POTENTIALITIES OF THE IMMERSIVE VIRTUAL REALITY IN ENVIRONMENTAL NOISE ANNOYANCE STUDIES

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RESUMEN

En las últimas décadas los estudios sobre la correlación entre el ruido ambiental y las molestias que este origina, han sido de vital importancia para la definición de los límites acústicos establecidos por legislación y para evaluar las molestias que el ruido provoca a la población. Estos estudios se han llevado a cabo generalmente bajo una metodología única, en la cual una serie de estímulos auditivos se presentan a un grupo de personas para conocer las reacciones subjetivas que les provocan. Sin embargo los sistemas de percepción humana presentan una importante cooperación entre los sentidos, lo cual requiere de un análisis de carácter multisensorial.

Las técnicas de realidad virtual inmersivas han ido mejorando en los últimos años hasta aumentar considerablemente su fiabilidad e integrando sistemas de auralización mejorados.
Estas técnicas pueden ser usadas para simular ambientes audiovisuales y poder registrar las reacciones subjetivas que provocan en los participantes, consiguiendo así una información más completa y veraz.

Este artículo presenta una serie de ejemplos recientes de la aplicación de estas técnicas, con el fin de discutir y analizar su efectividad a la hora de evaluar la molestia ocasionada por el ruido ambiental.

ABSTRACT

During last decades the results of the studies on correlations between environmental noise and annoyance have been extremely important to define legislation limits for several sound sources under different conditions and to evaluate and predict the annoyance impact of old and new infrastructures on the population. These studies have been generally conducted in a uni-modal condition in which the acoustic stimuli were presented to a group of people and the subjective reactions to these stimuli were registered. The literature on human perceptual systems has however shown a deep cooperation between sensory modalities. In the real life the

multisensory information is integrated by people in such a way that the reaction or perceived annoyance could be not as expected.

The Immersive Virtual Reality (IVR) techniques have recently increased their reliability: the well-developed visual representation have been integrated with auralization systems that have been improved obtaining more convincing audio presentations. These techniques can be then used to simulate the environment and to register the reaction of a sample of population under, at least, bi-modal (audio-visual) stimuli obtaining more and deeper information.

In this paper are presented recent example of applications of the IVR for the definition of environmental noise annoyance and the potentialities of the techniques for future development are discussed.

INTRODUCTION

The researches to comprehend the specific effects (auditory and extra-auditory effects) of noise on people, constituted the scientific base to determine cause-effect correlations of the noise on the human health. Moreover when it consider the case of environmental noise the specific effects of noise exposure are considered in terms of a nonspecific effect called generally as “noise annoyance”. The noise annoyance is widely accepted to be the most important effect of environmental noise pollution as well as the sleep disturbance [1, 2, 3]. The scientific researches as well as the international and national regulation efforts were focused on measurement and prediction of environmental noise levels and on its influence on noise annoyance and sleep disturbance.

The results of these researches were carried out by means of large social surveys [4] where were investigated the annoyance contribution of different types of transportation noise sources (road traffic noise, railway noise, aircraft noise and industry noise) on residents living around these infrastructures. The answers of the population in the social survey were then interpreted in terms of relations between percentage of noise annoyed people and sound equivalent levels. The results of these studies has carried out a set of dose response curves for different category of annoyed people, and noise sources led to determine cut off values used to identify noise limits levels. These criterions were then largely accepted by experts and now they are the main basis of the European Noise Directive 2002/49/EC [5].

Nevertheless, noise annoyance is a multi-faceted concept where the psychosocial factors play a role on noise annoyance as well as the noise level [6]. Variations in noise annoyance differ from one community to other due to these psychosocial factors [7, 8]. Standard relationships and models, not considering the complex interactions that occur when people hear sounds - *sounds recall memories and previous experiences trigger a multisensory processing which leads to identification of the source, finally form judgments as a function of the context in which the sound is heard* - , can mislead the noise impact assessment when it is applied to different contexts, to different communities [9].

The mentioned complex interactions in auditory experiences, occurs in both two ways of environmental perception; concept-driven (top-down) [10] and data-driven (bottom-up) [11] perceptive processes. Concept-driven perception happens when experience and expectations guide the interpretation of sensory information. The influence of psychosocial factors on noise annoyance is a consequence of this. On the other hand data-driven perception happens when the sensory information guides its own interpretation. The physical context is the important point on this case, because of the coexistence of complex sensory information – via different modalities – for a specific sound event. Humans acquire information in parallel along separate channels and this multisensory information is converged to create a single coherent and robust perception [12].

