ABSTRACT

In this paper, we will present a review about the orientation and navigation processes considering the improvement of complex building’s design as main aspect to promote the Inclusive Design in built environments. The Ergonomics and User-Centered Design were considered as important issues during the architectural planning phase, as well as the understanding of human behaviour during interaction with unfamiliar complex buildings. Some recent researches in wayfinding were analyzed in order to know what have been done in this area. The Virtual Reality appears as an important method to analyse people’s behaviour during interaction with built environments. Therefore, the potentialities of Virtual Reality in wayfinding studies were also discussed.

Keywords


INTRODUCTION

Nowadays, the improvement of built environments is a problem which is more pertinent. The main issue is to improve buildings design in way to turn them accessible and, still more, inclusive.

The inclusive project is a new approach to make products which are used for a largest possible number of people. It comes from a project philosophy with a lot of names as: Universal Design, Design for all and Inclusive Design. They have the same goal, to made products and built environments that can be used for a large number of people without special adaptation or special projects.

The inclusive project is, basically, to identify the needs and desires of users, to identify projects requirements, expand and evaluate them and, finally, to propose a more inclusive product (Alvarenga, 2006).

If we consider that everyone can, in some period of our lives, to develop a disability (temporary or permanent), and also considering the increase of life expectancy and productive age of the population, the development of studies that have as objective the improvement of buildings projects in a inclusive perspective are very important.
In a brief analysis of architects’ activity of planning we can quickly conclude that these professionals consider 4 basics aspects: Functional, technological, esthetical and financial. Of course, there are a lot of others aspects that are also considered as sustainability and ergonomics, but they are considered in a reduced scale when we compare with those main 4 aspects.

Basically, demand of a specific program of necessities for each building, the technological and financial available resources and the esthetical aspects are the components that guide the architectural project.

From Ergonomics point of view - as a science which studies the Human interaction with the environment in order to optimize it – is very important to include the aspects related to human needs among planners preoccupations in way to reach Ergonomics’ main objectives (safety, user’s well-being/comfort and the effectiveness of the system where the human is inserted).

Therefore, the User-Centered Design (UCD) appears as a methodology which can help in the building design improvement process in way to turn the built environment inclusive. “User-centered Design (UCD) is a broad term to describe design processes in which end-users influence how a design takes shape” (Abras, Maloney-Krichmar, & Preece, 2004).

In this perspective, the end users are an integral part in the project’s process and their opinion must be considered as an important requirement to be embedded in the project. This methodology can promote a larger knowing of users needs when it is incorporated in the planning phase. In this way, the UCD can contribute to turn buildings suitable to receive all people in an autonomous and safety way.

The UCD has been widely used in objects’ design and in Human-computer interaction area. However, its utilization in architectural can produce buildings which better answer the end-users needs, making these built environments more inclusive.

Thus, expecting the building design improvement in order to turn built environments inclusive, we can:

- Project focusing in users;
- Improve the orientation and navigation inside buildings.

Therefore, we can propose two ways to improve building design during planning phase in order to turn built environments inclusive areas: 1) considering the end users opinion during all architectural planning phases in order to improve the users interaction with the built environment and 2) knowing the end users behaviours during their interaction with built environment in order to produce a knowledge basis and its can be used by designs and architects during all planning phase.

Focalizing in the second point as the central idea of this paper, some researches have been developed considering the questions related to the people’s orientation and navigation in environments. Many of them are centered in the understanding of human behaviour during the interaction with urban environment (Cubukcu & Nasar, 2005b; Hund & Minarik, 2006; Kim, 2001; Sohlberg, Fickas, Hung, & Fortier, 2007). However, the studies that consider the building are still few (Morganti, Carassa, & Geminiani, 2007; Raubal & Egenhofer, 1998; Umemura, Watanabe, & Matsuoka, 2005).

People’s individual differences are also considered in many of the studies about orientation and navigation processes. But, in most of the researches, the variable gender is the only one considered. Few of them also considered the age influence in wayfinding, disabilities and cultural influences.
WAYFINDING STUDIES

The orientation and navigation processes in built environments take part in daily experience of the most people. These processes, even when they occur by a natural way, are based in the human perception, decoding and action with the environment. Generally, it results in decisions related to the choice of paths which are the best way to reach a destination.

