Navigating the Workplace Environment as a Visually Impaired Person

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Abstract. An inclusive workplace environment should be comfortable and functional for all of its users. Over the past decade, workplace environments have changed to offer more flexible spaces in a variety of ways and locations. Modern office designs blend different working and social spaces, which include, for example, modular workstations, corridors, furniture, non-traditional layouts and open spaces. In this way, workplaces are designed to offer spaces for the effective collaboration of staff and to optimize work practices by promoting spontaneous and free-flowing communication. However, new design tendencies often lead to greater complications in moving around the workplace. Such complications may affect all workers, but they will mainly affect those with sight loss who experience extra difficulties in pursuing their target destination.

Keyword: Visual impairments

1 Introduction and Background

Workplaces are usually characterized by outdoor/indoor spaces full of equipment, plants, modules, offices and floor levels. Most of the time, they are also composed of smaller fragmented spaces, often with limited spatial information and many direction changes [1]. Thus, workplace navigation 'requires explicit decision-making such as selecting routes to follow and orientation towards non-perceptible landmarks and scheduling the trips' [2]. As a result, if a person does not have previous common knowledge and visual input about the building structure and space, the navigation experience is a complex and stressful task.

Studies of spatial navigation in absence of vision have been approached from diverse perspectives and disciplines such as engineering, psychology and neuroscience. This vast research has contributed to increase our understanding of spatial knowledge acquisition, spatial behavior, cognitive mapping, and technological devices among others topics. Despite these advances, there is still a lack of consensus regarding the mechanisms underlying spatial navigation by visually impaired people as well as an overreliance on the potential of technological solutions [3]. It broadly recognized that our daily movements in large and small-scale environments are mainly guided by our visual perception [4]. However, some people also use nonvisual modalities to construct more sophisticated spatial representations [5].

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Researchers have widely assumed that sighted and blind people develop similar abilities for acquiring spatial knowledge. However, there is a lack of clarity regarding the spatial learning processes behind navigation performance. Visually impaired people have to cope with the daily challenge of finding their way around built environments. They can easily be disoriented and intimidated as a result of the difficulties they experience in interpreting the built environment [5].

1.1 Acquisition of Knowledge Navigation

We are constantly navigating indoor and outdoor environments in order to reach a destination. This navigation process usually involves planning and executing a series of decisions that, according to Montello, [6] encompass wayfinding and locomotion, which are components of spatial decision-making. Locomotion calls for immediate responses to environmental features such as avoiding obstacles or stepping over corners. This corresponds to 'orientation', a common term used in visually impaired literature. As such, locomotion and/or orientation refer to a group of invariably egocentric responses acquired by the observer's body. On the contrary, wayfinding (frequently mentioned as 'mobility' in visually impaired literature) underpins a transitory (short-term) and permanent (long-term) reasoning of mental representations in a person's immediate and remote environment that adopt reference frames acquired directly from experiences (allocentric) [7].

Throughout the navigation process, people learn environmental features that they may use to establish a frame of reference known as a 'landmark'. Afterwards, they construct routes by connecting each landmark. This 'route stage' enables the person to begin to create 'mini-maps' that 'are locally, but not globally coherent' [8]. They will then subsequently integrate these mini-maps to develop a bigger 'cognitive map' of an objective frame of reference. Finally, the survey knowledge stage enables an individual to draw a line distance between two points. In this sense, we can identify three main components in the acquisition of navigational knowledge as follows (Table 1):

Table 1. Components involved in the acquisition of navigational knowledge

Landmark: the visual representation of structures or elements in the landscape that people identify as unique points to guide themselves [9].
Route: the sequential process description from one point to another in the environment. This involves all the landmarks at which an action (e.g. turning right or going straight on) should be taken [10].
Survey knowledge: refers to graphics or image-like representations of the entire geographic area such as maps of a location or a layout of all the elements of a place and the spatial relationship between them [9, 12]

