An immersive, multisensory and interactive approach for landscape study in virtual environments: the wind turbines' case

Jihen Jallouli and Guillaume Moreau

J. Jallouli (Corresponding author)
Laboratoire CERMA UMR CNRS 1563, ENSA Nantes, Rue Massenet, 44300 Nantes, France
Tel.: +33 2 40 59 43 24; fax: +33 2 40 59 11 77.
E-mail address: jihen.jallouli@gmail.com

G. Moreau
Laboratoire CERMA UMR CNRS 1563, ENSA Nantes, Rue Massenet, 44300 Nantes, France
Ecole Centrale de Nantes, 1 Rue Noé, 44300 Nantes, France
E-mail address: guillaume.moreau@ec-nantes.fr
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Abstract:

Nowadays, where public projects are more and more committed to sustainable development, the user perception become a determinant factor for the decision-making process. This paper targets to evaluate the use of an immersive, multisensory and interactive method based on virtual reality (VR) system in order to study human behaviour and perception. Today, non-immersive, non-interactive and mono-sensory (visual) representation tools are rather used to explain the project to inexperienced users which do not tally with the immersive and interactive user’s experience of the real public space. Wind turbines (WT) are used as a landscape case study because they are disputed and the present impacts’ studies do not take into account the multisensory and dynamic aspect of the object, neither the dynamic point of view of the observer. A VR approach is here proposed - thanks to immersion and interaction potentialities - in order to assess dynamic and multisensory WT impacts. For that, a comparison between a real park and the same virtual one is needed to evaluate impacts restitution and biases. The real and virtual parks are evaluated using an immersive path-based method (perception in motion) and interaction in the virtual world is done through an instrumented bicycle. Results confirmed for one, the importance of human motion restitution in landscape studies; and for another, the participation of landscape, by multi-sensory modalities and dynamics (e.g. temporal dimension, physical factors, shapes), to construct the perceived space. The VR approach demonstrates then good potentials for sustainable landscape aims: a communication and discussion tool in the decision-making process.

Keywords: landscape, virtual reality, wind turbines, impacts, perception, motion
1. INTRODUCTION

Sustainability concerns are about favouring a better future to all humans: user is henceforth the purpose of all political, economical and social actions. It means that every action must understand the people for whom the action is directed and answer to their relevant needs. The best way to understand one’s desire is to ask him; that is why today, in landscape and urban planning, the user participates as a decision-maker in public projects. He has to express his desired vision of the world by assessing the proposed representation of the project; that means the user must perceive the same world once constructed. In this paper, we propose VR as a new representation tool for sustainable landscape projects because of its perception restitution potentialities.

Landscape results from the “observer-environment” interaction (Zube 1987); it is a multisensory perception that changes depending on observer’s point of view and motion. Perceptual assessment of rural space rarely uses an immersive and dynamic point of view contrary to some urban methods which study observer’s instant perception through a predefined path. This type of method can be suitable with immersive, multisensory and dynamic landscape experience.

VR has been involved in landscape and environmental planning thanks to immersion and real-time interaction. In this way, real-time virtual landscapes have drawn considerable attention for public participation (e.g. Stock & Bishop 2006; Döllner et al 2005) but most of landscape studies only consider visual perception and visual cues for displacement in the space; acoustic perception and physical motion are often integrated: they are our VR challenges. VR is here proposed as an immersive multisensory and dynamic approach that is able to restore landscape experience and thus it can be a good representation tool for the decision-making process.

WT impacts’ study is the application case of the immersive, multisensory and dynamic approach. Today, international context (Kyoto Protocol) encourages WT which energetic gains are barely contested contrary to impacts: indeed, WT make visual contrast with the rural background and acoustic nuisances in the neighbourhood. That is why, WT impacts have interested many researchers but most of studies remain monosensory, non-immersive and non-interactive (e.g. Bishop & Miller 2007). Here, we will try to assess WT impacts on landscape by the VR approach; in other words the VR system must render both visual and acoustic impacts. For this purpose, we propose to compare perception of a real WT landscape to the same virtual one using an urban path-based method which tallies with observer’s experience. The comparison of characterized and contextualized perception in both worlds will evaluate potentialities and limits of the VR system.
In the first part of this work, we will first explain the theoretical framework: landscape issues, VR potentials and limitations for public projects, as well as the WT impacts’ studies. In a second step, we will describe the comparative approach; and finally, results will be discussed in order to propose the immersive multisensory and dynamic approach as a discussion tool for landscape and public project.