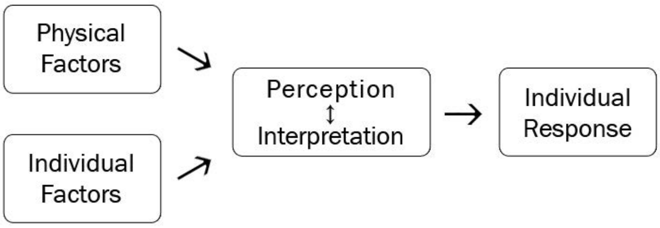

Figure 1. General scheme of environmental perception.

Various recent studies have shown the influence of different non-acoustic stimuli on the sonic environments assessment [13-15]. Thus ecological assessment of sound environments should take into account the variability among different communities or group of people exposed to noise and also the multisensory and interdependent nature of human perception.
Extensive social surveys taking place in real life settings offer an advantage in order to achieve this objective. However they are expensive, time-consuming and not applicable to assess future scenarios (new projects). For this reason, new methods are usually preferred for investigation in laboratory conditions. The settings can be prepared in two ways; preparing a physical stage that represents real life which can be named as simulator, or preparing a virtual stage (virtual environment) in order to display the scenario through a computer interface. These laboratory tests should stimulate the listeners' feelings and emotions (such as pleasantness, excitement, contentment) in order to have realistic reactions to the sonic simulated environment. In other words by these methods the sound and the complex environment are experienced together [16].

Simulators usually offer more realistic experiments but they are expensive and generally suitable to represent indoor conditions like living room or a vehicle cabin [17, 18]. On the other hand, virtual stages are relatively cheap and fully customizable for any kind of experimental need. There are several efforts in order to enhance conventional laboratory listening tests and achieve a satisfactory virtual stage [19-22], however they offer limited interaction with environment and usually limited immersion with only a static representation (images/photos) of the environment. Besides, high-end immersive virtual reality (IVR) systems offer satisfactory realism through high quality display and high level of interaction. The potentiality of various types of virtual reality systems in acoustics related studies is under study. Virtual reality systems can be utilized for dissemination of the results of noise maps [23], soundscape design and urban planning [15, 24-27].

In this paper it is aimed to present an overview of the technique, the actual applications and of the potentiality of the Immersive Virtual Reality use for the definition of environmental noise annoyance.

VIRTUAL REALITY

The term 'Virtual Reality' (VR) is defined in many ways since it serves wide range of activities. Recent developments in both hardware and software technologies supporting accurate and user friendly virtual reality systems, let various professions to use VR as an operational tool. Nowadays, VR systems are in the phase of adaptation to complex professional computations to give wanted outputs in real time. They are gaining a seat in our living rooms as well. Consequently the term has gained a broader definition; VR is an environment generated in the computer, which the user can operate and interact with in real time. A contemporary and more specific definition of virtual reality (and closer to IVR) is given by Burdea et al. [28], "Virtual Reality is a high-end user-computer interface that involves real time simulation and interactions through multiple sensorial channels, these sensorial modalities are visual, auditory, tactile, smell and taste". Immersive virtual reality systems employ various output devices (effectors) in order to reproduce full spectrum of sensory information.

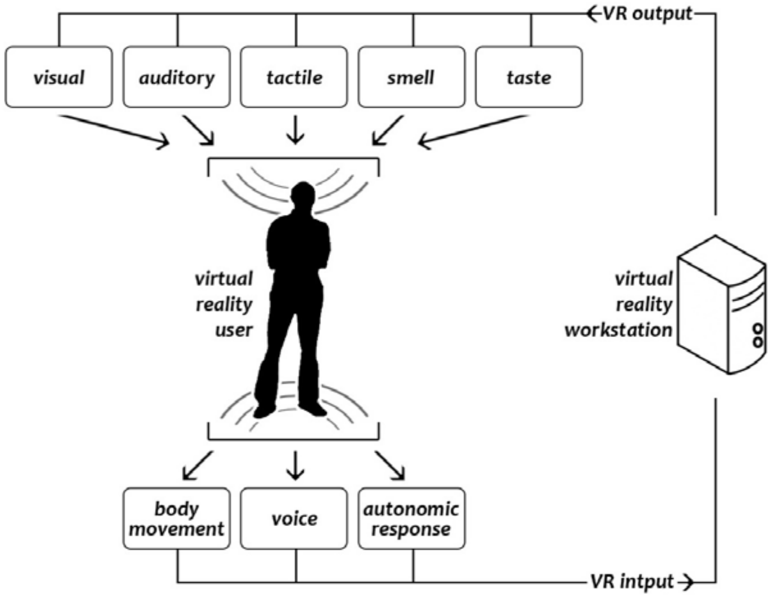

Figure 2. Range of possible input (sensors) and output (effectors) devices for a IVR system (adapted, Biocca&Delaney,1995) [29].