1.2 People with Sight Loss and the Navigation Process

Certainly, 'landmarks make the wayfinding task more simple' [6] because human beings use them as reference points to navigate themselves, especially in unfamiliar places. The non-visually impaired person will use clues (landmarks) to find their way in an unfamiliar indoor environment. These clues will be, for example, information given by other people, indoor maps or any other wayfinding services that provide a location. As such, empirical evidence suggests that most people naturally tend to set out specific reference points that help them to explore their environment by fixing a landmark as a base to navigate their surroundings. Indeed, whenever they get lost or they want to start over to go in a different direction, they return to the base. Likewise, when they feel familiar with an area, they move from one landmark to another to navigate through larger spaces. In this way, vision therefore plays a significant role in acquiring spatial knowledge to create routes. Furthermore, 'spatial cognition' changes as a result of direct experience in the environment [11]. In this sense, more experience leads to more survey and route knowledge [12, 13].

In contrast, visually impaired people set out landmarks based on their hearing, tactile, and olfactory capabilities by fixing as reference points door movements, the number of people around them, the quality of air (fresh or more concentrated), restaurants, kitchens, etc. They also find small details such as light contrasts produced by windows, lamps, or the wall and floor colors helpful. Likewise, people with sight loss use their cane as a tactile tool to acquire spatial information. They also learn about the environment they are in by identifying the differences between narrow or broad corridors, stairs, floor textures, and obstacles in their path-route [13]. In this way, a common problem for visually impaired people when faced with independent navigation in the workplace is the lack of information that they are provided with in order to make decisions about routes to move from one point to another. In general, existing navigation systems do not provide accurate guidance, and non-visually impaired people offer instructions based on their visual capabilities, which are insufficient for the visually impaired.

A non-visually impaired person will therefore use traditional frameworks of spatial knowledge to produce survey knowledge (cognitive maps) [14]. However, individuals with sight loss use different strategies to acquire spatial navigation knowledge, for example audible representation. Acquiring different types of spatial information is based in spatial learning that is mainly formed by experiences and depends on the reliability of the cues provided by each perceptual modality (e.g. the ability to identify an object's location) [5, 15–17]. A visually impaired person will develop skills to compensate for their lack of visual representations by encountering specific information in the built environment.

As explained above, 'people use landmarks when they give route directions to anchor actions in space or to offer confirmation that the right track is still being followed' [18]. We use environmental information instruction (both verbal and pictorial) to facilitate our navigation in the workplace or any other indoor facility. As such, the two following questions arise: 'What factors do visually impaired workers find useful in acquiring spatial information?' And, 'To what extent do these factors influence the navigation process?'

The aim of the current study was to evaluate what workplace features visually impaired people value when they are navigating their surroundings and environments and how they manage unfamiliar spaces to orientate themselves inside workplace facilities. This information enabled us to clarify whether people with sight loss prefer tactile, audible or olfactory representations when creating landmarks.

This study was conducted by reviewing relevant literature in order to gain knowledge from previous research on spatial navigation from multiple perspectives. We then designed a pilot study to explore the factors that influence the spatial learning and spatial behavior of visually impaired people [17, 19].

2 Method

The aim of this study was to learn about the navigation experience of Chilean visually impaired workers in unfamiliar indoor spaces. We attempted to gain knowledge of what factors influence their acquisition of spatial knowledge which enables them to navigate through their workplace. A triangulation strategy consisting of a small pilot study divided into two phases was designed to firstly capture the self-reported information provided by visually impaired workers through a qualitative analysis and secondly to explore the factors influencing the way in which they acquire knowledge to improve their navigation process. In this way, for the first phase, we conducted semi-structured interviews to identify the conceptual factors that the participants reported as relevant aspects influencing their navigation process. In addition, we carried out a second quantitative analysis to assess the factors they reported as relevant in acquiring spatial navigation. Therefore, in order to analyse the self-reported experiences of visually impaired workers themselves, a semi-structured questionnaire was designed where participants freely talked about their navigation process in familiar and unfamiliar environments in their workplaces, and a subsequent online survey was applied to quantify and explore the factors that influenced their acquisition of spatial knowledge.

