Towards a Virtual Reality Tool for Lighting *Communication and Analysis in Urban Environments*

TAHRANI Souha[1], JALLOULI Jihen[1], MOREAU Guillaume[2] and WOLOSZYN Philippe[1]
[1]CERMA UMR CNRS 1563, [2]Ecole d'Architecture de Nantes, Nantes, France

Keywords: virtual reality, 3D city modelling, environmental simulation, visual perception

Abstract: The objective of this paper is to evaluate the use of virtual reality as a potential decision-making tool to cognitively evaluate urban daylighting ambiences. This paper evaluates the *solar effects* visual perception in a real urban path in comparison to a virtual urban path in order to extract the characteristics of these effects and use them to figure out the necessary conditions for generating a physical and sensitive phenomena simulation. The comparison is based on questionnaires and interviews with participants on their judgements on sunlight during their walk through the chosen path. Our results highlight the relation between perception and the context of the urban environment, and prove that -in spite of its limits- virtual reality is able to simulate a large part of real *solar effects*.

1 INTRODUCTION

Studying the urban environment is a complex procedure that is heavily influenced by the multi-layered interaction and dynamics between the built environment (the mixture of volumes, shapes and materials that form the cities), the physical factors (wind, light, sound, pollution etc.), and their physical and cognitive representation by the human sense, what we might call the architectural and urban ambiance. The study of this multi-layered interaction is processed through an interdisciplinary approach, that complements classical ones with the use of Virtual Reality (VR) technologies as study tools.

There are many urban studies that primarily focus on visual perception analysis and its relation to movement in the urban space. These studies generally show a sensitive examination of the city (Lynch 1960, Cullen 1971), but don't look into the physical factors that play a very important role in controlling the urban pedestrian movement. A few studies focus on the interaction between the physical and psychological factors in immersive environments (Woloszyn 2003).

Our aim is to develop a dynamic immersive tool that uses visual perception as an analysis method to study the impact of the *solar effect* on space acknowledgement.

To do that, the following questions are asked: How can the spatial factors influence our visual perception? Is it possible to measure the perceptive impact? What are the requirements for representing this impact?

In this paper, we will present an experimental study that compares the perception of *solar effects* in real and virtual environment. The first part will be devoted to a theoretical study. The two later sections will concentrate on describing the experimental study, the adopted methods and the obtained results.

2 BACKGROUND

Our study is based on two tools: *solar effects* and *VR technology*. This part will focus on a study of "solar effects" concept, as well as an overview of VR and its applications in the architectural and urban field.

2.1 Solar Effects

Human vision is conditioned by the existence of light, producing physical and psychological effects. In this logic, the concept of lighting ambience is defined by the position of human beings in the space and their visual perception of environmental daylight.

Several studies described the "effect of light" on architecture (Jungman 1995) by studying the way to visualize light in the architectural image. Other studies treated the notion of "ambiance effects" by using these effects as an ambiance analysis and design tool. This concept was initiated by the "sonic effects" - *effets sonores*- proposed by J.F. Augoyard and H. Torgue who defined this notion as: "*the interaction between the transmitting source, the elements of built space and the perception of the receiver"* (Augoyard 1998). Furthermore, some studies attend the notion of "effect of light" leading to "visual and luminous effect" (Thibaud 2001a). Although this work is not yet complete, there are several experiments that are based on this double sided concept "visual and luminous effects" and "sonic effects" (Follut 2000).

This perspective introduces the interaction between light and space through "solar effects" concept that is generated by combining the three following factors: observer (visual perception), space (architectural and urban forms), and daylight. In our work, we approach the "solar effect" as a tool for phenomenal interpretation of the public space. It is an essential component in building the urban scene (Figure1). Figure 2 shows an example of some "solar effects" used in this paper, such as the effect of "*Attraction"*: an effect that attracts the attention in an uncontrolled or conscious way. "*Repulsion"*: an effect implying a solar phenomenon into a rejection attitude and "*Opening*": effect highlights the opening of space, related to the position of the observer.