With a system approach, the designed virtual reality environment is presented through various user-computer interfaces covering all five sensory channels (visual, auditory, tactile, smell, taste), the VR user is immersed with VR stimulation and reacts immediately in different manners; looks, navigates and interacts with movement (body movement), makes sound and speaks (voice) and his body performs physical changes like increased respiratory rate, hemodynamic response (change in blood flow), electrical conductance of the skin, etc.(autonomic response). These reactions are captured by appropriate sensor in order to send input to the VR workstation. The VR workstation interprets the input according to the interaction design of the virtual environment, process and sends the resulting virtual environment information to the sensory interfaces (effectors) of the VR system in real-time.

Recent developments in both hardware and software technologies let us to adapt VR systems to complex professional computations to give wanted outputs in real time through sensory channels. There is a wide range of effector and sensor hardware offering different levels of immersion and usage for these operations. The visual interfaces are the most advanced effectors of VR systems; they are supposed to provide images to the human eye that is “indistinguishable from that experienced in reality in terms of quality, update rate, and extent”. Head mounted displays and CAVE systems are the most accurate and famous interfaces. Audio interfaces are generally simpler like headphones but also there are multiple loudspeaker systems like in ambisonic systems which are more accurate and expensive. Haptics means both force feedback (simulating object hardness, weight, and inertia) and tactile feedback (simulating surface contact geometry, smoothness, slippage, and temperature). Despite the recent research efforts on haptics interfaces, it is behind the maturity of video and audio interfaces. There are force feedback gloves and new attempts to have non-contact tactile interfaces. Smell and taste are usually considered together as chemical senses and there are very few prototypes of these interfaces. On the other hand, various sensors are being used in order to capture reactions of the VR user. The whole body movements of user is generally captured with optical trackers, in order to have a realistic visual output eye movement is captured with eye trackers. In addition to this, speech recognition systems can be used to command or communicate with other elements of the virtual environment.

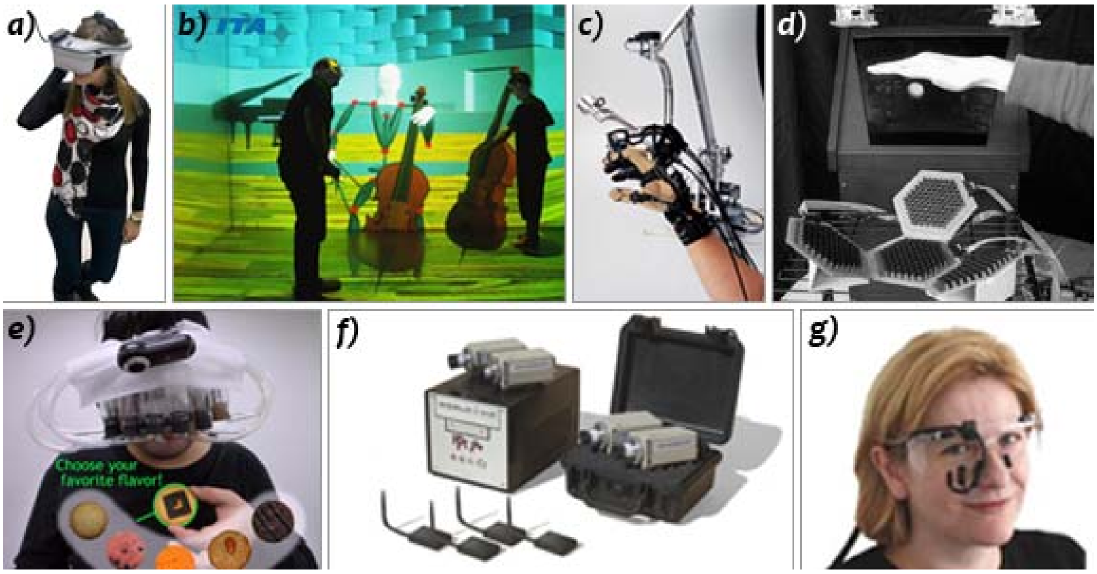

Figure 3. a)HMD-nVisor SX 60 (CSVR Second University of Naples), b)CAVE system (RWTH Aachen University), c)CyberForce haptic hand [30], d) non-contact haptic system [31], e) olfactory effector [32] f) PPT X optical tracking [33], g) ViewPoint EyeTracker [34]

AURALIZATION

Realistic audio representation is important in the immersive virtual environment applications as it enhance the sense of immersion and spatiality. For this reason auralization, defined by Vorländer as “the technique of creating audible sound file from numerical (simulated, measured, or synthesized) data” [35], is particularly important to obtain convincing spatialized audio for VR applications. Since late 1960’s there are efforts to create computer models for auralization. Today there are a few commercial auralization software widely used in this field, however most of the developed software and the research behind are focused on indoor auralization. Hence outdoor auralization is still underdeveloped. Furthermore, VR applications require higher update rates in auralization systems in order to obtain real-time interaction. But because of the computational shortcomings most of the existing systems are based on offline auralization techniques.

