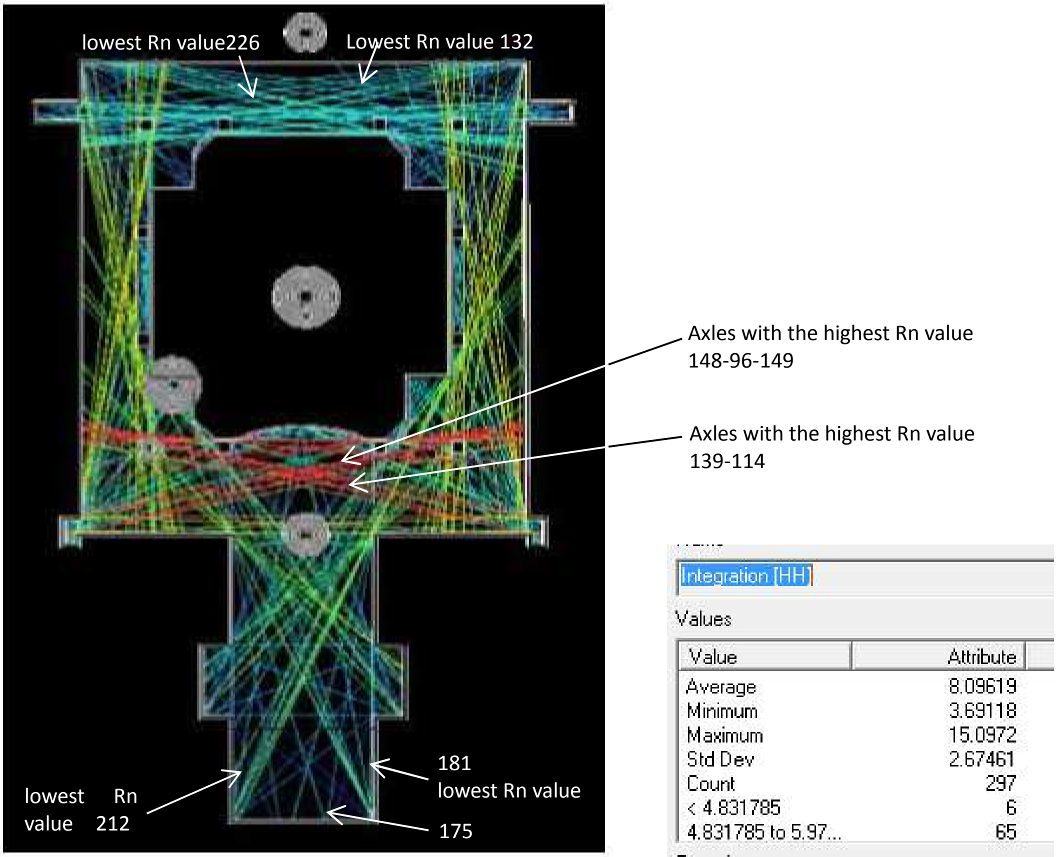
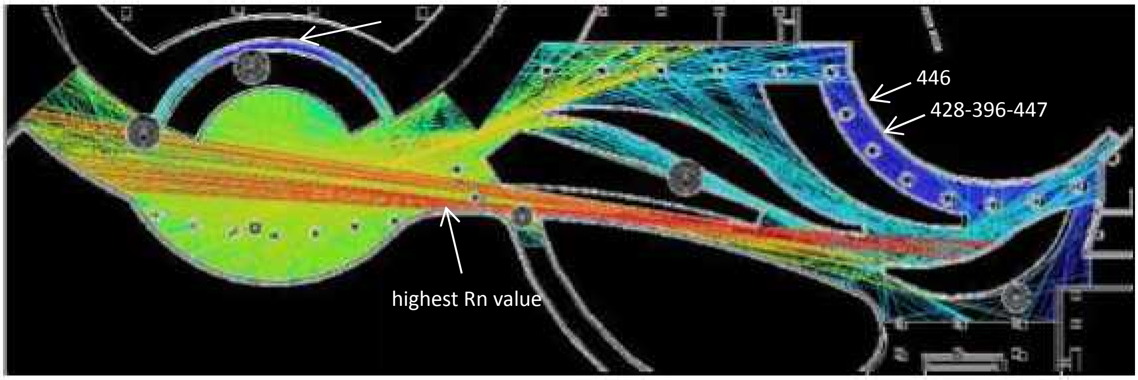


Figure 5: (A) SM Integration analysis and marking the landmarks



Integration [HH]

Values

Value	Attribute
Average	8.86305
Minimum	3.21142
Maximum	18.9027
Std Dev	2.94341
Count	2117
< 4.780544	341
4.780544 to 6.34...	90

Figure 6: (K) SM Integration analysis and marking the landmarks

4. DISCUSSION

This study has explored the impact of the characteristics and location landmarks within spaces and their perception through multiple senses on the legibility of spaces for the visually impaired. Landmarks were found to be important for the navigation and the subsequent legibility of spaces for the visually impaired. In addition to the identification of landmark, the ability to correctly place it is influenced by both the characteristics as well as the location of the landmark. The integration and connectivity values of the axes where the landmarks were located were inspected, which were determined to be related to the correct identification. Areas of high connectivity and integrity are considered to be highly understandable and preferred areas of use. When these areas coincide with landmarks there were also strongly preferred by the visually impaired, implying the correct area to place the landmarks.