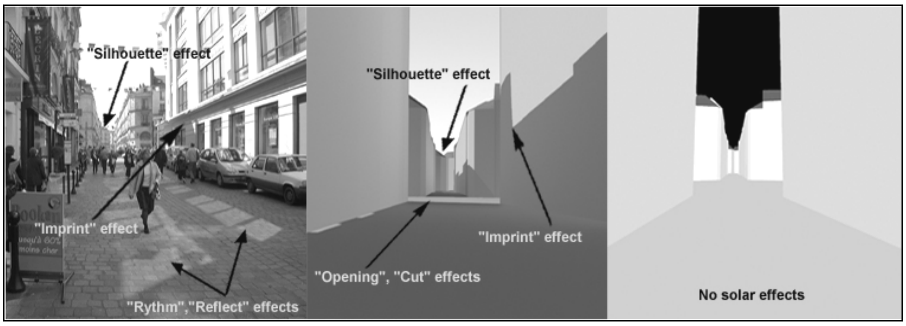

Figure 1 The same view of the Barillerie Street in Nantes, with and without light, shows how "solar effects" play a crucial part in our space comprehension

Figure 2 Solar effects demonstration: Attraction, Repulsion and Opening

2.2 Virtual reality in architectural and urban filed

According to Fuchs (Fuchs and Moreau 2003), VR is a set of multi-disciplinary tools and techniques that allow the immersion of an user in an artificial world permitting him to change of place, time and interaction type. VR interacts with the human senses by introducing the concept of immersion (perception) and real-time interaction (action). These are studied on three levels: the physical realism of the model, the behaviour and the experience of performing a specific task in the virtual world.

Four classes of interaction primitives can be distinguished: observing, moving in, acting in and communicating with the world. Our study is limited to the 2 first categories, where the user will observe the daylight during his walk in the real-time 3D environment. Despite the latest evolution of VR, there remain several constraints. In our work, we were confronted by some difficulties related to visual representation:

- Immersion limitations: screen resolution, weak projector contrast and triangle/texture limits in real time rendering. Moreover, the limited field of view may reduce the immersion feeling and we shall not forget that perception is here exclusively visual.

- Interfacing problem: How to locate and direct the user's movement in the real-time 3D environment while maintaining a high degree of freedom? Inspired by Azpiazu (Azpiazu et al. 2004) we are looking at the "guide" metaphor: liking the user's motion to a guide that he can stop whenever he wants. During stops, he can wander about.

For many years, research has been more focused on improving VR systems (free navigation, better rendering, better colour representation, etc.) than on studying perception, especially in outdoor environments. This is why our work tries to evaluate daylight in the urban space through the way it is perceived by using VR tools.

Bishop (Bishop et al. 2000) described the rationale for using virtual environments by taking an experimental approach to explore aspects of landscape perception. That experiment was encouraging for the further use of virtual environments. The quality of indoor daylighting was examined by comparing different types of images: real space, photography and computer-generated images (Charton 2001). The results showed some disagreement between perceiving light in real space and in images and confirm that movement is essential in having a better light perception. A similar study (Billger and Heldal 2002) tried to investigate the issue of colours, lights and size perception in architectural models and showed that neither the desktop model nor the VR model sufficiently represented light and colours, thus disqualifying models from being a design tool for buildings.

3 EXPERIMENTAL STUDY

Throughout the study, we investigated the way people evaluate urban daylighting by studying their behaviour and personal classification of real and virtual space lighting (both physical and cognitive).

We used two tools in the experiment: the subjective acknowledgement of the "solar effects", and the objective characterization offered by VR technology. The objectives of the experiment are to validate our methods by cognitively evaluating urban daylighting ambiences and to explore the "solar effects" characteristics as cognitive descriptors of the urban space. This paper is looking into the subjective way that the observer perceives real or represented "solar effects" - *perceived solar effect*- further than entering deep into the technical aspect of producing these effects in real time digital environment (which could become further research if required).