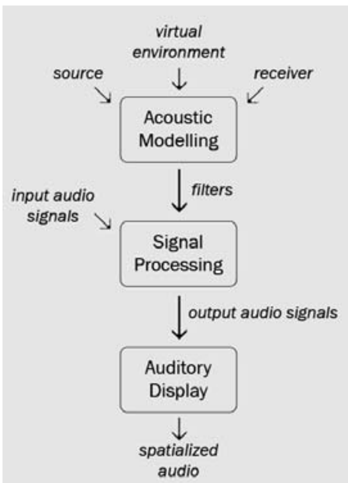

Figure 4. Basic auralization flowchart

However, scientific research is recently engaged in improving the outdoor auralization systems, optimizing complexity of audio rendering and obtaining more convincing audio representation in real-time.

One of the most advanced acoustic simulation systems for room acoustics is developed in Institute of Technical Acoustics, RWTH Aachen University and it is called RAVEN (Room Acoustics for Virtual ENvironments) [36]. RAVEN is hybrid room acoustics simulation software that combines a deterministic image source method with a stochastic ray-tracing algorithm in order to compute high quality room impulse responses on a physical basis. The most important feature of the RAVEN system is that it is capable of on-line auralization letting free scene interaction; sound sources and receivers can move freely in virtual environment and the geometry of virtual environment can be manipulated during runtime without any limitation in real-time auralization process.

On the other hand, outdoor auralization methods are currently being developed. In order to lower computational load of auralization for complex outdoor environments with relatively higher number of sources and higher level of interaction, perceptually plausible resulting sounds are usually aimed rather than physically correct results, in outdoor auralization processes. For this reason outdoor auralization efforts put special emphasis on human auditory perception phenomena and benefit from limits in our auditory perception and localization accuracy. Tsingos et al. [37] introduced a dynamic perceptual culling and spatial clustering method of sound sources. His method dynamically eliminates inaudible sound sources and groups the remaining audible sources in order to process each group as one single sound source. This method significantly reduces the computational cost of auralization process.

Traffic Noise Synthesizer (TNS) is another method of outdoor auralization which was presented by Head Acoustics [24]. TNS is focused on auralization of traffic noise as a function of vehicle type and driving conditions within a traffic scenario. It creates synthetically every (near field) sound of each vehicle and sums up contributions of all vehicles to obtain resulting traffic noise and lets user to listen to results at desired positions around the virtual road.

Metropolis project, an inter-disciplinary study carried out by Trinity College Dublin, presented another outdoor auralization method for dissemination of noise maps by making them audible [23]. The developed system dynamically filters a source audio that represents the background noise of the environment, according to the pre-computed noise maps. The filtering process continuously updates the input levels from noise map respect to the position of the user, breaks the source signal into four separate octave frequency bands centered at 500, 1000, 2000 and 4000Hz, applies the dynamic filter of corresponding position and sums up separate bands in order to reproduce auralized sound. Additionally, other single sound sources such as footsteps and character conversations address certain listener expectations adding to the level of immersion of the virtual environment. These point sources are auralized with general approach as sound design for game development. The resulting auralization of the virtual environment is reported to be plausible and efficient to relate information non-technical users.

Similarly, Ri.A.S. laboratory of Second University of Naples has introduced an auralization method based on an offline signal processing algorithm [38]. Having an offline signal processing algorithm, high computation load during the immersive virtual reality IVR annoyance tests is avoided. The source audio signals are processed, according to appropriate filters extracted from the resulting transfer functions between the sound source and receiver positions of pre-computed noise maps. Totally 31 filters were applied to source signals, with central frequencies ranged from 16 Hz to 16 KHz. The auralized sounds are reported to be plausible as a result of pair comparison experiments (loudness and frequency similarity).

RECENT APPLICATIONS OF IVR AND NOT-IMMERSIVE VR IN NOISE ANNOYANCE ASSESSMENT

Road traffic noise

Transportation infrastructures (airports, railways, roads) are the main noise sources that we are exposed to and the main cause of noise induced annoyance. For this reason the noise control measures are generally focused on transportation activities and their effect on people. The road traffic noise is the most diffuse transportation modality that we experience almost at any time of our daily lives. The mentioned VR applications combined with auralization systems are recently being used in dissemination of noise information to the community and to predict the possible future effects of new transportation infrastructure.

Environmental Protection Department of Hong Kong has introduced three-dimensional noise mapping method in order to avoid shortcomings of 2D noise maps for high-rise townscape of Hong Kong with the help of a VR application (Figure. 5a) [39]. Additionally particular attention is given to dissemination of noise information to the community through a use-friendly interface over internet. The developed application has an embedded audio system that enables user to listen representative audio samples calibrated according to the computed noise grids. The introduced VR system is not using an immersive interface that enables realistic user experience and audio representation considers only road traffic noise.