Sampling and Measurement. For the qualitative study, we interviewed 2 males, aged 41 and 35, and 1 female, aged 27. They were all Chilean customer service workers who talked to us about their navigation process experiences. In addition, using Qualtrics Survey Software, we randomly distributed a closed questionnaire to members of the Chilean National Union of and for Blind People (UNCICH). The questionnaire assessed the relevant conceptual factors identified in the preliminary qualitative study. The questionnaire consisted of 67 questions of which 28 were rated on a seven-point Likert Scale. We tested the reliability of our results by using Cronbach's alpha, and all of the data was above 0.7. This confirmed that the questions we had designed were reliable.

We randomly sent the online questionnaire by email to 55 members of the organization. However, only 26 members completed the questionnaire. By analyzing the data achieved, we found that the scale used had a good internal consistency, with a Cronbach alpha coefficient of 859. However, some of the issues explored in the questionnaire were not considered be worthy of retention; therefore these items were removed before going on to the exploratory factor analysis.

Data Collection. This study was carried out from 15 December 2015 to 15 January 2016. 55 electronic questionnaires were randomly sent by email to members of the Chilean National Union of and for Blind People. The participants were selected from the members of the Union who were currently working in private or public organisations.

26 questionnaires were completed, and the respondents were 53.8 % female and 46.2 % male (see Table 2 for further demographic details of the participant profile).

Table 2. Demographic data

Variable	Frequency	Percentage
Age		
21–30	4	15.4
31–40	8	30.8
41–50	11	42.3
51–60	3	11.5
Workplace Size		
Small building (less than 4 floors)	9	34.6
Academic campus	7	26.9
Large building (more than 4 floors)	10	38.5
Working Time		
Full time	11	42.3
Part time	6	23.1
Flexible time	9	34.6
Visual impairment		
Blindness	18	69.2
Low vision	8	30.8
Age of Impairment		
0–1	7	26.9
2–14	8	30.8
15–44	11	42.3
Education		
Postgraduate	4	15.4
Undergraduate	12	46.2
High school	9	34.6
Primary school	1	3.8

3 Data Analysis from the Qualitative Study

3.1 Preliminary Findings from the Qualitative Data Study

We explored the data collected using a thematic analysis in its simplest form. This allowed us to create categories that were subsequently assessed in the quantitative analysis. In the analysis, we coded words and phrases that allowed us to identify the categories associated with the acquisition of spatial knowledge described in the existing literature.

Landmarks. The qualitative study showed that those who had low vision fixed similar landmarks to those who were completely blind, giving strong value to contrasts of color and light. Participants stated that they made their navigation easier by identifying obstacles or things such as lifts, doors, stairs, floor textures, corners, darkness, and even the people around them. In addition, they remarked that they usually fix landmarks by remembering where an obstacle is located, the difference in the texture of the floor, or by smelling, for example, air fresheners, food, humidity, or any other recognisable odors. The participants also mentioned that they used audible information to fix reference points, for example environmental noises produced by printers, telephones operators, and even people's conversations. They explained that they even learn about indoor spatial environments by identifying the air temperature which enables them to recognize, for example, halls, open spaces, corridors, doors or entrances. Another relevant factor mentioned by the participants to construct spatial knowledge was texture differences on the floor which helped them to remember where they were or to follow a route.

Route Construction. The participants explained that it took them about one month to learn the route from the building entrance to their workstation. This task became more complex if any change in the route took place; if furniture was moved from its original position, for example, they were forced to look for alternative routes, and this was extremely confusing for them. The participants also stated that they preferred to avoid new routes; they usually followed the known paths, even though they may be considered longer or more complex by non-visually impaired people. They also clarified that they do not need information such as how many stairs they should go up or down, but rather they need to know, for example, whether there are stairs in front of the lift, if the toilet is on the right-hand side of the stairs, if the kitchen on the left-hand side of the lifts, and so on. In addition, they suggested that if audio or tactile guidance is provided, it should be allocated in standard places, otherwise it would be impossible for them to find. They said, for example, that they frequently have trouble finding bells and door opening buttons. Thus, if the tactile, audible or olfactory signals are not perceptible to them, they will be useless at providing them with any information.

