Spatial Navigation in Virtual Reality

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Abstract

For the past decade, we have carried out a number of participation projects using full-scale modeling as an aid for communication and design. We are currently participating in an interdisciplinary research project which aims to combine and compare various visualization methods and techniques, among others, full-scale modeling and virtual reality, in design processes with users.

In this paper, we will discuss virtual reality as a design tool in light of previous experience with full-scale modeling and literature on cognitive psychology. We describe a minor explorative study, which was carried out to elucidate the answers to several crucial questions: Is realism in movement a condition for the perception of space or can it be achieved while moving through walls, floors and so forth? Does velocity of movement and reduced visual field have an impact on the perception of space? Are landmarks vital clues for spatial navigation and how do we reproduce them in virtual environments? Can “daylight“, color, material and texture facilitate navigation and are details, furnishings and people important objects of reference? How could contextual information clues, like views and surroundings, be added to facilitate orientation? Do we need our other senses to supplement the visual experience in virtual reality and what is the role of mental maps in spatial navigation?

Our Interest in Spatial Navigation

For several years, we have worked with participatory design using full-scale models as an aid for communication. The aim has almost exclusively been to model buildings from the inside and the interior design has partly been determined by the users, experience of the models. For the past year we have been part of an interdisciplinary research group, the aim of which is to compare different visualization techniques and design tools, among others, full-scale modeling and virtual reality, in design processes with lay-people. The tools will be used to visualize as well as to give shape and design to environments.

The VR-technique is fairly new and unfamiliar to us, but we have already noticed that experiencing space with such a tool differs from trials in full-scale models. An obvious difference is that individuals can relate their bodies to the space. When we compared users experiences of full-scale models to other media, such as drawings and models on a 1:10 scale, in previous studies, we discovered that it is crucial to use your own body as a measure for, e.g. the size of a room.

In this paper, we discuss the differences between experiencing movement in virtually designed space and in real space. We base our reflections on former experience as well as on literature on spatial navigation in the domains of cognitive psychology and information technology. What should the requirements of virtual reality be when used as a design tool? What clues are needed to compensate for the reduction of reality when using this media?

Man and Space

Space is an essential concept to architects. Space can be both *social* and *physical*. Theories about social space have, as a result of the division of scientific disciplines, mainly been developed within the social sciences. Architects and art scientists have, however, developed theories about physical space. According to several authors (f.i. [9]), this is an unfortunate split since *action and space* can not be separated. Social space transforms physical space into a stage. It becomes the framework for *social interaction,* but it does not determine people's space of action. Without users or activities there is no point considering the concept of space. Despite this, our paper focuses on physical space. Virtual reality is not yet widely applied to social interaction and literature within the field deals mainly with the physical aspects.

Physical space has been defined in various ways. Some architectural researchers define it as the empty space created by the walls of a building. Others are convinced that physical space has to be experienced continuously, as a network of spaces, that can be experienced visually and by moving along the boundaries [10]. According to Zevi and others people, representations of space can be created with the assistance of different media, though the experience can only be transmitted by attending them. Only when we have access to space, walking it through, using ourselves as measures, we can truly understand it.

> "There is a physical and dynamic element in grasping and evoking the fourth dimension through one's own movement through space.(...)Whenever a complete experience of space is to be realised, we must be included, we must feel ourselves part and measures of the architectural organism." [10]

Primarily Zevi means that the proportions of a space are essential to the spatial experience. But other factors also have consequences for experience of space; for example light, shadow, color, texture, dominating horizontal and vertical lines, the observers, expectations, the use etc. Further more, he emphasizes the difficulties in envisioning space. Even if, for example, scale-models are appropriate tools they offer neither enough information nor understanding about the relationship between buildings and measures of man.

> "Internal space, that space which cannot be completely represented in any form, which can be grasped and felt only through direct experience, is the protagonist of architecture."

> "The character of any architectural work is determined both in its internal space and in its external volume by the fundamental factor of scale, the relation between the dimensions of a building and the dimensions of man." [10]

In a study, Daniel Henry [4] tried to evaluate VR as a tool for architects. He alleges that VR fulfils the necessary criteria to give the user a correct perception of movement and space. VR creates the feeling of the body being in movement. The media gives a characteristic change of the visual field and a good apprehension of the spatial qualities, for example, limitations, connections and proportions of rooms as well as the quality and direction of light. Henry states that a strong motive for using VR in design is the impact movement through rooms has for experiencing them.