Another important study employing VR techniques for dissemination of noise information was carried out by Trinity College Dublin [23]. Metropolis project introduced a simulated lifelike city, where real people will be able to move around and experience total immersion in a computer generated Virtual Dublin (Figure. 5c). A core of the project is to simulate realistic traffic noise in a virtual environment and validate the level of realism achieved with principles of human multisensory perception. The project is based on the Audio Noise Mapping by mean the audio information is incorporated into the virtual environment after the noise map is constructed. This combination of information has the potential to be used both to disseminate environmental noise information and also as a method for engaging in collaborative feedback from the general public.

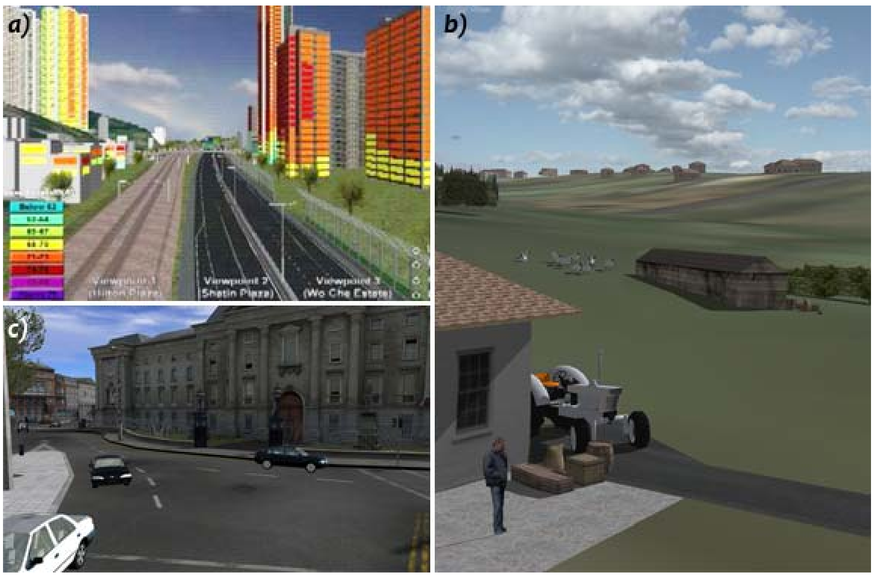

Figure 5. Examples of virtual environments for assessment of road traffic noise

Similar approach is used in the synergic study of the RIAS Laboratory and the Laboratory of Cognitive Science and Immersive Virtual Reality of the Second University of Naples [40]. In this study the traffic noise simulation prepared integrating audio and visual stimuli, were then presented with IVR system (Figure. 6) and with the help of subjective questionnaire. In particular in a case-study of a new highway (Figure. 5b), it was found out that conventional methods to assess noise impact based on noise maps and noise limits did not match even the real response of the population. During the tests a significant correlation was found between visual annoyance and noise levels (Leq,A). These preliminary results confirm that the application of a methodology which contemplates the audio and visual annoyance reaction of a sample of the population can lead to more information for the noise impact assessment of a new project.

Figure 6. IVR system of the Laboratory of Cognitive Science and Immersive Virtual Reality of the Second University of Naples

Noise Mitigation Actions

In Hong Kong, the Environmental Protection Department (EPD) has implemented several retroactive mitigation projects (Figure. 7a) to tackle the noise problems using an advanced tools called iRMAS "Interactive Web-based Retrofitting Noise Measure Assessment Software" [39]. This technology based on the integration of noise modeling, GIS and computer graphics, portray largely the noise environment of the city and offers enhancement of the interaction through internet, enabling tools that can help to promote stakeholders participation in environmental problems.

Joynt and Kang [41] presents a research on the subjective perception of the noise barrier material (Figure. 7b) based on the answers to three main questions: (1) Do preconceptions held about the constituent materials of an environmental noise barrier affect how people perceive the barrier will perform at attenuating noise? (2) Does aesthetic preference influence the perception of how a barrier will perform? (3) Are barriers, which are deemed more aesthetically pleasing, more likely to be perceived as better noise attenuators?. The researchers used a virtual reality setting based on film to improve the contextual realism of the inter-sensory interaction test, presented with the RAVE- Reconfigurable Advanced Virtual Environment suite, at the University of Sheffield. It was aimed to compare the perceived effectiveness of five standard 'in-situ' noise barriers, including concrete, timber, metal, transparent acrylic and a vegetative screen. The audio stimulus was held at a constant sound pressure level, whilst the visual stimulus changed. As the noise levels during the study were held constant, it was possible to attribute the participant's perception of noise attenuation by the barriers, to preconceptions of how the varying barrier material would attenuate noise. The results of this study showed that there was an inverse correlation between aesthetics and perception of how a noise barrier would perform. The transparent and deciduous vegetation barriers, judged most aesthetically pleasing, were judged as the least effective at attenuating noise.