2. BACKGROUND

2.1 Landscape: the user as a decision-maker in the project

In last decades, landscape has evolved from a passive concept that leads to protect (freeze) the environment to an active tool for planning. This new status is confirmed in 2000 by the European Landscape Convention that promotes the protection, management and planning of landscapes and restores landscape to its central and active role. In fact, the Convention was motivated by the international attention for sustainable development (sustainable landscape) that considers users as an objective of all economical, social and ecological concerns. Since that, the user grows to a preeminent and central part of landscape issues and to a central actor of public projects in decision-making process.

In fact, the user also has a central role in landscape concept. Indeed, landscape is resulting of a complex relationship between environment and individual (Zube 1987): individual’s perception and exploration of space provide him with information from all directions via multisensory modalities and prompt his action. This individual’s experience of landscape – also called the “landscape experience” – is generated by a continuous “action/perception/interpretation” cycle that re-creates landscape (Figure 1). In this way, the landscape experience is immersive (space), multisensory (perception/interpretation) and dynamic (action) because it involves an immersed observer that interacts with space thanks to his senses and movement. Indeed, the ecological approach of perception (Gibson 1986) showed that the observer’s motion enhances perception and links time to space information: while the observer walks, he evolves through a space that offers new shapes and ambiances. We thus assume that immersion, multisensory modalities and motion are required conditions to the landscape experience that any study of landscape must integrate.

[insert Figure 1]
The user’s integration in the decision-making process raises many questions because the user is an inexperienced actor of landscape issues compared to the other specialized actors (designers). One of the major questions is about a representation tool for the communication and the discussion of the landscape project between the different actors. For an inexperienced actor, the representation tool must be on one hand, accessible (all actors can use it), understandable (all actors can understand it) and reversible (it can be quickly modified) (Stock & Bishop 2006); and on the other hand, faithful to the real “immersive, multisensory and dynamic” landscape experience.

Presently, representation tools have evolved from maps, photographs and photomontages (static visualizations) to animations and interactive virtual environments (Lange & Bishop 2005) because today landscape specialists insist on the restitution of the immersive, multisensory and dynamic experience in order to study the landscape. For example, Danahy (2001) and Lim et al (2006) asserted in their studies that dynamic vision and motion – through real-time interaction – is a better way to evaluate landscape. But most of those methods are mono-sensory (vision) and rely only on motion cues that are only visual (Harris et al 2002) which is insufficient to restore real landscape experience. That is why we propose here a multisensory method based on physical motion in order to study landscape.

2.2 Virtual reality: immersion and interaction potentialities and limitations

Since the 90’s, VR is finding increasing interest in landscape and environmental planning. VR assets are immersion and real-time interaction because they improve public participation and ‘allow rural communities to evaluate possible future landscape scenarios’ (Stock & Bishop 2006, p. 260). Immersive environments that satisfy dynamic visual perception are easily feasible thanks to panoramic projections (looking around, large field of view, 1:1 scale) but other senses are seldom integrated in VR application. Obviously, visual immersion is overriding and is the only aspect of most of virtual studies (e.g. Coeterier 1996); however, some researchers like Bishop and Rohrmann (2003) proved that acoustic perception coupled to vision improves realism and user’s landscape experience.

A digital landscape experience must also involve real-time interactivity. In fact, natural movement is the main issue of “user-VR system” interaction because of the scale difference between the virtual environment and
the experimental VR facilities. Indeed, existing tracking and display systems are generally limited and constrain
the user to move in a small physical area while landscape projects are rather extended. That is why most of
virtual environments are based on walkthrough animations (passive visual motion) which at least give richer
information about human behaviour (Bishop et al 2001) than a static scene. But active physical motion is a
particularly potent self motion cue and tends to dominate others (Allison et al 2002). Some researchers have
used the omni-directional treadmill (Darken et al 1997) or the “cyber-sphere” (Warwick University) to provide
natural walking but these technologies remain experimental and expensive. One approach has used an adult-
sized tricycle (Allison et al 2002) which has been instrumented to measure the rotation of one of the rear drive
shaft and the steering angle: natural movement is provided but the device requires an available large free space.