Two urban paths, *in situ* and *in vitro,* were studied throughout our experiment. The experimental process consists first of "solar effects" observation in the real urban path, to formulate our questionnaire. Then, we tested subjects in both real and virtual path by using "*the commented circuit*" method (Thibaud 2001b) before completing a brief questionnaire. The last stage is devoted to the analysis of subjects' commentaries and questionnaires answering.

3.1 Experiment Study Area

The study site is the downtown of the city of Nantes – France; a pedestrian axis of the city with an approximate length of 500 meters. This is a varying space that contains different urban types from three different architectural periods. It starts by "*Pilori square*" (Middle Aged) and finish by "*Royal square*" (19^{th} Century), going through a contemporary avenue called "*Cours des Cinquantes Otages*" (figure 3). This vivid variety generates an extensive collection of "solar effects" throughout this path.

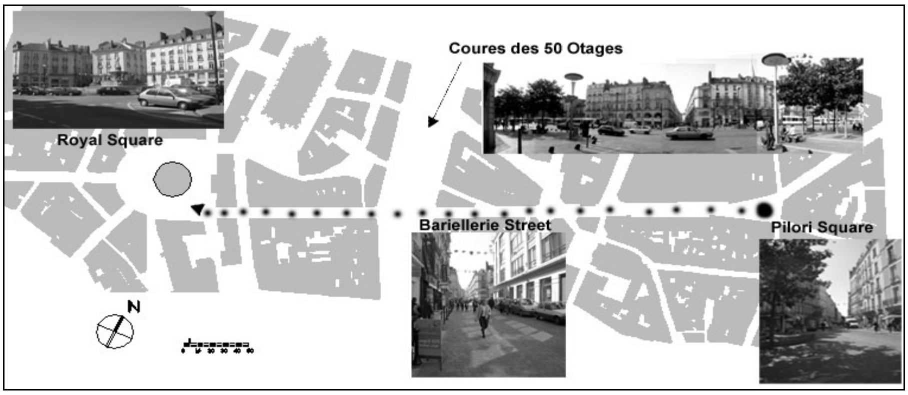

Figure 3 The chosen urban path

The 3D digital urban path was built with AutoCAD. Textures and light computation were made with 3D VIZ4 under the following conditions: *Elevations textures*, as photographs of real path elevations, computed for simulating light at (April 1^{st} - 2002 at 1:30pm). *Daylight simulation* was carried out according to Nantes location (Latitude: 47°15', longitude:1°33') and at the same date that photographs were taken. The computation daylight integrates sunlight, skylight, as well as radiosity, to simulate the way that light interacts in the selected environment (Figure 4). In order to export the model with its light and shadows to VRML file, the "*Render to textures*" technology was applied with 3D MAX5, that allows to create a texture maps based on objects' appearance in the rendered scene.

Since, due to technical limitations, we couldn't yet simulate free movement in the virtual world, we used a walkthrough camera in the model to symbolize the user's field of view during his walk through the virtual path. The camera was placed 165 cm higher than the model ground, with 61.6°of field of view, that corresponds to a user positioned 150 cm away from a 238 X 190 cm screen. These settings allowed the user to forget virtuality and to concentrate on space light perception. The digital model has then been exported to a VRML file to be projected in the immersive room. The room is equipped with a powerful workstation, a large rear-projecting screen to visualize the VRML model on 1/1 scale (Figure 4).