What is Spatial Navigation?

According to the Oxford English Dictionary navigation is *any of several methods of determining or planning ones position of course*. Tommy Gärling, a cognitive psychologist, defines spatial navigation as *a position in relation to a reference position* [3]. He distinguishes the body's orientation from, *the ability to maintain specific positions of different parts of the body in proportion to the ground* and spatial environmental orientation. The latter concerns *keeping the direction and position in comparison to the environment*.

In design work, spatial navigation also has the crucial dimension of experience from the point of view of content. In our field of research, navigation not only concerns finding the way from one place to another but is also expected to inspire creativity; altering and improving the observed environments. Therefore, the general definition of spatial navigation is insufficient. It is not only a matter of perceiving and learning a structure to create a mental map, but also, to appraise how the environment can be changed and adjusted to suit individual preferences and needs.

Navigational Aids for Representation

How then can spatial navigation be understood within our research field and how can spatial navigation in virtual environments be facilitated? What clues are used for navigation; have landmarks and mental maps the same significance when moving in virtual environments as in real environments and how are they created? How does the speed of movement and the visual field influence our experience? Does view, survey and visual contact with the immediate environment have an impact on orientation? Is our image of spatial connections shaped by realistic movements through buildings or can it also be obtained moving through walls and floors?

Light, shadows, color, material, texture and structure are fundamental to the experience of space and orientation in real environments. Details, interiors, furniture and individuals (the navigators and the people they relate on) provide further interesting reference objects. Can these also be used as navigational aids in virtual reality? There is a reason to believe that senses other than sight are important to the ability to orientate. Is it, for instance, likely that different kinds of sounds, such as footsteps, wind, running water, machines and traffic could facilitate navigation in virtual reality?

How can we attract the navigator's attention to the specific qualities of the environment and thus direct their movements? Should it be done as a dialogue by posing strategic questions about the environment? Or can sound, light and color be utilized to call attention? In a postgraduate course in *Human Computer Interaction*, we had the opportunity to examine some aspects of spatial navigation in virtual reality in practice. As a part of an interdisciplinary group of six people, we designed and carried out a minor test.

The Lay-out of the Test

The task was to create a tool for people looking for apartments and for an estate agent selling and renting flats that have not yet been built. Lay-people should be able to navigate in the entire building, enter the flat virtually and move around in it. They should easily obtain a mental map of the lay-out. They should also get a view of the surroundings and have control over the interior, changing wall-paper, cupboards etc. Mobile furniture should be available allowing for individual choice. The test consisted of four steps, in each of which the flat was presented in different ways. The main objective was to investigate how a map affects the ability to navigate within a flat that is unfamiliar. Two of the presentations were computerized, the third method was a video-tape of the flat built in the full-scale laboratory and the last was the full-scale model itself.

We selected five people, two female and three male to be our subjects; three architects, one psychologist and one secretary, implying that only two of the subjects were lay-people.

The *first step* was shown on a computer screen. Views of the rooms were displayed by clicking on descriptive buttons which were grouped by room. A movement history was recorded and displayed. The subjects could, thus, check where they had been and in what order they had visited the different rooms. The *second step* was the video recorded walk-through of the full-scale model of the flat. The *third step* again showed the flat on a computer screen. This time, a map was added, and the subjects could navigate by clicking on arrows in the map, indicating in which directions the picture was taken. Likewise, the movements were historically recorded. The *fourth and last visualization* was a real walk-through in the full-scale model. The subjects were guided through the ground-floor of the two storey building and their remarks were noted.