2.3 Wind turbines’ impacts: thresholds of visual and acoustic studies

WT setting up on a territory is not neutral in particular from an aesthetic point of view. That is why many
people contest WT impacts on landscape and local authority support participative approach and the user’s
integration in the decision-making process of the WT project. In fact, conflicts are either visual (wind turbines
damage/revalue landscape) or acoustic (nuisances among nearby residents); that is why this section is dedicated
to the impacts’ context and the limitations of current studies.

Visual impact: The visual aspect is the main feature of WT landscape but this impact strongly depends of
distance. That is why some WT guidelines (University of Newcastle 2002) specified 3 levels of perception
(recommended Zone of Visual Influence) that must be considered for each park study (Figure 2). In the Distant
area (radius greater than 10 km), WT are not always visible because the nearest objects generally draw more
attention but in an extended empty landscape vision focuses on WT. The Intermediate area (radius between 1
and 10 km) is the most studied perimeter by the photomontages because it consists in an overall view of the
park. At this level, WT visually dominate the space because of their height that occupies an important amount of
space; and they are also attractive because of their moving blades. For these reasons, visual impact must be
considered. In the Immediate area (less than 1 km), WT even more dominate visual perception because of their
size and the moving blades are visually and acoustically attractive. That means visual and acoustic impacts are
very important. According to those 3 levels of perception, visual impact must be assessed from potentially many
points of view whereas actually, only a small set of photomontages from the intermediate area is presented to
defend visual impact of new projects. This visualization tool is non-immersive, mono-sensory and static which is far from the real WT landscape experience on site.

[insert Figure 2]

**Acoustic impact:** WT produce both mechanical and aerodynamic noise but only the blade-wind friction propagates to hundreds meters around and disturbs neighbours; it must enforce relative ratios of background noise levels that are used in France (1995/04/19 Decree). In the compulsory Environmental Impact Assessment, WT acoustic issue is presently addressed by technical studies which are not understandable by inexperienced users. Few studies however tried to assess acoustic perception: as an illustration, Pedersen (Pedersen & Persson Waye 2006) used questionnaires to show that the annoyance risk was enhanced among inhabitants who see turbines from their dwelling and among those who live in a rural area by comparison with a suburban area. Furthermore, Pedersen demonstrated that perception focuses on the WT noise because of its incongruity with the background sounds. Most of acoustic inquiries quantify annoyance and do not qualify perception.

Visual and acoustic perception is required to assess WT impacts on landscape. It is maybe easier to separate visual and acoustic studies but we think that senses’ interaction tallies with real-life experience and gives richer sensory information. Indeed, some studies showed the influence of visual factors on acoustic nuisances’ perception (Pedersen & Larsman 2008). But in digital WT studies on landscape, visual assessment is still the most studied (e.g. Bishop & Miller 2007; Thogersen & Nielsen 2003).

### 2.4 Conclusion: an immersive, multisensory and interactive approach for landscape study

Thanks to sustainability, the user’s main role in public spaces is recognized; that is why the user is nowadays a principal actor in the decision-making process. At this step, the represented project must be easily understandable and must restore the real perception as when the project is constructed. For that, the best way is user’s immersion in the represented project in order to interact – thanks to his senses and motion – with the multisensory and dynamic space. since the 80’s, immersion and interaction with space are used on site by some urban approaches through the experience of walking: the *wayfinding* method (Passini 1984) or the *commented city walk* method (Thibaut 2001) solicits a pedestrian in order to walk, observe and describe the space by his
own words; that ensures the characterization of the inhabited space and the contextualization of the pedestrian’s perception. The multisensory path-based method is suitable with a rural context because it emphasizes the walker’s real experience. We choose the commented city walk method to study the landscape experience in real and virtual environment because it has showed great potentialities in VR-based ambient daylighting study (Tahrani & Moreau 2008).

