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# Virtual Reality as an Ambience Production Tool

## An application to immersive sound recognition

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*ABSTRACT. For many years, architectural and urban ambiances have been the main subject study of our laboratory, dealing with the urban built shape interactions. Classical results are predictive numerical models, which provide parameters related to the environment physical factors. Through interaction with environmental parameters such as light or sound, urban and architectural spaces generate ambiances with identifiable characteristics. This notion of ambiances is related to the human being position through its perception of environmental physical phenomenon. This is why virtual reality seems to be a relevant way to evaluate architectural and urban ambiances focused on the engineering production field. Application of this exploration field exposes an acoustic ambience study relative to an identified architectural location. Experimental results are then developed before discussion.*

*RÉSUMÉ. Depuis plusieurs années, les ambiances architecturales et urbaines sont le point focal des recherches au sein de notre laboratoire. Les résultats classiques se traduisent par des modèles numériques prédictifs, qui fournissent les paramètres physiques relatifs à l'environnement. C'est par l'interaction avec ces paramètres environnementaux comme la lumière ou le son que les espaces architecturaux et urbains génèrent des ambiances avec des caractéristiques identifiables. Cette notion d'ambiance est conditionnée par le positionnement de l'homme au sein de ces phénomènes environnementaux par sa perception. De ce fait, la réalité virtuelle se positionne comme un moyen pertinent pour l'évaluation des ambiances architecturales et urbaines orientée vers le champ de l'ingénierie de production. Une application de ce champ exploratoire présente une étude d'ambiance sonore dans un site donné. Les résultats expérimentaux sont développés avant d'être discutés plus avant.*

*KEYWORDS: virtual reality based systems, ambience production, urban planning.*

*MOTS-CLEFS : systèmes d'exploration en réalité virtuelle, production d'ambiance, projet urbain.*

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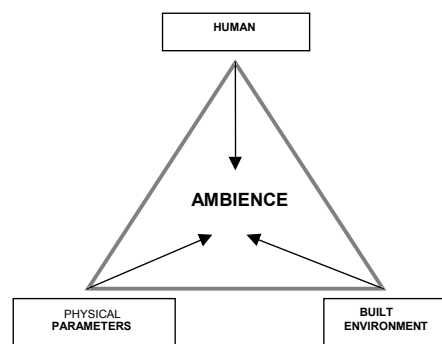
## 1 Introduction

Virtual Reality approach is full of promises for integrating human into the scientific knowledge of architecture and urban production. Through this possibility of an anthropocentric rendering system, including space (town), process (environmental physics), and actor (human), the powerful multidimensional toolbox offered by Virtual Reality would complete the main “classical” topics of building engineering, including thermal, aerodynamical, acoustical or lighting qualification processes.

## 2 Notion of Ambience

Architectural and urban ambience production is related to the following three main interacting parameters (Figure 1):

- the specified built form, which shape and material characteristics are able to generate an identified physical ambience condition,
- the specific urban physical factors, which cover a large spectrum of environmental phenomenon such as wind, temperature, sun exposure, acoustical propagation or pollution dispersion,
- the human being, both identified as an actor of the environment and as a subject (an ambience perceptor).

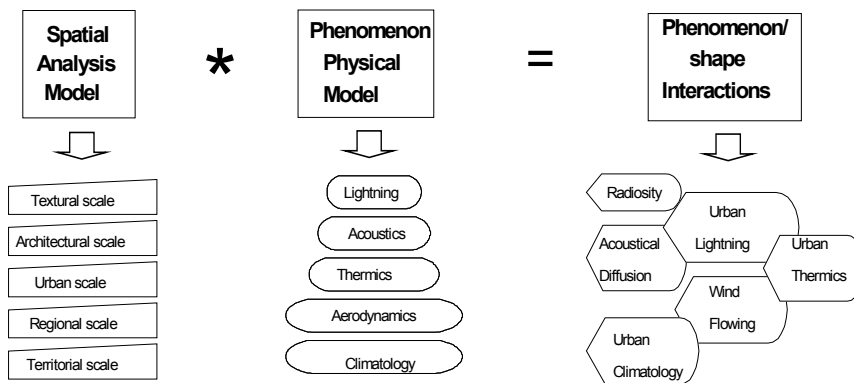


**Figure 1.** *Ambience scheme*

In this way, we define ambiances as an anthropocentric view of the global environmental production through physical, human and built constraints of architectural and urban design.