Landmarks were found to be significant in the navigation and the subsequent legibility of spaces for the visually impaired. When landmarks are considered the most easily perceived in these two SMs were smell and sound. In the trial, the smell of coffee and the sound of water from the pool were most frequently identified. In SM (A) many subjects identified the smell of coffee, however only 67% of those who identified the coffee shop could accurately mark its location on the sketch. The results of integration analysis for SM (A) indicate that the coffee shop is located on the axe with the lowest Rn (global) integration value. Assuming that people tend to use the paths with high integration and high connectivity values more often and that certain physical elements on these paths, such as landmarks, can be utilized when creating cognitive maps, landmarks placed on axes with low Rn integration values are not expected to impact the cognitive maps of the visually impaired.

All subjects who perceived the pool in SM (K) also successfully marked it on the sketch. In this case, the pool in SM (K) is close to the axes with the highest Rn (global) integration and connectivity values. In the axes with the highest Rn (global) integration values in SM (A), there are no structural elements that other than columns. This explains why the coffee house, which was easily perceived by the visually impaired, yet not accurately positioned on the sketch. In this case the sense of smell is not sufficient in accurately perceiving the space. We conclude that, **landmarks positively influence the legibility of the space for the visually impaired, when they are accurately (and statically) located.** This conclusion confirms the hypothesis. **The characteristics and location of structural and sensory landmarks within a space are important for the perception of a space, and consequently for the navigation of the visually impaired.**

Another significant observation was the fact that more people were able to identify landmarks in SM (K). Among the subjects12 were able to perceive 3 to 5 landmarks, whereas in SM (A) only 7 people were able to perceive 3 to 5 landmarks. The reason is because the landmarks in SM (K) are located on the axes with high connectivity and integration values. Furthermore**, it is difficult to identify structural elements as landmarks in uniform and symmetrical layouts.** A totally impaired and frustrated participant stated: “I keep going around and around and come to the same spot in a circular space” to describe SM (A). Although the task of navigating and identifying landmarks "simple" layout (a square area) may seem trivial, it turned out to be very confusing. When the participants were asked to mark the landmarks, which they identified during navigation, on their drawing they often failed. This suggests that **in spaces with uniformity resulting from symmetrical layouts and lack of landmarks undermines the ability to navigate and develop cognitive maps.**

Nevertheless, the gallery space which was perceived by 9 subjects in SM (A) and the columns which were perceived by 2 subjects were accurately marked on the plan by those who perceived them. Both of these landmarks are located on axes with high Rn (global) integration and connectivity values. **The structural or sensory landmarks located on axes which have high integration and connectivity values clearly influence the cognitive maps of the visually impaired.**

In SM (A), the starting point of the route was perceived by 78% of the participants, however only 67% of them could accurately mark it on the sketch. In SM (K), the starting point of the route was perceived by 93% of the participants, all of whom accurately marked it on the sketch. The single-line and straight corridor (Figure 2) of SM (K) was effective in this outcome. **Spaces that address multiple senses offers ease of navigation and independent movement of the visually impaired.** In SM (K) the central roof of this SM is open, resulting in the sunlight and wind to create important sensory inputs. Furthermore, SM (K) was more crowded than SM (A), resulting in a great deal of sounds of speech and footsteps. Visually impaired people tend to follow other people during navigation to ensure accurate navigation and to avoid any unnoticed structural dangers. It is therefore known that they feel uncomfortable in unpopulated spaces. SM (K) has an advantage in that regard. However, the sound of wind due to open air, and loud music occasionally disturbed the participants. A similar discomfort was experienced from the angle of sunlight, which resulted in a sharp contrast between lighted and shadow areas. This was particularly troubling for the partially impaired (due to dazzling, which reduced sight to 0 – zero – for a certain period). **Spaces addressing multiple senses offer an advantage in the legibility of spaces for the visually impaired; however, any some poor design choices in details may adversely impact the legibility of spaces.**

In summary, legibility of spaces for the visually impaired is improved by the use of the right landmarks in the right places, and by appealing to multiple senses. When the layout is designed with consideration of appropriate sensory and structural landmarks, spaces will be legible for the visually impaired. Furthermore, particularly for public spaces, the structural details (stair details, heights, etc.) must conform to international standards to ensure safe navigation for the visually impaired.

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