Survey Knowledge. The participants explained that usually they are not given clear instructions on how to get places, and that sighted people often do not understand what kind of instructions are most helpful to them. They also said that it took them a long time to get to know the workplace and some of the participants even disclosed that they only knew how to get to the essential areas such as the workstation, kitchen, toilet, lifts, and the way out.

The participants also suggested that braille is an old-fashioned system which does not help them gain information about their surroundings. Although braille is often used and put forward as an appropriate system to help blind people access lifts, for example, very few people use it (either because they have never learnt the system or because they find other ways more useful, such as knowing the position of the lift number required in the panel). The participants believed that in general there is a lack of knowledge and awareness of their real capabilities to acquire spatial knowledge, because audible guidance which tells a person loudly which floor they are on is more useful to visually impaired people than any braille-based information.

Lastly, when the participants were asked about travel assistance aids such as tactile maps, they thought that, in theory, they could be useful to help them learn about an area, but that the tactile maps they had come across had not been fully usable because they needed someone explain the map to them, and the symbols used by the designers. They mentioned that there are no standard codes or symbols used to understand maps, so they usually have to rely on someone with vision to explain the map to them; they cannot use the map independently. Therefore, they suggested that tactile maps should include audible information that helps them to understand the tactile information without asking for help (Fig. 1).

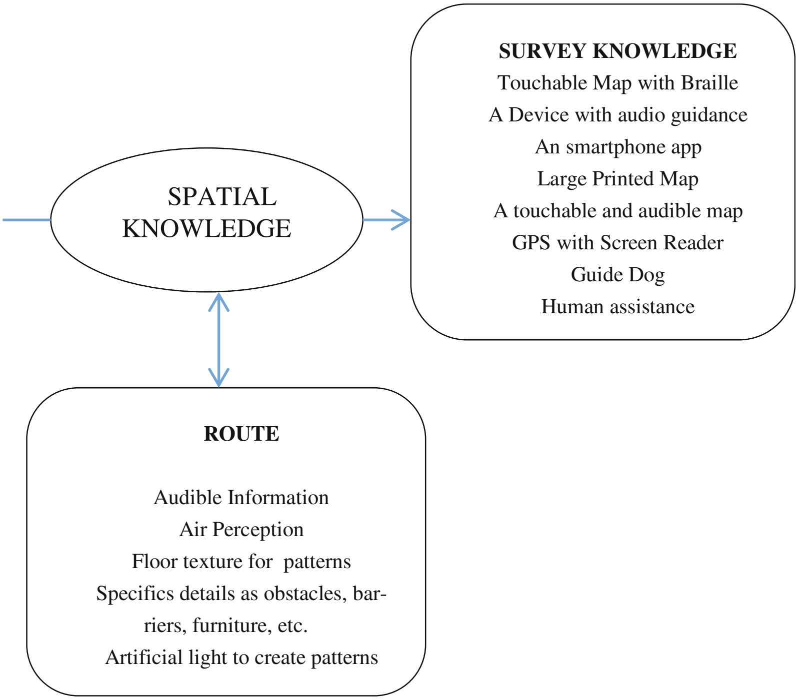


Fig. 1. Set of variables grouped in the three components mentioned as influencing the acquisition of spatial knowledge.