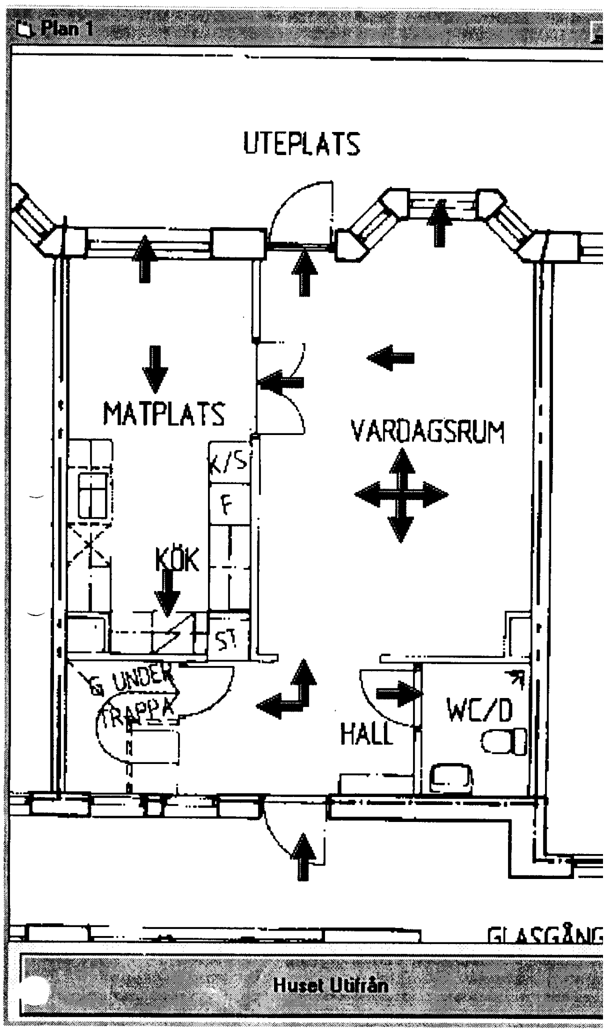

Fig. 1 Plan-drawing with arrows at the third step.

After each step, the subjects completed a questionnaire which asked what kind of supplementary information (text, map, animated pictures, sound) they required. They were also asked to rate how well they could interact with the test-version and orientate themselves using the different tools. After completing each of the questionnaires associated with the first and second steps, the subjects were requested to sketch the flat they had visited. They were also asked to compare the quality of navigation using the different media in all four tests, in particular, whether the map improved orientation.

The Results

Observation-time was limited. The subjects had to break their navigation tour after five minutes. The video-tape lasted about four minutes and could not be rerun. None of the test-systems were regarded as particularly interactive in the way they were used and presented. To increase interaction it should be possible to replay the video back and forth. The plan-drawing combined with photos, where the subjects could click in any order, was regarded as the most interactive navigation tool in this study. The plan-drawing was a big contribution in this respect.

The Flat Presented in Photos

The subjects were allowed to view the pictures for five minutes and some of them used all that time. They commented that a map would prove useful but found that the text added to the photos contained the most important information. Sound and animated pictures were not regarded as important.

There were some critical comments about the test-system, that is, the lack of pictures and the inconsistency in color and brightness. This made it difficult to consider them as a whole. Another deficiency was the lack of correspondence between photos and arrows. The historical review was very seldom used. On the other hand the system invited the subjects to push the buttons in their displayed order.

The system was not conducive to navigation. This was confirmed by the subjects, drawings. The two women were not able to understand the lay-out of the flat. The three men made a complete lay-out, even if is was not correct in all concerns. They had the correct interpretation of the relationship between kitchen and living-room and two of them also perceived the bay window. The site of the stairs and the bathroom were, however, difficult to interpret.

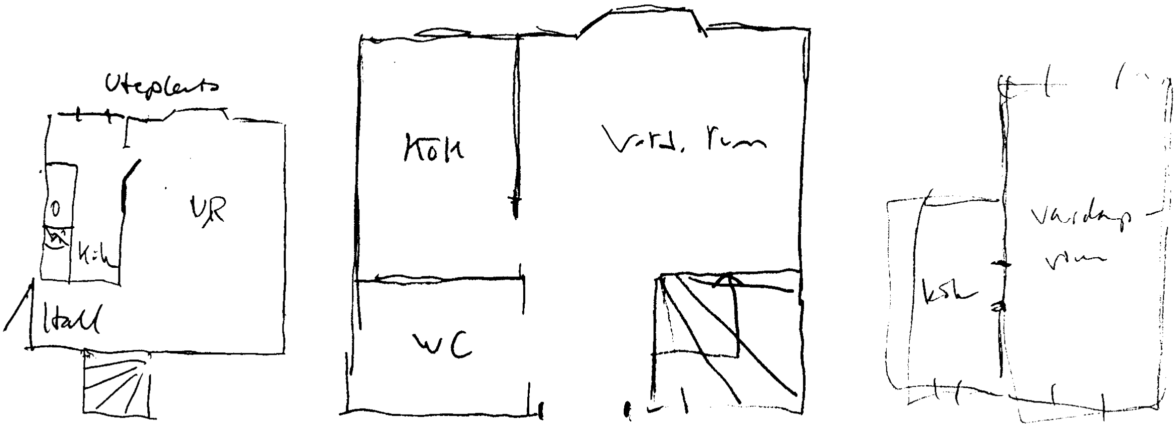

Fig. 2 The first sketches made by the three male subjects.