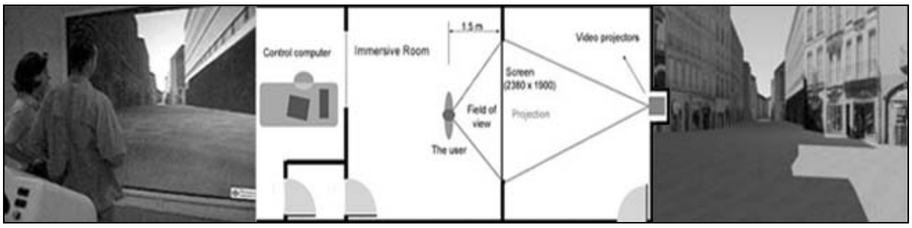

Figure 4 Plan of the immersive room and Simulated viewpoint of *Pilori square*

3.2 Procedure and Tasks

This exploratory study was leaded with 18 participants in the real path and 11 participants in the virtual one. The participants were males and females, mainly students between 20-35 years old. 39% of the participants are used to the selected urban path, 34% have a knowledge of the bath and 27% were their first travelling through.

We asked the participants about their judgements on sunlight during their walk through the chosen path by using the "*commented circuit*" method. This method allows them to interact with public space by performing 3 interaction modes: "walk, observe and describe" so as to characterize their light perception in space. The participants spent about 12-15 minutes to walk through the real path, between 11:30am-2:30pm. Their impressions and daylight evaluation for each space were collected via a Dictaphone. They were then asked to complete a questionnaire, and then evaluate their experience in each world. In order to study the collected data, we analysed, first the recorded statements of the subjects to extract the description of the perceived (*in situ*) and the represented (*in vitro*) "solar effects". Then the questionnaires to get the memorable properties of the "solar effects". that highlights the most remarkable "solar effects" in the urban path. The results of each experience were studied on three levels to facilitate the interpretation:

- Preparing "Evaluation lists" that regroup the synonym subjects' commentaries to extract the characterization of perceived "solar effects".
- Determining the conditions that generate each type of "solar effects" by studying a part each space of the path as described in the subjects' commentaries.
- Studying the different stages in the paths as categorized by the participants light evaluation on the closed questions. The analysis of split spaces is inspired by "Régnier's Abacus" method (Régnier 1989). The method allows a simple, fast and precise systematisation of the opinions expressed in a group. It is particularly adapted to the collection and the treatment of qualitative information by employing a technique of coloured votes. The decision is taken by choosing a colour code from a grid of 5-7 colours that express the degree of agreement or not of each item in the closed list (between 5-15 item by list). White colour indicate a neutral opinion.

4 RESULTS

Through comparing those two urban paths, the results are split into three levels as mentioned on (3.3): subjects' judgements of subjective splitting of the paths, evaluation listing (*in situ, in vitro*) and emergence conditions of the "solar effects".

4.1 Subjects' Judgements Space Division

There were different subdivisions of the urban path in the two worlds- 5 urban spaces on the real world and 4 urban spaces on the virtual one-. For example, the majority of participants didn't distinguish the beginning of the path -"*Pilori square*"- in the virtual world. This was due to the predefined field of view of the walkthrough camera. For that, "*Pilori square*" isn't included in our comparison. Comparing users' daylight judgements is done through the "Régnier's Abacus" method, which proposes a choice between opposite qualification items: (luminous-dark), (opening-closing), etc. (Figure 5). The collection of subjects' choices gives a coloured diagram. That allows to evaluate the daylight in each stage of the bath, then to reveal qualifications of several "solar effects" in the chosen context.

Figure 5 illustrates as example of "*Royal square*". It shows similarities between some items, such as size, reflecting, and opening. The (rhythmic- random) item was judged differently. Consequently, that common qualifications allow to isolate some effects such as "*Attraction*" and "*Opening*". This confirms that theses effects are perceived the same way in both environments.