Moreover, noise barrier insertions are also used to mitigate the noise effects at receivers of train pass-by. In order to investigate the influence of visual stimuli for different types of barriers (matt/transparent barriers) on noise perception, VR scenarios of a railway line were prepared (Figure. 7c) in Ri.A.S. Laboratory of the Second University of Naples. The prepared VR scenarios include auditory stimuli based on in-situ pass-by recordings and audio signals manipulated respect to the appropriate sound attenuation of different types of barriers. A subjective test conducted to evaluate perceived efficiency of introduced noise barriers by means of pair comparison technique.

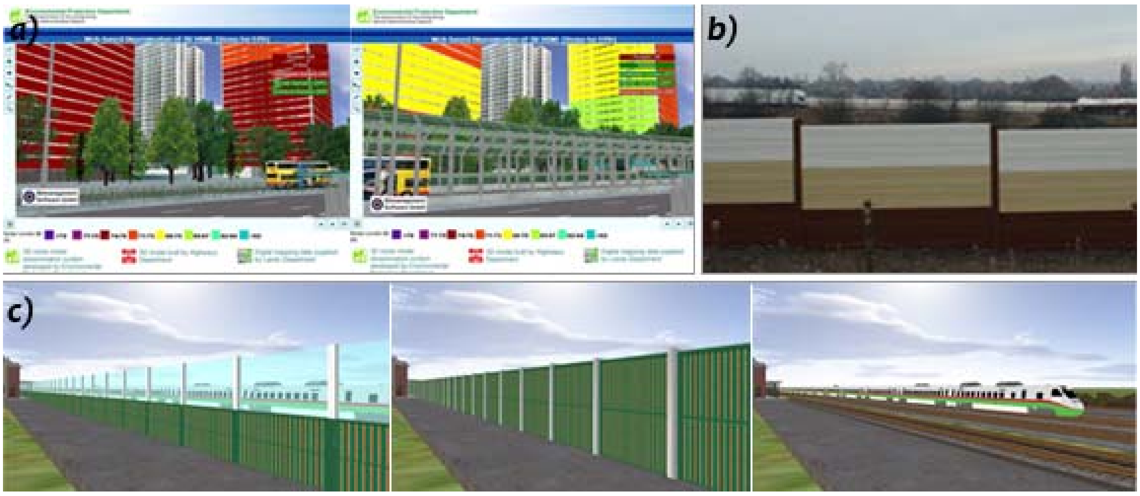

Figure 7. Examples of virtual environments for assessment of noise mitigation interventions

Wind Farm Noise

Another application field of the Immersive Virtual Reality is constituted by the prediction of noise impact caused by the wind farms. Wind farms which are usually built in areas characterized by conserved natural values, like calmness, recreational activities, landscape scenery and natural soundscape result have stronger intrusion on conserved existing soundscape and landscape. This can cause unexpected variations in the global judgment of people in terms of noise annoyance [42,43] respect to others noise sources (road traffic noise, railway noise, aircraft noise and industrial noise). Actually according to different studies, wind farm noise annoyance seem to have a characteristic dose-response curve and researchers are working to enlarge the bases of data to find a more generalized dose-response curve for wind turbine (WT) noise [44,45]. Furthermore, many researches underline the influence of non-acoustical factors, like the visibility, the geographical distribution, the color, the movement as well as the attitude towards green energy, the degree of involvement in the project and the economic benefits from wind turbine installation [46-48] which represent moderator factors on WTs noise impact.

Among the recent studies where IVR were used in order to evaluate multisensory impact of wind turbines, Jallouli et al. [26,49] evidence as most of the study on the impact of WT on landscape remain non-immersive and non-interactive while others deal with only uni-sensory perception. In their study tests composed of commented country walks and questionnaires, both in situ and in vitro conditions were prepared building a digital world by 3D Max introducing different sounds (blades noise, road traffic, birds and wind). The virtual experience took place in an immersive room equipped with a screen and 4 spatialized speakers, a computer and 2 video projectors. This study proves that VR does have the potential to anticipate the WT landscape experience and present a good discussion tool for public projects. For the future the authors plan to improve the VR system by introducing natural physical motion in vitro (more free moving). It is demonstrated that the effort of pedaling (cognitive and proprioceptive cues) coupled to visual displacement provides natural motion which is important for perception of distance.