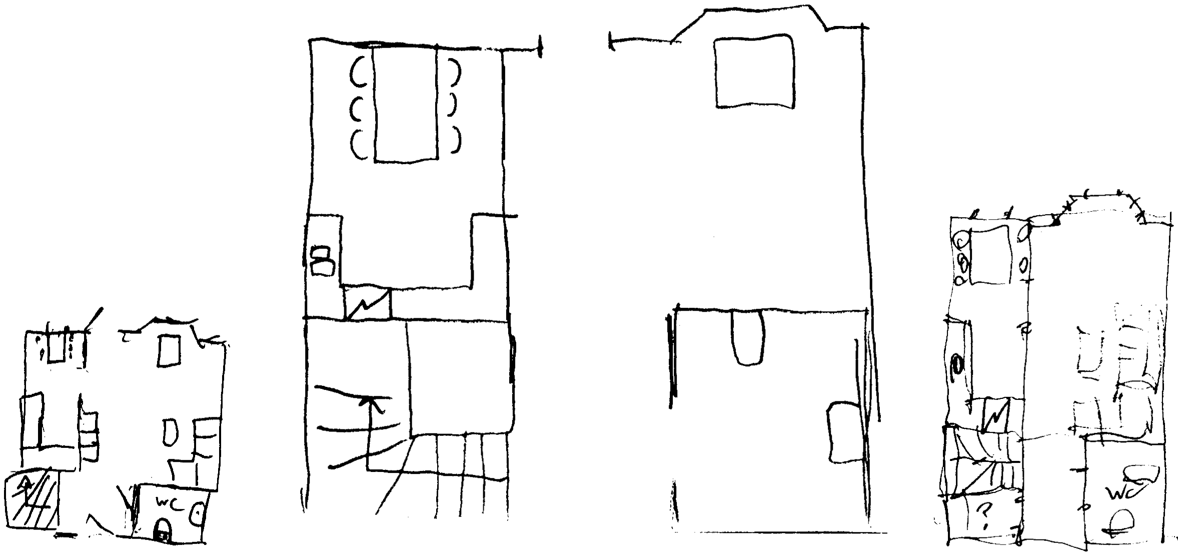

Fig. 3 The second sketches made by the three male subjects.

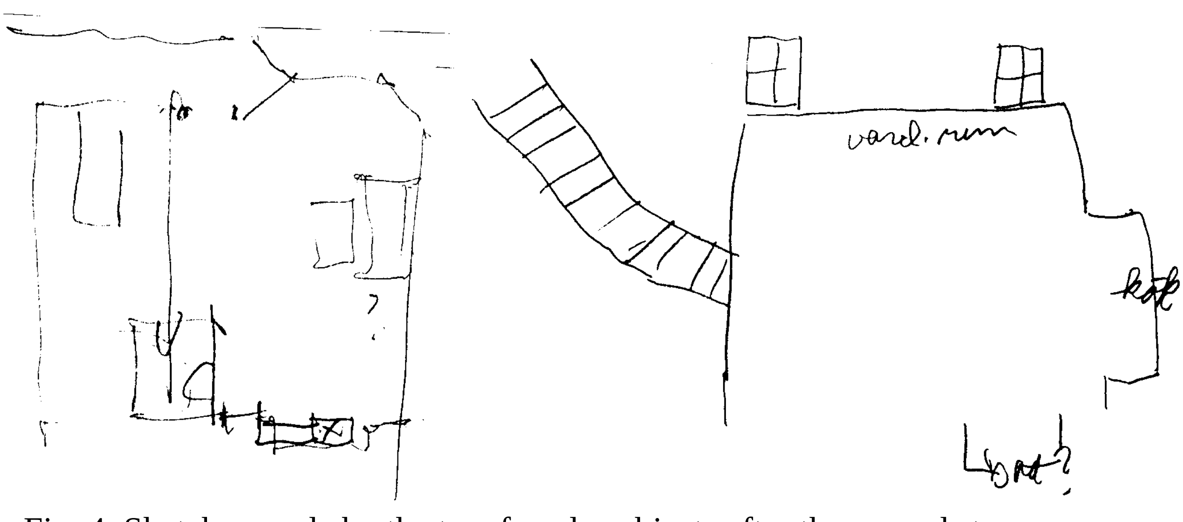

Fig. 4 Sketches made by the two female subjects after the second step.