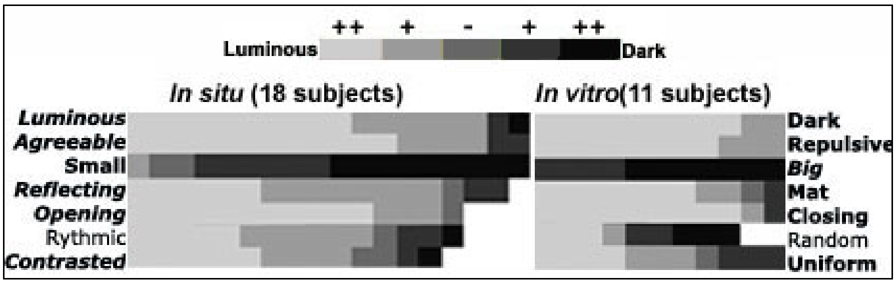

Figure 5 Subjects judgment results of Royal square through Régnier's Abacus

4.2 Evaluation Listing

This level is based on the comparison between evaluation lists made for each world in order to evaluate the way that subjects express their visual perception in each world. Do they have the same perception of the same effect in the two worlds? The evaluation list of "solar effects" *in situ* is richer than the *in vitro* one. In the real path, subjects' perception varies during the walk through the path, whereas in the virtual world, perception sometimes stays fixed although space changes. That is because the real world is far more complex since it is more animated, it contains pedestrians, cars, urban furniture etc.; a lot of stimuli that influence visual perception and make it richer. However, we have found many similarities in the participants' comments on the two paths in terms of visual perception. Table 1 shows an example of the users' comments on the effect of "Attraction/Repulsion" and "Opening".

Table 1 Comparison between the evaluation *in situ* and *in vitro* grids

Solar effect	Users' comments		Analysis
	In situ	***In vitro***	
Attraction/ Repulsion	Attracted by, looking at there, want to go, not to like, to accelerate, turn, slow down …	That gives desire, disagreeable, ugly., pick up the attention, not okay here, doesn't interest me, We aren't attracted.	The lack of free movement in the virtual world makes the perception of these effects as a wish, contrary to reality
Opening	A big, large, wide, spacious space, there is more of light	A sensation of space, illuminated space, It's big, space around me.	The same perception in the two worlds.

4.3 Conditions of Solar Effects Generation

This level compares between generated conditions of each effect type in the both urban paths. It allows to evaluate the characteristic of each effect in a specific urban space real or virtual. This asks the following question: in the same specific space (real and virtual), which phenomena are perceived similarly, and which aren't, and why? Which elements permit the emergence of some effects in one world and not in the other?

For example, at the "*Barillerie street*" (*in situ* and *in vitro*), "Attraction" and "Opening" effects aren't perceived by everybody *in situ* because the contrast in the virtual world highlights the opening on the "*Cours des 50 Otages*". On the other hand, the "Opening" effects in the "*Royal square*" is perceived similarly in both worlds. The example shows that perceiving "Opening" effect is changed from world to other although preceding results demonstrate that this effect has same perception in the two worlds. In this case the context (morphology, human presence, etc.) play an essential role in perceiving effects.

4.4 Discussion

Comparisons between the two environments allow us to determine the effects that are perceived similarly or differently in both worlds, as well as which effects disappear or appear in the each world. We claim that perception of the "solar effects" in the virtual world depends on the limitations imposed by the VR system:

- *Motion restrictions*: Predetermined walk through the path allows immersion but not total interaction within the space;
- *Sun presence*: Several real "solar effects" related to the direct presence of the sun which is absent in the virtual world;
- *Model quality*: "Solar effects" dependence of the quality of the virtual model (the texture, the resolution, the relief, etc.);
- *Urban ambiances*: "Solar effects" interaction with the other urban ambiances that are absent in the virtual world as well as pedestrians and urban furniture.

Visual perception of urban daylight varies between the real and the virtual world due to the particular conditions of each experiment. So we can conclude that visual perception in both real and virtual worlds largely depends on the urban context.