3. METHOD

The aim of this paper is to assess VR potentialities in order to be a valid tool for decision-making process in public projects, especially landscape ones. It must then restore – like in real context – immersive, multisensory and dynamic landscape experience. Applied to the WT impacts’ study, the VR method must restore visual and acoustic perception. That is why the comparison of perceived impacts between the experience of an immersed user in situ and in vitro is required. The objective is not only to have the same perception (characterization) but also the same perception conditions (contextualization). The discussion of those conditions will highlight potentials and limitations of the VR method.

3.1 Tasks’ procedures and analysis

The in situ and in vitro surveys are similar; they are composed of commented country walks – the commented city walks (Thibaut 2001) applied to the rural context – and questionnaires. This type of qualitative method gets interesting results with about 20 persons (Thibaud 2001; Tahrani & Moreau 2008). In our study, 18 persons have participated in the in situ survey and 19 persons in vitro. Every survey took about 45 minutes. The commented country walk is based on perception verbalization: the participant, accompanied by the investigator, is required to walk along a predefined path, to observe and to describe what he feels. The comments are video filmed and audio recorded. After the immersive experiment, the user is asked to answer to a questionnaire with open questions.

The audio recorded comments highlight the ‘instant’ perception, the participant’s behaviour and the motion role in perception. We use the discourse analysis method (Gee 2005) to examine the transcribed
comments: it is a qualitative approach and a deconstructive reading and interpretation of a text. In our case, it emphasizes the perception characterization and contextualization (Frohmann 1992) because it aims at revealing the motivations and actions involved in the comments. We classify the discourse within 3 topics: WT (visual, acoustic, and other features), landscape (visual and acoustic features) and VR system biases (modelling, immersion and interaction) (Table 1). The analysis is done simultaneously with transcription and video projection in order to include user’s behaviour (influence of context, stop points, visual attraction, etc.) which could not be deduced from the transcribed comments.

The video recordings highlight the user’s behaviour which is not verbalized in the discourse. They are watched at the same time with audio recordings. For example: the user is silently moving forward and the camera is fixed on the blades at the same time (visual attraction).

The questionnaires identify the ‘remembered’ perception after the commented walk and bring out the path features that marked the most the participant. Here, the analysis is statistic. It is a way to get a quick general idea of results before the comments’ analysis. The questions are about: 1/ landscape: visual and acoustic attraction in the path; 2/ WT: visual and acoustic impact; 3/ path structure: path division in sequences according to landscape aesthetics; and 4) VR system: the In vitro questionnaire contains questions about modelling, immersion devices and interaction devices.

3.2 Investigation site: Plouguin

Real site: The study park is installed in Plouguin (France) since 2004 and surrounded by flat agricultural fields and few hamlets. The 7 WT are streamlined with smooth shapes and coloured with light grey-blue in the high part and with a green graduation in the base; that makes them original and recognizable. The park is easily accessible from 2 main roads. For this park, the intermediate and the immediate areas are the most important levels to study because in the distant area, the nearest objects draw more attention. 2 paths tally with those areas and are frequently visited by tourists and inhabitants: Path1 is at the WT feet and Path2 is 0.5 to 2 km far from the park (Figure 3).

[insert Figure 3]
**Virtual site:** The digital world was built thanks to 3D Max and GIS data. Vegetation was the main issue of modelling: in order to optimize easy real-time navigation, we decided to use 2D planar vegetation textured by photographs taken on site. This option gave preference to a monoscopic projection because stereoscopy would accentuate the reading of 2D plans succession. The digital Path1 has a grey sky while Path2 has a blue sky in order to respect the weather conditions in real surveys. The 3D model was then exported to Virtools which manages the interaction part of the experiment.

### 3.3 VR application: an instrumented bicycle for an active motion in landscape

**Virtual study protocol:** The developed VR application is based on a design and evaluation method (Fuchs et al 1999) that outlines 3 levels of immersion and interaction (I²) in order to build a VR application: 1/ the *functional I²* define the tasks that have to be performed in the virtual environment. In our case, there are 3 tasks: the user observes the virtual landscape while he is walking along a path and talking to the investigator beside him (real world). 2/ the *mental I²* describe how the user is implicated in the virtual environment. In our case, they will be validated by the comments. 3/ the *sensory-motor I²* define the “user-VR system” physical relation (devices). In our case, they are determined by visual and acoustic devices (immersion); and by motion devices (interaction).