The Video Recorded Full-scale Model Walk-through

No sound was added to the video-tape and all subjects found this important supplementary information to be lacking. Including a written text would be fairly insignificant. Not all of the subjects were convinced that a map should be added to the video although most of them thought it would be helpful. The video seemed to give a good orientation of the flat. The two female subjects could now draw an incomplete plan-drawing, though their sketches did not correspond well with their earlier photo based ones. The male subjects attained a more congruent picture and modified their former plans, supplementing them with fittings and furniture. The view in the laboratory was confusing, as, for example, one could see a part of the laboratory hall through the entrance-door of the flat. Outside the model's outer wall, the laboratory's glassed wall could also be seen. This was perceived as a windowed passage belonging to the full-scale model. The video movements were sometimes too rapid.

Flat-show with Photos Added with a Map

When the photos from the first test (only photos) were combined with a floor-plan and presented to the subjects, the text grew in importance while sound appeared to be even less important than before. The plan-drawing offers a contextual understanding, which was appreciated. At this stage the subjects did not think that the video-film could add further important information. The plan-drawing facilitated orientation particularly for the male subjects. Their perception was similar to those acquired during the former tests. The plan-drawing was regarded as essential by all the subjects.

The Actual Walk-through in the Full-scale Modeled Flat

When the subjects finally “visited“ the flat in the full-scale model, they were already quite acquainted with it, since they knew the lay-out. Though the dimensions did not correspond to their expectations. The video-film made the large space look larger - the living-room and the kitchen gave a deeper impression whereas smaller spaces, like the hall were unexpectedly larger in reality.

Some Interesting Findings

Four of the five subjects had the opinion that the flat that was presented in a plan-drawing supplemented with the photos gave the most realistic impression. One of the laypeople disagreed and regarded the video-film as the best presentation-media. The subjects were very critical about the quality of the photos. They thought they ought to be more consistent in brightness and color to be interpreted as the same flat. The video of the full-scale model also confused the subjects, as it was not obvious what belonged to the flat and what belonged to the laboratory environment.

It was only on the video-showing, that sound was found to be missing. The echo (lingering note) for example, would be a useful source of information for the room size. The subjects used the bay window as a navigation landmark. It proved to be a useful reference point. As the subjects knew they were being introduced to the same flat in all the media they collected data from each step. The experimental design was thus thought to inhibit its educational value, however this carry-on effect could not easily be avoided.

Different Perspectives on Spatial Navigation

Different approaches to spatial navigation are presented in the literature. In the information technology field, the concept is used to explain orientation in hypertext. Spatial metaphors such as the city and streets are used to increase understanding of its structure.

Holmlid [5] discusses the suitability of using the navigation concept to interpret accessibility and path-finding on the Internet. He suggests that navigation in a hypertext structure like the Internet, is determined by the media and its mechanisms. Since the present media are built on links and nodes, there are insufficient qualities for it to be defined as navigation. He questions Diebergers use of spatial metaphors and the term navigation in the connection with hypertexts, since “every move along a line is to move an artificial distance in a spatial description“.

This way of using the concept of spatial navigation does not refer to real, physical environments and is therefore of less interest to our topic. However the descriptions of spatial orientation in the literature of cognitive psychology are of more interest. Gärling [3] has, amongst others, been investigating people's navigation underground. He suggests that spatial orientation in real environments depends on their cycle perspective, their ability to master an environment, their motive for movement and how the environment is organized.

On the basis of this discussion, we would like to pick up some threads that partly encapsulates spatial environmental orientation with the focus on the virtual objects and tools that represent them as well as body orientation, here including the individual's subjective experience.

Physical Environments and Spatial Navigation

Recognizable landmarks and specific clues and reference systems, seem to have some influence on people's ability to orientate themselves [3, 7]. The environment's expressiveness is also important to orientation; differentiation of the landmarks, shape and color increases the likelihood of finding them. We have also experienced this in the full-scale laboratory, where the building system includes only white fittings. When the models are watched and estimated through video-films the lack of clues becomes apparent.