When people try to find their way to a destination in an unfamiliar environment, they look for external information that will complement their orientation and navigation processes in this unfamiliar environment. Many of the information that people need to reach a destination are in the world (knowledge in the world) and the human’s mind is perfectly able to understand this world. It is what made the people able to orientate and navigate themselves in environments that they never interact before (Norman, 1989).

The analysis of the human interaction with the built environment is beyond of to obtain the users’ subjective opinion. It is necessary to understand which the consequences of the aspects related to the orientation and navigation during the human interaction with the building are, in way to promote safety, comfort and effectiveness of the system Human-Environment. Thus, the Human must be considered as integrant and central part of the system, taking in consideration its characteristics, needs and limitations.

Associated to the Ergonomics’ researches about human interaction with the environment are the studies about human wayfinding. Human wayfinding research investigates the processes that take place when people orient themselves and navigate through space. The main goal of human wayfinding is to find the way from one place to another. Theories try to explain how people find their ways in the physical world, what they need to find their ways, how they communicate directions, and how people’s verbal and visual abilities influence wayfinding (Raubal, 2001).

Lynch’s book *The Image of the City* (1960) is considered by many authors the foundation for theories of human wayfinding (Elvins, 1997; Raubal, 2001; Raubal & Egenhofer, 1998). In his work, Lynch divided the contents of the city’s image into paths, edges (boundaries), regions, nodes and landmarks, in order to divide the environment into smaller and clearly connected more manageable pieces also underlying the importance of frequent directional cues to orientation maintenance. These pieces can than be directly encoded into hierarchy of special knowledge (Darken, 1995). When the adults learn a new space, they first become familiar with landmarks, then routes, and finally configurations. (Hunt & Waller, 1999).

Two concepts were also suggested: *Imageability* (considered as the quality in a physical object which gives it a high probability of evoking a strong image in any given observer) and *Environmental Legibility* (the easiness with which all parts can be recognized and organized in a coherent structure) (Lynch, 1960). These concepts led to studies which argued that the physical characteristics of the urban environment could influence wayfinding performance.

Thus, the urban environments have the potential to make easier or harder for people to acquire spatial knowledge and to perform various navigation tasks. This concept of environmental legibility and its effect on wayfinding were later clarified and three main physical characteristics were distinguished: complexity, differentiation and visibility (Omer & Goldblatt, 2007).

The literature suggests that environment’s configuration aspects have significant cognitive consequences in human wayfinding (Kim, 2001). Thus, the spatial layout of the built environment can also influence the accuracy of cognitive representations of real-world spatial information (Appleyard, 1969; O’Neill, 1991). Higher levels of configuration understanding are generally associated with more efficient wayfinding.
performance. In this way, buildings where the overall configuration is confusing or hard to imagine can be considered environment where the users are more disoriented (O’Neill, 1991; Weisman, 1981).

The researches in human wayfinding consider also the human individual differences beyond the configuration aspects of the built environment. But, most of the time, they are related to gender, considering mainly the way how women and men interact with the environment. (Hund & Minarik, 2006; Lawton, Charleston, & Zieles, 1996; Lawton & Kallai, 2002).

Other studies consider the age influence (Cubukcu & Nasar, 2005b; Kirasic, 2000; Moffat, Zonderman, & Resnick, 2001), but few of them have as individual’s difference the aspects related to people disabilities (Blackman et al., 2003; Sohlberg, Fickas, Hung, & Fortier, 2007).

Therefore, based in the researched literature we can number some variables which were considered in wayfindings studies. These variables can be grouped in:

- Environment’s physical characteristics - Complexity of the environment plan (configuration aspects), environment differentiation, signalling, visibility;
- Human individual differences - Age, gender, culture, disability;
- Performance - Task execution time, distance travelled, errors.

In order to analyse the influence of those variables in human wayfinding, the reviewed researches use some interaction’s environment. In Table 1 we can see the relations among those variables studied in the researched literature, the interaction’s environment where the study took place and the tools adopted in the methodology.