**VR application:** The virtual world behaviour includes: 1/ *visual perception:* the blades’ rotation. 2/ *acoustic perception:* the different sounds (blades’ noise, road traffic, birds and wind) were recorded on site and implemented in virtual paths with respect to reality. In Path1, 3 sounds were associated to 3 objects (blades’ noise/blades, road traffic/road and birds’ noise/central object in the path); the blades’ noise was pitch-defined in order to match with a medium rotation speed (12 revs. per minute). In Path2, the WT were not heard in the *in situ* surveys then only birds’ noise and road traffic were implemented. In both paths, every sound has a sphere of acoustic influence and decreases at a certain distance like in the real paths (Figure 4). Spatialized sound is also used in order to cope with a real landscape experience. 3/ *perception in motion:* we assumed that an instrumented bike could be a solution: motion would be natural. We also assumed that biking (*in vitro*) is different of walking (*in situ*); that is why we fixed maximum biking speed at 7 km/h. To cope with a very limited budget, we simply used the opto-mechanical sensors of 3 mouses that were plugged to the PC and
implemented natural motion with a Virtools building block. Rotations of the rear wheel and of the handlebar were measured to provide realistic natural motion to the user. A third mouse wheel has been fixed on the handlebar and used to control head vertical orientation. The system instrumentation is presented in Figure 5.

[insert Figure 4]

[insert Figure 5]

The experiment took place in an immersive room equipped with a large rear-projected screen (2.4x1.92m), 2 spatial sound speakers, a control computer and 2 video projectors (Figure 6). We decided to place the user 1.5m far from the screen which ensures a field of view of 77 degrees horizontally (1:1 scale). The virtual camera is positioned at 1.6m from the digital floor in order to match with a common cyclist’s eyes position.

[insert Figure 6]

4. RESULTS AND COMPARISON

In situ, 9 participants participated in Path1 survey and 9 others in Path2 survey (Jallouli & Moreau 2008) (in vitro: 10 participants – Path1; 9 participants – Path2). The questionnaires’ results are separated from the comments’ ones because we want to show that on one hand, ‘immediate’ perception drew more information and results than ‘remembered’ perception; and on the other hand, the comparison between real and virtual worlds was more obvious through comments’ analysis than in questionnaires’ answers. But we think they complemented each other.

4.1 Questionnaires’ analysis

The questionnaires enhanced ‘remembered’ perception of WT impacts, landscape features and path sequences. The VR system characteristics were discussed in the in vitro questionnaire.

WT impacts: the questionnaires confirmed that WT impacts are both visual and acoustic. 1/ Visual impact: in Path1, most of participants found out that the WT scale is the most important visual impact (60% in vitro and
88% in situ) and 50% of them considered that the WT has got a positive impact (variety, colour, focal point). In Path2, scale was also the most impressive feature in both worlds but only for 50% of participants and blades’ rotation was the most important asset of WT (77% in situ vs. 33% in vitro) because from Path2, WT develop a rhythmic horizontal that is animated by blades’ rotation. 2/ Acoustic impact was deduced from Path1 because only one participant heard WT noise in real Path2 (wind direction was favourable). In virtual Path1, the WT noise was assessed as not disturbing (60%), annoying (20%) and annoying because of its repetition (40%). In real Path1, answers depended of wind speed; when it was strong (more than 35 km/h), the WT noise was impressive and very annoying.

**Landscape:** the most remembered landscape features were also visual and acoustic. 1/ visual features: in both real and virtual Path1, 90% of participants were mostly attracted by WT and moving blades but in virtual Path1, 40% of participants brought back flat vegetation. In real and virtual Path2, WT were visually the most attractive (66%) then fields, houses and cows. 2/ Acoustic features: in Path1, WT noise was the most significant acoustic feature (100%) then the birds’ one (60%). In Path2, participants mentioned birds’ noise first then road traffic.

**Path sequences:** by moving, the participant evolves in space, changes his point of view and discovers new sequences, motion constructs the space mental representation. This question shows participant’s understanding of the world where he was (especially in the virtual world) and which elements structure his space. In both worlds, most of participants sketched straight paths with main visual elements (Figure 7). We notice that WT structured the sketched Path1 while in Path2, others landscape elements such as fields, cows and houses also participated in the path mental image.