Visual accessibility is also essential to spatial orientation, for example by providing references by views through windows! This possibility is, for example, entirely missing in underground environments. These environments are furthermore rather poor and undifferentiated [3]. Therefore orientation in this type of space demands guides and posts (arrows, text information etc.) as well as simple systems for transportation and maps. The question is whether this is also needed in constructed environments like, for example, virtual computer environments.

The Significance of Maps for Spatial Navigation

The drawing-plan gives an overview of the whole building and it has therefore considerable significance as a tool for representing architecture. This merit was already pointed out by Zevi in the 50's [10]. The equivalent function of the map is also confirmed by other researchers. The main demand is that it can easily be translated into the real environment [3]. However it is not clearly stated what this means.

Libens [6] has established that even young children delight in using a map to understand and explore an environment before they reach it. This strengthens the map's significance for navigation. In our own study on navigation we also noticed that the use of maps is crucial. Henry [4] had the same experience. He established the importance of plan-drawings as additional information in spatial orientation when lay-people manipulate spatial environments in virtual tools for architectural purposes. In Henry's opinion it facilitates the users, revision and updating of their own cognitive maps of space.

“Mental Maps”

People's emblem and imagination of the environment seems to mean a lot to their ability to navigate in virtual environments. Cognitive or mental maps are recreated for every place explored in computer navigation and navigation models [11]. They can also be created (or rather recreated - a chicken and egg situation) as the cognitive map for a certain place begins with a generic scheme based on the type of place which, in turn is based on both topological and descriptive knowledge.

According to Zimring, people, at least partly, seem to make their spatial choices based on general topological knowledge of a building, organization e.g. he uses the hotel-building. The cognitive map for a particular hotel is based on the general image, a scheme of “a hotel“. The scheme announces the type of building and the spatial relationships one can expect. The investigation of the specific object, the particular hotel, results in a more specific mental map replacing the original schema of the hotel. Knowledge in building categories makes it easier to recognize places and to orientate in unknown buildings. It facilitates first-time visitors in finding their way around a building.

In his empirical research involving lay-people, Henry [4] has reflected on their difficulties in creating a cognitive map of the spaces they are exposed to in VR-environments. He claims that lack of kinesthetic feedback [13] might have an impact on the experience of harmony with the vision of movement. The movement dimension is, in other words, an interesting and perhaps important aspect of spatial experience, that has to be added to artificial environments.

Landmarks as Clues

It can be difficult to navigate in an unfamiliar environment despite it being interpreted by previous knowledge about other, similar environments. But what happens when we are supposed to orientate in environments that we have no comprehension for? What clues are needed to make the personal representation, our image, complete and to make the user able to navigate in the environment and to design it?

When we describe orientation in a city, the word “landmark“ is often used. Kevin Lynch, who introduced the term in his book *The Image of the City* [7], means that landmarks, in this case mostly connected with buildings, are characterized by their uniqueness or differences from their surroundings. They are easier to visualize if they have a distinct shape. The shape in contrast to the background also seems to be an important criteria. Lynch distinguishes between two kinds of landmarks - the ones which are visible at a distance from different places and the ones that appear locally and diverge from their context. The former are mostly used by strangers in cities. The number of elements that will be perceived as landmarks depends on how well the observer knows the environment as well as the characteristics of the elements. Sound and smell can sometimes reinforce the meaning of visual landmarks but they can not replace them. People do not entirely navigate with the assistance of landmarks but also relate to other associated objects that help to announce, for example, distance to the landmarks. The impact of texture and other tricks to deceive the eye into making perspective interpretations is further something that is used on theater stages.

According to Gärling, children relate things in their surroundings to their own bodies whereas adults use landmarks and reference systems, for example the walls of a room. The reference systems are not general but vary with the place. To be able to orientate, some adults memorize the way while others rely on the reference system.

The psychologists M. Tlauka and P. Wilson [8] state that the use of landmarks is one of several strategies people can use for navigation. When using landmarks, other equivalent strategies are suppressed. They have investigated the way in which people learn to navigate in computer simulated large-scale environments. Tlauka and Wilson define landmarks as distinctive spatial features that, by virtue of their shape, color, semantic value etc. have the potential to help individuals to orientate and find the way around an environment. They have found that both adults and children (compare with Gärling) use landmarks for navigation in unfamiliar environments. There is, however, no connection between landmarks and ability to orient.