<table>
<thead>
<tr>
<th>Interaction’s Environment</th>
<th>Variables</th>
<th>Tools</th>
</tr>
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<tbody>
<tr>
<td>2D plans</td>
<td>Complexity of the environment plan</td>
<td>Maps analysis through “space syntax”. Interviews Sketch Maps</td>
</tr>
<tr>
<td>Slides Projected in a screen</td>
<td>Complexity of the environment plan</td>
<td>Questionnaires Interviews Sketch Maps</td>
</tr>
<tr>
<td>3D Model</td>
<td>Gender</td>
<td>Navigation Task</td>
</tr>
<tr>
<td>Real world</td>
<td>Gender, Age, Culture, Disability (Cognitive Impairment), Complexity of the environment plan, Environment differentiation (existence of landmarks), Task execution time</td>
<td>Questionnaires Interviews Sketch Maps Navigation Task Pointing task Estimate distance Indoor Wayfinding Scale Wayfinding strategy Scale Spatial anxiety scale State-Trait Personality Inventory</td>
</tr>
<tr>
<td>Virtual Reality</td>
<td>Gender, Age, Disability (Cognitive Impairment), Complexity of the environment plan, Environment differentiation (existence of landmarks), Task execution time, Distance Travelled, Visibility, Errors, Signalling</td>
<td>Questionnaires Interviews Think Aloud Navigation Task Pointing task Sketch Maps</td>
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</table>
Concerning to methodological aspects we can identify in those studies five main ways to observe and to acquire information about people interacting with the environment which are: i) interaction with real world; ii) interaction with 3D models (as plywood models); iii) using slides projected in a screen, photos and/or Videos; iv) using 2D plans and v) interacting with virtual environments through Virtual Reality.

Most of the reviewed studies used the real world as interaction’s environment to analyse the user’s behaviour (Blajenkova, Motes, & Kozhevnikov, 2005; Haq & Girotto, 2003; Kim, 2001; Kirasic, 2000; Lawton, 1996; Lawton, Charleston, & Zieles, 1996; Lawton & Kallai, 2002; Sohlberg, Fickas, Hung, & Fortier, 2007)

In these studies people who never interacted with a space (urban or building) have to move around the environment in order to reach some established points or to point the direction of some landmarks in the environment. The main advantage of this approach is that the studies’ participants have the real perception of the environment mainly regarding to materials, barriers, people’s movement in environment, the anxiety in using a space for the first time, sounds, light and many other characteristics related to the reality.

The interaction with real environments is commonly associated to interviews, questionnaires - we found some tools developed by authors as Indoor Wayfinding Scale, Wayfinding Strategy Scale, Spatial Anxiety Scale (Lawton, 1996), State-Trait Personality Inventory (Spielberger et al., 1979) - navigation tasks associated with think aloud, pointing tasks and sketch maps, as showed in Table 1.

However, interacting with real world has also many constraints. The main problem for a research in human wayfinding is to control the variables that can influence people orientation and navigation processes as: light, people moving around the environment, noise, eye direction, among others. Another problem is related to safety. When interacting with real world people is submitted to constraints that can put human physical a mental integrity in risk. The behavioral data (those related to users feelings and frustrations) is also very difficult to acquire during the interaction with real environments due the fact that most of times users’ verbalizations are missed during this interaction process.

Using slides projected in a screen, photos and/or video to know people behaviour in defined situations is also used in human wayfinding researches (Omer & Goldblatt, 2007; Raubal, 2001). These images are taken from an environment which participants never interacted before and represent decision points in pre-defined routes from where they have many options for choosing a way. Generally a task- where participants must reach a specified destination – is given to the participants.

This methodological approach is useful in way it does not put in risk the participants’ physical integrity. Another positive point is that the test can be applied in any place which few resources. Thus, it can involve a large number of participants with different characteristics.

However, the realism is very poor and depends of images quality and evaluators choices. Another point to consider is that this kind of approach directs the human point of view, this way the route choice is conditioned by route flow and people choosing a route through photos do not know what is behind themselves. From psychology point of view, space around is not seen as equal; front is most important, back next most important and sides least important (Hunt & Waller, 1999).

Another point to consider is when people interacts with an area for the first time they can show some fear or anxiety that can reflects in navigation errors, it can be considered as anxiety factor. Interacting with unfamiliar places through photo can exclude this anxiety factor.