[insert Figure 7]

**VR conditions:** remarks deal with modelling, immersion (visual and acoustic) and interactive devices. 1/ modelling: in Path1, 40% of participants were not satisfied about flat and unreal vegetation that borders the country road; and in Path2, 33% of participants dislike the lack of relief and depth that we impose with monoscopy in order to reduce flat vegetation reading. 2/ visual device: 20% of participants thought that the screen limited their field of view especially in Path2 where they cannot move forward and look to all WT on the left. 3/ acoustic device: 30% of participants regret the wind absence (sound and breeze). 4/ interactive device: first, 10 % of participants in Path1 vs. 66% in Path2 thought that they were limited by the bicycle speed. The
important amount in Path2 is justified by spread landscape (all elements are concentrated in the end of the path) that encourage participants to accelerate. Second, the VR device to look up (use the scroll wheel of the mouse) was not ergonomic for 40% of participants in Path1 (participants do not need to look up in Path2). Third, the VR device to look around (stop and turn the handlebar) was not ergonomic for 22% of participants in Path2 and many participants even forgot to use it.

4.2 Comments’ analysis

We show in Table 1 an example of comments’ classification. 3 main subjects were addressed by participants: WT, landscape and VR system biases. The following results tally with this classification.

[insert Table 1]

**WT:** they activated visual and acoustic perception in Path1, visual perception in Path2 and many ecological thoughts. They were a central subject in the comments’ particularly in Path1 because WT fulfill space more than in Path2. 1/ Visual perception: it differs between both paths. In real Path1, scale and moving blades impressed and were the focus point of vision for all participants while in vitro, they impressed less; but in both worlds, participants gave rather positive WT description (modern, elegant). In real and virtual Path2, the scale was less impressive than in Path1. But while in situ, Path2 generated a horizontal pleasant reading thanks to repetition and to moving blades; in vitro the limited screen stopped to 1 or 2 WT and participants seldom think about looking to the left: the reading is vertical and the rhythm of moving blades was then not seen (Figure 8). 2/ Acoustic perception: the integrated sounds improved immersion sensation. In Path1, 70% of participants classified the noise as mechanical (airplane, washing machine) which means that the WT is not assimilated to a countryside object. Otherwise, it was negatively perceived because of its cyclic repetition in both worlds. 3/ Others: Many participants appreciate WT because it is a renewable energy thus it must produce electricity all the time. A WT that do not turn is not only aesthetically ugly but it is principally not producing green electricity.

[insert Figure 8]

**Landscape:** Landscape features that were deduced from comments’ were principally visual and acoustic. But obviously, vision dominated perception (60% of comments are about visual features and 20% are about
acoustic features). 1/ Visual features: surrounding shapes and objects influenced perception. In Path1, the field of view was rather narrow and only opened on vertical and noisy WT (feeling of being overwhelmed); while in Path2, the field of view was widely open with an attractive straight road which encourages participants to accelerate. 2/ Acoustic features: in situ, acoustic perception varies a lot depending on wind speed and direction which is not the case in vitro (wind is an ambiance sound). Otherwise, the integrated sounds were assessed positively (like in real world) and they enhanced immersion especially the countryside sounds that were compulsory for the presence feeling.

**VR biases:** The VR system limitations are the same with those cited in the questionnaires’ answers for modeling, immersion devices and interaction devices but with a bigger amount of participants because many participants were not conscious of their remarks and do not remember them afterwards (e.g. “the vegetation angle is 90 degrees... but apart from that, the world seems very realistic...”).

### 5. DISCUSSION AND CONCLUSION

This paper aims to assess the VR multisensory and dynamic method in order to study landscape and to propose a better approach of decision-making process. In the following paragraphs, we will discuss the method application in WT context and then in landscape context.