According to Zimring [11] there is evidence that navigation is directed by memories of buildings, structures that have been experienced before. In his studies he found that people have the ability to predict the placement of important symbols in buildings they have never visited. When for example a high-rise office building is shown to them as a photo of a façade they can in most cases draw a simple plan-sketch showing the location of elevators and staircases. It appears as if location follows certain rules and many people can even describe where telephones and rest-rooms are located. People joining Zimrings investigations tended for example to organize buildings symmetrically and to locate elevators in the center. Also if people are not able to view a photo of a building but are presented with a concept, for example “office in high-rise building“ or “a warehouse“ most people seem to be able to make similar determinations.

To sum up, landmarks seem to have significance for people's ability to orientate themselves in familiar and unfamiliar environments. This also seems to include virtual environments, as we have experienced from our own pilot study.

The Subjective Dimension

Navigation is not only a matter of finding one's way. The aspect of experience from the architectural point of view is equally important! According to Zevi [10], all kinds of presentation tools have their deficiencies but together they offer a superior representation of architecture in comparison to what they would do separately. However, he considers that representations could only be used to visualize architectural space. The experience is far more complex and can not be fully reproduced. It is individual but at the same time dependant on the representations the subject is confronted with. A rich VR presentation can probably conjure up a more rich and dense image of the environment. A rich representation can probably also better hit the mark, as different individuals integrate different kinds of information in their cognitive system.

The significance of dimension is crucial for spatial experience. Therefore it is particularly important to represent them in a justifiable way. Henry [4] has stated that both horizontal and vertical dimensions as well as distance are experienced to be shorter in simulated environments. He has learnt that experienced distances are, to a greater extent, underestimated in the virtual environment than in monoscopic and stereoscopic “walk-through“ representations. One of his own proposals to solve this is to include many, well known scale-elements in the model. This type of correction can only be used as a tool for control but not as a design-tool, as it hardly contributes to a fair experience of the VR-environment. The prerequisite to be able to estimate a rooms, quality is, also according to Henry, to be able to experience what it is like to be in it. In his studies he experienced that a wide visual field has a big impact on people's perception of different kinds of projections. This should therefore be taken into consideration when different visualization techniques are to be chosen. One solution is to increase the visual field of the display, he argues. Another is to use retroprojection, an immense screen with projection from behind.

The media also have an impact on rapidity of growth of the mental picture. Learning is an important element affecting navigation in virtual environments. Amongst others, Gärling is concerned about the ability to familiarize oneself with an environment. It is harder to become familiar in environments with poor spatial orientation. Gärling considers navigation as a way to learn:

- the route between defined places;
- the route-network and
- spatial relations (distances and directions) between different parts.

The Relationship Between the Body's Movement and Navigation

In experiencing the real world and full-scale models, movement adds an additional dimension that is separated from the media but close to the navigation system. In Henry's [4] test the subjects were particularly troubled with the movement metaphor in a virtual walk-through. The visual information was poorly equated with the few physical signals that were generated by the walk.

Sighted people that are constantly exposed to perspective transformations develop a sense of their own body's relationship to the environment. The effect of sight on navigation has also been investigated by Reiser, Guth and Hill [6]. They studied sighted and blind people's ability to link different parts of a room to each other. Due to their results, cognition seems primarily to rest on visual experience.

How is this experience used for spatial navigation in VR-environments? One can suppose that perspective consistency is, in some way, significant to how environments are experienced and to the manner of orientation within them and rendering of them. This was also implied in our pilot-study. The subjects, estimation of the flat's spatial dimensions diverged a great deal when it was experienced via video-recording as compared to a full-scale model. The physical model was experienced to be extremely small compared to the virtual one.

Individual Differences and Socio-emotional Factors

As some aspects of navigation are primarily linked to the VR rendering tool and others are linked to the human dimension, the personality [3] is yet an additional dimension, directing the experience of the environment. Liben refers to Golbeck for example, who compared subjects, ability to recall furnishing and executing their own drawing with the same subjects, competence to categorize and point out the connection.

Gärling stresses that some individual differences are related to development and age. He stipulates that, for example, children relate things in their surrounding to their own body. But according to Liben [6] studies reveal that blind children tend to achieve a fairly adequate inner representation of an environment by reading “tactile“ maps.