Some latter researches use virtual reality-based environments to study human
wayfinding (Blackman et al., 2003; Cubukcu & Nasar, 2005a, 2005b; Moffat, Zonderman, & Resnick, 2001; Morganti, Carassa, & Geminiani, 2007; Omer & Goldblatt, 2007; Umemura, Watanabe, & Matsuoka, 2005).

The Virtual Reality (VR) is emerging as an important tool to overcome ethical and methodological constraints. One of the main advantages of VR is flexibility. The use of VR allows the researchers manipulate systematically the environment's layout, and different kinds of interactions can be designed in order to create suitable experimental conditions. VR also allows monitoring and recording the behaviours through which an explorer gains spatial knowledge for further evaluation (Morganti, Carassa, & Geminiani, 2007).

Unfortunately, VR still has some constraints. The main one is the sickness sensation that some users feel when interacting with VR. Another constraint to consider is the Field of View (FOV) once it is suggested as important aspect in VR to achieve the sense of being in an environment and performance. The normal field of view (FOV) for human is approximately 200 degrees, with 120 degrees of binocular overlap (Sherman & Craig, 2003). A 21” monitor display has around 40 degrees horizontal FOV and HMD display has approximately 50 degrees horizontal FOV (Ruddle, Payne, & Jones, 1999). The ranges of FOV for projection screen displays are usually wider than desktop’s FOV (Pramanik, 2006). Table 2 shows some advantage and disadvantage for main types of interaction’s environment.

Table 2 – Advantages and Disadvantages of main Interaction’s environments

<table>
<thead>
<tr>
<th>Interaction’s Environment</th>
<th>Advantage</th>
<th>Disadvantage</th>
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</table>
| Real World                | • Real perception of the environment  
                          • Accurate Kinesthesia  
                          • Real lighting and sounds increasing the sense of reality | • Difficult control of variables that can influence people wayfinding;  
                          • Can put human physical a mental integrity in risk;  
                          • Data related to users’ feelings and frustrations is difficult to acquire Users’ verbalizations are missed during this interaction process.  
                          • High costs in changing the environment to study the influence of variables |
| Photos/Video               | • Do not put in risk the participants’ physical integrity;  
                          • Test can be applied in any place;  
                          • Few resources required;  
                          • Can involve a large number of participants;  
                          • Can involve participants with different characteristics. | • Do not provide the sense of presence;  
                          • Depends of images quality;  
                          • Depends of evaluators choices;  
                          • Directs the human point of view, the route choice is conditioned by route flow. |
| Virtual Reality            | • Do not put in risk the participants’ physical integrity;  
                          • Provide the sense of presence;  
                          • Allow to manipulate systematically the environment's layout;  
                          • Different kinds of interactions can be designed to create suitable experimental conditions;  
                          • Allow monitoring and recording the behaviours for further evaluation.  
                          • Low costs in changing the environment to study the influence of variables | • Sickness sensation that some users feel;  
                          • The FOV is smaller using VR equipments than the FOV in real world  
                          • People do not have accurate kinesthesia  
                          • Specific equipments for immersive VR |

VIRTUAL REALITY POTENTIALITIES IN WAYFINDING STUDIES

Virtual Reality could be defined, in a simplified way, as an advanced interface between
human and computer. With VR people are able to visualize, to manipulate and to interact with virtual environments. The user’s intuitive knowledge of the real world can be transferred to manipulate the virtual environment through the use of some equipment as Head Motions Displays (HDM), gloves among others.

The most common use for Virtual Reality (VR) is desktop VR. In this case the observer sees scenes on a conventional computer screen. The user is usually invited to imagine that he is in the environment rather than being a teleoperator. Motion through the environment is controlled by keystrokes or by the use of a mouse, joystick or similar pointing device and sound can be presented using speakers or headsets.

Desktop VR is the simpler way to interact with VR and maybe the cheaper one. However desktop VR is not the best way to promote the sense of presence and to turn the user experience as real as possible.

Another technology available to VR is Immersive VR systems where nothing intrudes upon visual field except a scene in the simulated environment. For immersive VR systems, participants usually use Head-mounted Displays (HMD). A typical HMD has two miniature display screens and an optical system that channels the images from the screens to the eyes, thereby, presenting a stereo view of a virtual world. The position and orientation of the users’ head is continuously measured by a motion tracker and it allows the image generating computer to adjust the scene representation to the current view. As a result, the viewer can look around and walk through the surrounding virtual environment. The main advantage of this system is the high sense of realism and presence that participants experiment.