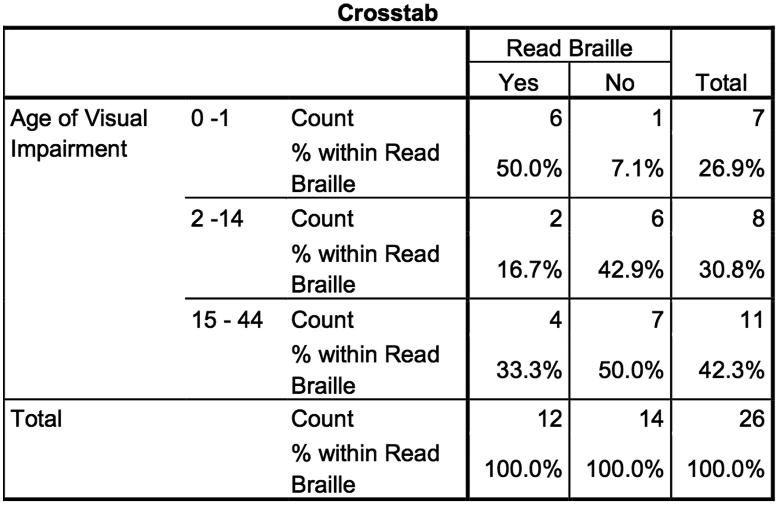
General categories to be tested in the quantitative analysis

4 Data Analysis from Quantitative Study

Preliminary Findings. Out of all of the participants, only 46.2 % had learnt braille, with a higher number of females than males. In addition, among those who read braille, 19.2 % never used it and 15.4 % used it less than once in a month to read labels, for example in medicines. 50 % of those who learnt braille were blind from birth, and

50 % of those who had acquired their visual impairment never learnt the system (Table 3).

Table 3. Crosstabulation: age of acquiring visual impairment vs. ability to read braille



Crosstab

			Read Braille		Total
			Yes	No	
Age of Visual Impairment	0 -1	Count	6	1	7
		% within Read Braille	50.0%	7.1%	26.9%
	2 -14	Count	2	6	8
		% within Read Braille	16.7%	42.9%	30.8%
	15 - 44	Count	4	7	11
		% within Read Braille	33.3%	50.0%	42.3%
Total		Count	12	14	26
		% within Read Braille	100.0%	100.0%	100.0%

Exploratory Categorical Factor Analysis CATPCA. We had a large number of variables which were mostly ordinal; thus an Exploratory Factor Analysis was employed, using Categorical Principal Component Analysis (CATPCA). This technique enabled us to reduce a large number of variables and therefore facilitate our understanding of the relationship between the factors analysed and the acquisition of spatial knowledge. SPSS was used to analyse the survey data. We got 26 valid cases and no missing value. The analysis was based on positive integer data. We analysed the mean, standard deviation, skewness and kurtosis to test normality; however this assumption was not achieved. To run the analysis from the menu we chose Analyze > Dimension Reduction > Optimal Scaling.

Three groups of categories were created to explain the acquisition of spatial knowledge through landmarks, survey knowledge and travel aids (Table 4). All variables were non-parametric (Fig. 2).

5 Results

There is no missing value for all the variables tested. We assessed the stability of the CATPCA solutions for the subsets with regard to (a) total percentage of variance accounted for and Cronbach's alpha (b) the loadings and (c) the category quantifications in order to assess the appropriateness of the choice of the optimal scaling level, of the number of dimensions and of the component structure of spatial knowledge. In addition we investigated whether or not the three components defined in our qualitative

Table 4. Model Summary

Dimension	Cronbach's alpha	Variance accounted for		
		Total (Eigenvalue)	% of variance	Rotation^a
1	.953	9.739	57.289	11.005
2	.627	2.441	14.357	3.433
3	.514	1.937	11.396	2.832
Total	.987^b	14.117	83.042	