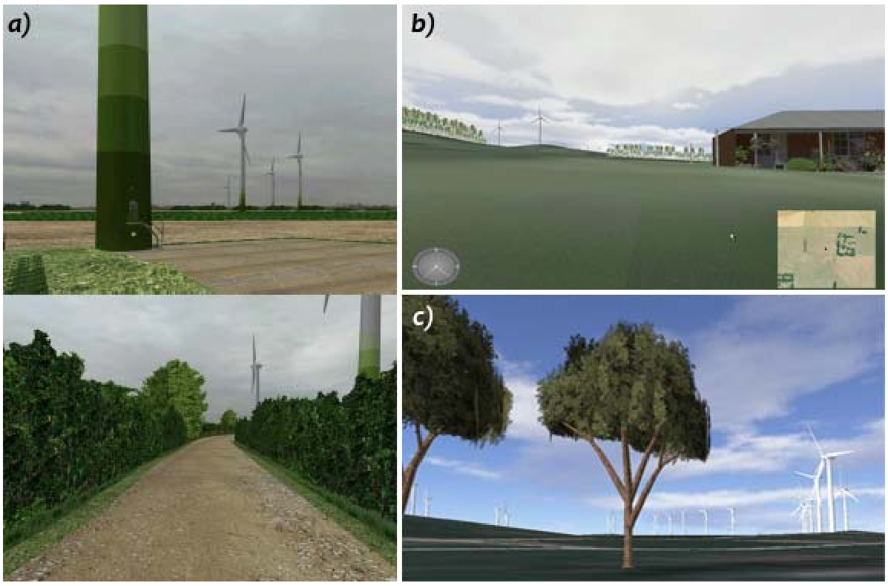

Figure 8. Examples of virtual environments for assessment of wind farms

Other applications were experienced by Bishop et al. [50] with the intention to give to people the ability to see, and hear, a project from their own particular point of interest. He sustain that people need to manipulate design elements while exploring the virtual space and that this experience should not be experienced alone, but it should be shared with the community at appropriate stages and with project proponents and any arbitrators linked to the decision-making. He applied this idea in the case study of an existing wind farm developed in the Challicum Hills area some 150 km west of Melbourne in south-eastern Australia, using a system based on GIS dataset and a viewer "SIEVE" where users were able to explore a proposed wind turbine farm allowing them to manipulate individual elements of the environment (e.g., moving objects or adding and deleting objects such as shielding trees). The built scenarios are also integrated with auditory stimuli and presented through a 3D sound system, enabling a realistic soundscape at different positions allowing the exploration of visual and noise pollution.

The potentialities of IVR application for wind farm impact assessment investigated in another study conducted by Ri.A.S. Laboratory and the Laboratory of Cognitive Science and Immersive Virtual Reality [51]. The author examined the case study of a wind farm in San Giorgio la Molara (BN), sited in the Apennines area between Campania and Molise regions. The wind farm consists of 340 pylons and lattice towers 40-50 meter high, each of which has three blades rotors with a diameter between 30 and 35 meters. The 3D scenarios of the area were modeled both with traditional noise prediction software and with Virtual Reality software. Every 3D simulation of the investigated wind farm represented the actual condition, characterized by the presence of the wind turbines (post operam condition) and in a simulated scenario representing the condition before the installation of the wind turbines (ante operam condition). Simulations were prepared integrating visual scenario with audio stimuli recorded in situ and afterwards manipulated using the transfer function source-receivers extracted from the results of the noise prediction software. First results of the test were focused on the cutoff distance, e.g. that distance where noise annoyance doesn't change away from WT, could be identified between 100 and 250 meters. However, authors suggest further understanding and investigations on cutoff distances for noise annoyance could provide insight to set buffer zones around WTs.

Urban Design and Soundscape Studies

Apart from noise annoyance studies conducted so far, in last decade soundscape approach has been emerging with a special emphasis on sensorial qualities as well as annoyance. The soundscape approach integrates the exposed people as local experts to design and planning process in urban related issues. There are several efforts that employ VR applications in order to enhance the communication between actors of spatial decisions as a user-friendly presentation tool, to support urban design practices with a multisensory approach and to evaluate overall quality of urban soundscapes [25, 52].

George Drettakis et al. [25] presented an interactive virtual environment offering a high level of audiovisual realism with 3D sound, shadows, sun coverage, vegetation and crowds, to be used in architectural design and urban planning domains. The developed VR application enables the working group of a real-world urban planning project (redesign of public spaces as part of the construction of a new Tramway in the city of Nice in France) to see and discuss issues concerning the design of the square. The presence of spatialized 3D sound such as fountains, the tramway and buses in VR application is reported to be an important aspect to evaluate the overall ambience and atmosphere formed by design scenarios. The resulting VR application aided in decision making and brainstorming process of the real-world project and it is used as a presentation tool of design scenarios.