The objective of the WT study is to characterize and contextualize perception in both worlds in order to evaluate VR restoration of landscape experience:

- **Perception characterization:** in the WT context, it concerns visual perception, acoustic perception and inter-sensory perception. 1/ results of visual perception were rather satisfactory because we get the same perception of WT object (impressive scale, moving blades attraction, aesthetics) and of landscape (open vs. closed space). But the flat vegetation changes visual perception of the road (it is not the purpose of WT study but for landscape study it is important); furthermore, the screen proximity (1.5m) made the “rotor-observer” distance unreal: at the real WT foot, when participant look above to see the blades, this distance is more than 50m. Consequently, even with 1:1 scale, the WT is less impressive than in a real park. 2/ acoustic perception was also realistic. The WT noise was described in the same way in both worlds. The only limitation affected the variability of the wind sound and then the blades’ noise because
it was absent of the VR system. 3/ the immersive experience highlight the inter-sensory perception since
the countryside sounds make the VR world more realistic and the WT vision is not enough for
participants: in Path2 where WT were not heard, some participants asked why WT noise was not present.

- **Perception contextualization**: contextualization (context influence) was possible thanks to the immersive,
  multisensory and dynamic method that showed on one hand, the influence of movement and
  environmental features on perception and on the other hand, the landscape participation, by multisensory
  modalities and dynamics, to construct the perceived world. The comparison *in situ*/*in vitro* gave good
  results of contextualization especially thanks to interaction (motion and movement). The
  “walking/riding” substitution succeeded and the *in vitro* physical motion improved immersion and tallied
  with natural interaction. But the visual device was horizontally limited for extended space in Path2 and
  vertically limited for high WT in Path1 (the mouse device of looking up was not really adapted; it
  reduced immersion).

Our VR method has technical limitations for WT projects but they could be overpassed. The rich and
diverse results of the immersive, multisensory and dynamic approach promote its use for the study and the
discussion of WT projects: WT establishment could be evaluated and conversed in a more realistic way by users
and inhabitants in order to prevent harmful impacts on landscape (without/with WT).

The discussion of our study in landscape context is double: discussion about the use of *commented country
walks* in landscape study and discussion about the use of VR method in the decision-making process of public
landscape projects. 1/ the *commented country walks* detected subtle details of landscape and ‘instant’ perception
was rich in multisensory information and took context into account; these information are important for
perception restitution and for *in situ* and *in vitro* landscape study. Furthermore, walking emphasized the
landscape temporal dimension which acted on visual and acoustic perception. This method tallies with the
landscape experience. 2/ VR is an accessible, understandable and reversible representation tool if we optimize
their immersion and interaction potentialities. In landscape context which is generally open and large, a large
visual device is required (e.g. CAVE); and for walking, the bicycle device is a good and cheap option.

In these conditions, VR allows immersive, multisensory and dynamic experience and restore perception.
The designed VR approach shows then great potentialities for landscape studies and for decision-making
processes that is why a future step consists of the application of such a method as a discussion tool about the
landscape project. Another work could apply immersive and multisensory approach to another landscape case because WT have specific characteristics (scale, moving blades and noise).

6. BIBLIOGRAPHIE


Figure 1: The “action/perception/interpretation” cycle in the landscape experience
Figure 2: 3 different visions of the WT landscape depending on perception levels
Figure 3: the studied paths (© GEOPORTAIL 2007)
Figure 4: Sound setting up and spheres of acoustic influence in the digital world
Figure 5: Instrumentation of the bicycle with mouses’ sensors
Figure 6: Experimental room
Figure 7: Example of participants' sketches
So now, I go to the WT foot... but like this, while I am moving forward to it, I do not see that it is a WT... I look up and I am impressed, I told myself that it is high...

The noise impresses me... I did not think that it has got this intensity... it is especially periodic and continuous.  

Souvenirs: I remember the WT of Boin in front of the ocean... they are often in open spaces...

Renewable energy: it produces energy without consuming, just with air! Electricity is so expansive!

I like country spaces with fields and cows...

I see wheat fields, a forest in the back, sky and clouds... it is a lovely day...

What I hear is the road traffic behind? It is nice to hear birds...

The WT noise impresses me much more than the scale.

I do not feel the wind... I am wondering what kind of wind sensation we have here on the foot of the WT.

The vegetation is too flat here...

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<thead>
<tr>
<th>WT</th>
<th>Landscape</th>
<th>VR system biases</th>
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<tbody>
<tr>
<td><strong>Visual impact</strong></td>
<td><strong>Acoustic impact</strong></td>
<td><strong>Others</strong></td>
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<tr>
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Table 1: Example of comment's classification
Figure 8: Extended field of view *in situ* vs. limited field of view *in vitro*