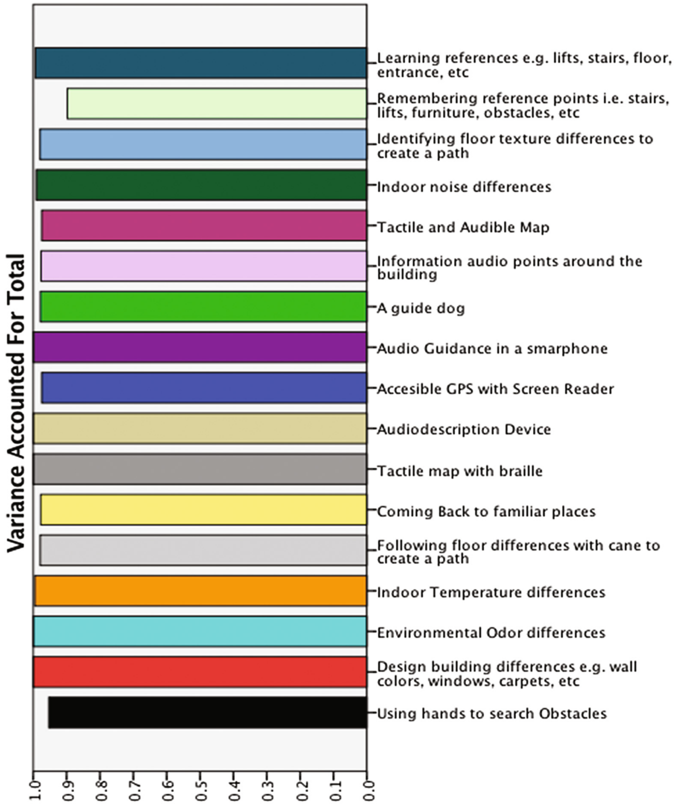


Fig. 2. Variance accounted for total.

analysis effectively influenced the spatial knowledge acquisition. The results of a three dimensional solution with ordinal transformation explains 83.042 % of the variance. The percentage of variance accounted for (PVAF) for the first dimension is the highest (57.289 %); almost triple the PVAF for the second dimension (14.357 %) and the third dimension (11.396 %). The variance accounted for the first dimension is equal to $.57289 \times 13 = 7.45$, with $.14357 \times 13 = 1.87$ for the second dimension and

11296 × 13 = 1.5 % for the third dimension. The largest Eigenvalue is 9.739 with a Cronbach's alpha of .953. The following table shows the factors that may be associated with the acquisition of spatial knowledge for visually impaired people in the workplace (Table 5).

Table 5. Factors influencing spatial knowledge

Accessible GPS with Screen Reader
Following floor differences with cane to create a path
Coming Back to familiar places
A guide dog
Identifying floor texture differences to create a path
Audiodescription Device
Audio Guidance in a smarphone
Design building differences e.g. wall colors, windows, carpets, etc
Remembering reference points i.e. stairs, lifts, furniture, obstacles, etc
Indoor noise differences
Using hands to search Obstacles
Indoor Temperature differences
Tactile map with braille
Learning references e.g. lifts, stairs, floor, entrance, etc
Environmental Odor differences

6 Conclusions and Future Work

This study aimed to identify the component structure of spatial knowledge self-reported by a group of visually impaired Chilean workers. Using nonlinear analysis for ordinal variables we created variables which, in the qualitative analysis, appeared to be relevant themes to construct spatial knowledge. These subjective themes reported by the participants were subsequently measured in an exploratory analysis that showed us that visually impaired people do not consider the use of white sticks as important to create landmarks, but rather they are an accessory which they believe to be absolutely necessary. In addition, the findings confirm that spatial knowledge acquisition is not influenced by demographic variables such as gender, age or education. However, the age of acquiring the impairment and the vision acuity (the degree of sight loss) do have an influence in the navigational process. Those who were blind from birth appeared to be more confident in creating audible landmarks, and those who had acquired their impairment still attempted to fix visual references such as stairs, colour contrasts or building designs.

Although important findings have been made from this study, further analysis must therefore be performed to confirm the relationship between the components identified and spatial knowledge acquisition. As such, a next step may be to conduct a structural equation model to establish the component structure. In addition, taking into consideration the limited number of participants, our results cannot be generalised to a broader population without extending this analysis to a greater number of individuals.

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