There are also gender differences in the way human-beings interpret spatial presentations. Men, regarded as a group, perform better in evaluating spatial measures than women [6]. Our own results also indicated a certain gender difference in subjects, competence to interpret virtual worlds.

When it comes to children, Liben [6] has verified that the test environments greatly affect their performance. They are influenced by the unsafe situation created by the laboratory environment. By first making the children acquainted with the test environment, this can, to a large extent be avoided. The conditions for elderly people are the same. Furthermore, there is an important relationship between socio-emotional factors and environmental cognition.

VR is a peculiar technique for representation, that might demand certain assimilation efforts to both adults and children. At the very least, this concerns the technical equipment, that one has to adapt to and handle. Henry, for example, discusses the design of the head-mounted display-helmets. The ones used in his own experiments were designed for men. Participating women found that the helmets did not fit their head shape, thus interfering with their experience.

Summary

Our viewpoint of virtual reality as a design tool bears the stamp of our experience from full-scale modeling and has immensely directed our reading. Additionally, being a tool for design, the full-scale model is a communication tool for users, who lack professional knowledge within the field of design. Participative design must make the users aware of their ideas and how to change and adapt environments to their individual assessments and needs. Used as a design tool in participative design, VR has to act as an intermediary between adequate representations of spatial qualities - spatial boundaries and proportions, amount and flow of light and inter-relation of room. Experiencing space is a crucial complement to the analysis work where, amongst other things, measuring and rational arguments are involved. It has to be related to the corresponding real space and to the activities within it. In this paper our intention was to discuss the difference between movement in virtual space created in VR and movement in real, physical space. One of our questions was: what demands should be put on VR as a design tool?

The physical space is a continuous network of spaces and the tool has to mediate the feeling of movement. Researchers who have investigated the effect of the body's interaction with virtual environments have found that, for example, kinesthetic feed back is important. Can deficiency of certain sensory impressions be compensated by empowering others, like blind people develop their audible sensitivity? Could it be stated that the ability to interpret develops over time in a way comparable to the process of learning? Or is the interplay between the senses essential for re-establishing the virtual world with the real one?

To operate as a general tool, VR should be easy to manipulate so that lay-people can master it as well. It also has to be adjusted to the diverse personalities of the individual's and the interface has to be designed to be adaptable to individual body measures. It is also valuable that VR is made mobile so that it can be placed in familiar environments to give a sense of safety to its users. A consequence of this might, however, be that the user sticks with the solutions and proposals that can be achieved within this environment.

Concerning the significance of navigation clues in VR-worlds, the available literature is unambiguous. Clues like landmarks are easier to find if their shape is distinct and if their color is differentiated. The contrast between figure (shape?) and background is crucial. It may not be possible to make landmarks in VR visible from several spots but it will be possible to make them diverge from their context. As landmarks, associated with sounds and smells, stand out with greater clarity, these attributes ought to be additional clues in VR.

References like a rooms, walls or views through windows play an important part to spatial orientation in the real environment. If there is no possibility to create reference systems, there is a need for guides of different kinds; arrows, written information etc. By adding scales and reference-objects to the VR-environments and offering a wide visual field, the estimation of spatial measures in VR-environments can be facilitated.

Navigation manner is partly directed by memories from earlier, experienced building structures. The tool thus ought to conjure up this kind of visual picture and to work associatively. Photos of buildings as well as merely written terms mediate emblems of the building type and ought to also be useful in VR. Simple navigation systems and maps/plan-drawings, that can easily be translated into the real environment, facilitate orientation. The plan-drawing gives an overview of the entire building and helps the users to revise and update their cognitive maps of space in VR.

Our full-scale models are, to a certain extent, self-instructive, as lay-people easily learn to handle the media/building system. In the full-scale environment, we as architects are also to a certain degree the users, “clues“ by interacting with them in a constant dialogue. VR has probably still better qualifications to operate self-instructively, since clues can be programmed for different purposes. The need to increase the amount of information and clues in order to direct and focus, is however in opposition to the goal of giving a dense and informative picture full of nuances. To create a tool that offers clues and at the same time does not direct the possibility of shaping new environments freely, is a difficult balancing act but also a big challenge.

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[12] Also other forms of “spinal learning” could be discussed.