Meanwhile HMD is often uncomfortable and intrusive. Alternative concepts are been developed as BOOM (Binocular Omni-Orientation Monitor) and CAVE (Cave Automatic Virtual Environment). In the first one is a head-coupled stereoscopic display device where screens and optical system are housed in a box that is attached to a multi-link arm. The user looks into the box through two holes, sees the virtual world, and can guide the box to any position within the operational volume of the device. The CAVE projects stereo images on the walls and floor of a room-sized cube in order to provide the illusion of immersion. However, this devices still have a high costs.

In wayfinding studies for built environment, VR emerges as a powerful way. Through VR researchers are able to manipulate those three groups of variables – Environment’s physical characteristics, Human individual differences and Performance – considering more aspects than using traditional interaction methods (real world, 3d models, 2D images). In this way, aspects related to changes in the design as: signalling, landmarks, complexity of building plan, light, layout, among others, can be studied as influence factors in wayfinding performance in a more specific way, with a high control. The same will happen with those aspects related to mental load during navigation tasks, noise, number of people circulating in the building, time and other variables that can influence the wayfinding process. Through the use of VR systems, the analysis of variables as mental load can be facilitated making the analysis more realistic.

The VR systems turn the access of all people easier and more safety than interacting with real world. With VR, tests can be made in a safety place, without the necessity of locomotion. VR allows researchers to diversify, in an easy way, the sample. Therefore, the presence of people with disability, old adults and children can be facilitate increasing their participation as sample of wayfinding studies, in way to understand their behaviour during interaction with built environments.

CONCLUSION

Nowadays one of the most important issues in built environments design is to turn those accessible and mainly inclusive. According to Kwan (2003), the key to the
studies about accessibility is the understanding of the behavioral answers for the spatial separation between origin and destination. In this way, to understand the human behavior during interaction with built environment in wayfinding processes could help to answer some of many questions that planners (design and architects) still have about how to plan inclusive buildings.

There are many researches about human wayfinding but most of them are centered in urban environment. The data acquired with the studies of human wayfinding in the urban environments is in most of times also considered for planning complex buildings. The researches in indoor wayfinding area point to some individual differences during human interaction with built environment mainly those related to the way how man and woman orient and navigate themselves in unfamiliar complex buildings. The differences related to age are also considered. However, the knowledge about people with disability interaction with the environment is still very limited to few studies considering the influence of different ways of information’s delivery in path selection in urban environment.

Another point to consider in wayfinding studies are the tasks that users must accomplish interacting with the environment. In real life, when we navigate into building we are generally thinking about many other things instead to pay attention in our way. Sometimes we are talking to a friend, answering a call or only thinking about a lot of things we have to do in few time. The number of people circulating and the noise into the building are others real stress factors that can interfere in wayfinding process.

In this way, to consider variables as mental load, noise, number of people in the environment, as well as, task execution time, complexity of building plan, signalling, environmental differentiation, distance covered, age, gender and people’s disability is a very important issue in wayfinding studies. However some of them are difficult to control in real-world interaction, mainly the mental load, the number of people in the environment the changes in building configuration (like layout and signalling) and the interaction of old adults, children and people with disability with the built environment (for methodological and ethical constraints).

Virtual Reality (VR) emerges as a helpful way to overcome some difficulties in human wayfinding studies, mainly those related to variables control. The immersive VR gives to the users the sense of presence near to the one that they feel when interacting with real-world environments. In this way, the use of VR allows the researchers to control, in a systematic way, those variables that in real-world, in 2D images or in 3D models were difficult to do.

Unfortunately, there are some constraints related to VR use as: sickness during interaction, field of view (FOV) in VR is minor than the FOV in real-world, VR is not real-world and in this way the sense of presence in VR is minor than in real-world, the users have to learn how to interact with the VR.

Thus, many fields are still open in wayfinding studies, mainly those related to indoor wayfinding. The lack of concrete data is problem for all planners who still need information about human behaviour during interaction with built environment in order to plan more inclusive buildings. Buildings that consider the needs and limitation of all people in order to increase human quality of life in built environments.

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