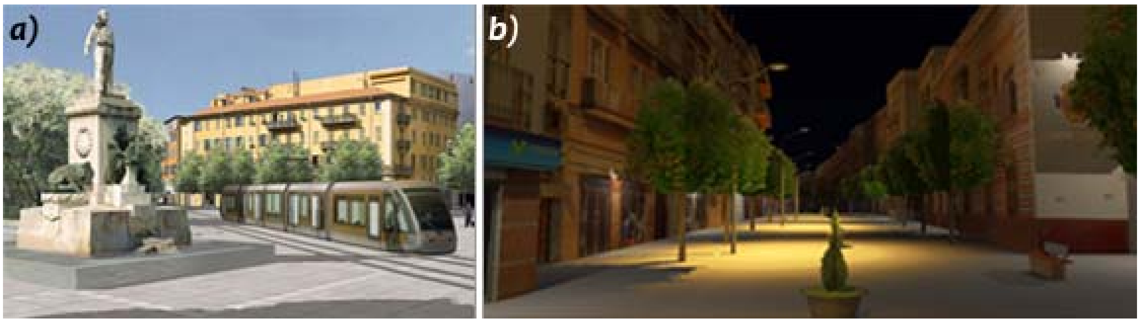

Figure 9. Examples of virtual environments for assessment of urban spaces; a) Place Garibaldi constructed for the study of a future Tramway project [25], b) Calle San Jacinto constructed fo future scenarios of lighting and soundscape [52].

One other study in same field was conducted with a collaboration of Ri.A.S. Built Environment Control Laboratory, Second University of Naples and the General Directorate of Climate Change and Urban Environment, Andalusia-Spain [52]. The study aimed to demonstrate the possible changes in urban environment due to the new regional regulations on noise and urban lighting through an interactive virtual reality application. The prepared VR application consists of three audio-visual scenarios of of the 'calle San Jacinto, Seville'; 1) the actual situation at daytime, 2) sodium-vapor lamp lighting at nighttime 3) LED lamp lighting at nighttime, all three accompanied with appropriate soundscape reproductions. The resulting application gives a qualitative insight about future of the mentioned street and it is intended to enhance this preliminary application in order to have a more realistic and precise representation to be used for a public opinion survey. A mobile IVR laboratory was developed by RiAS Laboratory so as to conduct surveys in situ with real users of the study area.

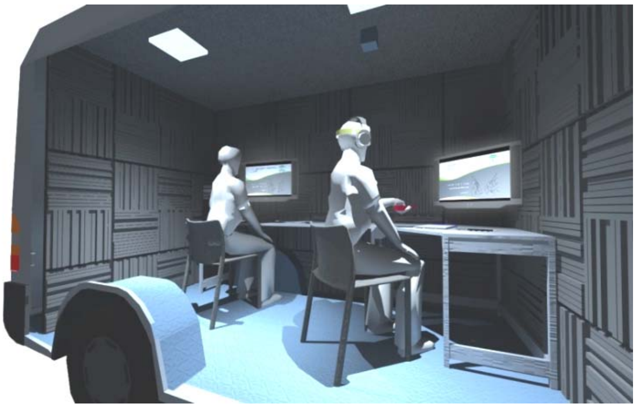

Figure 10. Mobile IVR lab of Ri.A.S., Second University of Naples.(in construction)

DISCUSSION

The experiences in traditional environmental impact assessment (EIA) often have showed as the traditional method to assess the impact of new infrastructures or of urban renovation projects can be not sufficient to consider completely the future effects of a new project on the interested population. At the same time many research have demonstrate again as the mono-sensorial perception of the physical stimuli don't even match the multi-sensorial perception which the population experiences in the real world, as well as that the vision represent one of the main moderator factor of noise perception. Moreover others moderator factors were identified into the individual sphere that involve psychological and social aspects.
Today thanks to the high growth of computer elaboration capacity and of the development of new output devices (effectors) in order to reproduce full spectrum of sensory stimuli new attempts to reproduce "virtually" the scenarios of project have been made worldwide by researchers. The Immersive Virtual Reality today represent the only application where all these aspects can converge. This technique offer several advantages over conventional noise annoyance studies in which noise and its effects are undertaken by means of energetic levels of sound and psychosocial variations between communities are under estimated. Also IVR approach introduces enhancements in laboratory experiments. The advantages include:

- Mediating variables are introduced with Multisensory Immersion
- Psychosocial variations are considered with appraisal of local experts
- User friendly interfaces are introduced for dissemination of technical noise data
- Public participation in decision making process is promoted through the presented future scenarios in a very transparent way to the end-users
- Fully customizable and affordable instrumentation promotes experimental design process

Nevertheless there are some important points to consider and to develop in order to take full advantage of the IVR approach.

- Outdoor auralization techniques should be improved in order to have scientifically accurate results.
- The experiment protocol should be designed with objective and subjective psychological measures considering short duration exposures and the overall characteristics of sonic environments
- Subject groups (local experts) should be diversified and chosen efficiently from the corresponding study areas.
- The process and steps of public participation should be well designed in order to take full advantage of public feedback and in order to support public acceptance for the proposed future scenarios

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