5 CONCLUSION

In this paper we have validated our methodology based on cognitive evaluation of the urban daylighting ambiences. However, it remains unable to completely extract the characteristics of "solar effects". Analysing visual perception of urban daylight through "solar effects" by using VR techniques shows that visual perception depends on: User's movement in the space, stimuli that occur during his walk through the path and ambiances which result from the combination of urban phenomenon (such as thermal and sound ambiances).

As in other design field application (such as design for manufacturing) where VR techniques allow to integrate the user earlier in the process and to detect major design flaws earlier in the process (Moreau and Fuchs 2001), VR has proved to be potentially of use in urban design. Future working directions include two research fields to set up VR as an assisting tool for the urban planning process but also as a complementary design tool:

- improving experimental conditions: it has been shown that motion is major cue in perception, we aim to use free movement in the virtual world by implementing the concept of "*guided visits*" navigation (Azpiazu et al. 2004). Additionally, the introduction of stereoscopic vision that should enhance visual perception of the roofs and their shape versus the background.
- Validating the whole methodology: a comparison between two urban paths with different identities, will be carried out in order to determine the "solar effects" role in space construction.

REFERENCES

Augoyard, Jean François. 1998. The cricket effect. Which tools for the research on sonic urban ambiences? In *Stockholm, Hey Listen!*. 1-8. Stockholm: The Royal Swedish Academy of Music and the Authors.

Azpiazu, A., C. Pedrinaci, and A. Garcìa-Alonso. 2004. A new paradigm for virtual reality: The guided visit trough a virtual world. In *IEEE VRIC 2004 Proceedings*, ed. Simon Richir, and Bernard Tavarel: 181-186. Laval: ISTIA.

Billger, Monica and Ilona Heldal. 2003. Virtual Environments versus a Full-Scale model for examining colours and space. In *Proceedings of Virtual Concept 2003*, ed. D. Couteillers et al.: 249-256. Biarritz: ESTIA.

Bishop, Ian D., JoAnna R. Wherrett, and David R. Miller. 2001. Assessment of path choices on a country walk using a virtual environment. *Landscape and urban planning 52:* 225 – 237.

Charton, Virgil. 2002. *Etude comparative de la perception d'ambiances lumineuses en milieu réel et en milieu virtuel*. Ph.D. Thesis, Ecole Nationale des Travaux Publics de l'Etat.

Cullen, Gordon. 1961. *The Concise Townscape*. London: the Architectural Press.

Follut, Dominique and Dominique Groleau. 2000. "Ambianscope" an immersion method to analyse urban environments. In *Proceedings of Greenwich 2000 International Digital Creativity Symposium: Architecture, Landscape, Design,* ed. C. Teeling: 139-148. London: University of Greenwich.

Fuchs, Philippe, and Guillaume Moreau. 2003. *Le traité de la réalité virtuelle*. vol. 1. 2nd ed. Paris: Les Presses de l'Ecole des Mines de Paris.

Jungman, Jean Paul. 1995. *Ombre et Lumière: un manuel de tracé et de rendu qui considère*. Paris: La Villette.

Lynch, Kevin. 1960. *The Image of the City*. Cambridge: MIT Press.

Moreau, Guillaume, and Philippe Fuchs. 2001. Virtual Reality in the design process: From design review to ergonomic studies. In *ESS 2001: Simulation in Industry*, ed. Norbert Giambiasi, and Claudia Frydman: 123-130. Marseille: SCS Europe.

Régnier, François. 1989. *Annoncer la couleur.* Nancy: IMQ.

Thibaud, Jean Paul. 2001a. Frames of visibility in public places. *Awards for design, research and planning* 14(1): 42-47.

Thibaud, Jean Paul. 2001b. La méthode des parcours commentés. In *L'espace urbain en méthodes*, eds. M. Grosjean, and J.P. Thibaud: 79–99. Marseille: Editions parenthèses.

Woloszyn, Philippe. 2003. Virtual Reality as an Ambience Production Tool. In *Proceedings of IEPM' 03* [CD-Rom]. Porto: FUCAM.