### 3 Physical constraints : the rule of phenomenon scaling

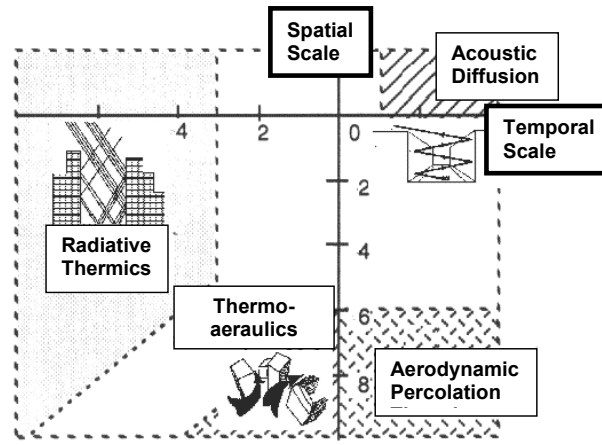
As the main support to analyze the phenomenon of architectural and urban environment is based on particular techniques like modeling and simulation, it is useful, in a first step, to segregate their three main elements into elementary physical manifestations, which involve specific parameters as seen Figure 2:



**Figure 2.** Physical ambiances phenomenon and their associated scales

For example, the sound wavelength, which corresponds to architectural and urban scales (from millimetre to metre), is very far from the light wavelength (micrometre), and from the microclimatic phenomenon characteristic scale (kilometre).

In addition, those *spatial* characteristic scales are complemented with the phenomenon *temporal* scales, which have to be taken into account in order to implement the physical parameters into the urban built geometry (Woloszyn, 1997) as seen Figure 3:



**Figure 3.** *Spatial and temporal scales applied to ambiances phenomenon*

Reference to various analyse systems will be necessary, as the most currently used methods, other than the direct phenomenon parameters measuring, imply a physical model for process evaluation. This multiphenomenon characterisation leads us to organise the urban space as a field of data aimed to ambiances physical parameters description. In order to exploit those data for building production process (i.e. the choice of a specified absorption material aiming a sonic quality of an indoor space), we'll focus on VR tools reliability for one-scale testing of the corresponding material properties. This physical constraints pre-testing of architectural solutioning of an ambience target constitutes one of the most powerful and flexible in- and outdoor ambience simulation application tools.

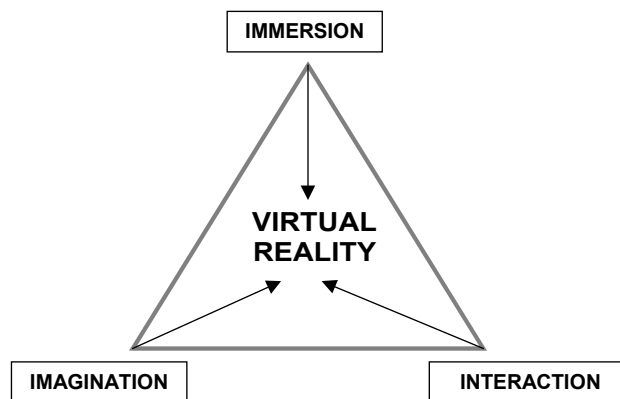
#### 4 Human constraints: the rule of sensorial interaction

Nevertheless, use of virtual reality techniques for environmental visualisation can't afford a satisfying ambience representation without integrating the sensitive aspect of phenomenal perception. In that way, we can consider this aspect as a sensation vector from subject (the human being) to the ambience complex. Taking sensorial interaction through the physical simulation process into account leads us to an hybrid ambiances representation model, rooted to our researches in the both domains of spatial analysis and ambiances perception (Woloszyn, 2002). The final

model we propose would enable the final user to “re-feel” the ambience parameters at each step of its wandering.

Those scalar physical phenomenon are perceived with specific “human sensors”, which perception and judgement iteratively act on the building engineering solution choice through ambience simulation. In fact, the laws of human perception, considered as a “sensorial filter” of the reality, are specific for each physical domain relatively to their spatial and temporal characteristic scale. Otherwise, psychological perception studies point out a noticeable difference between individual perceptors, which “ambiences sensitivity” is depending at the same time on the local context of perception situation and on the inner disposition of the human being (Dubois, 1993).

Following those remarks, we can afford to compare these complex interactions with the known Burdea’s virtual reality symbolisation (Burdea *et al.*, 1993), based on the three major principles of Imagination, Immersion and Interaction, figure 4:



**Figure 4.** *Virtual reality scheme (Burdea et al., 1993)*

The Immersion process (Slater *et al.* 1993) places human in an equivalent position of a “classical” urban pedestrian, with a height situated between 1.6 and 2 meters. The effect of this positioning is a simulation of physical phenomena and spaces interaction very near from the reality. This realistic interaction principle is conditioning the user’s freedom degree in the “re-feel” system.

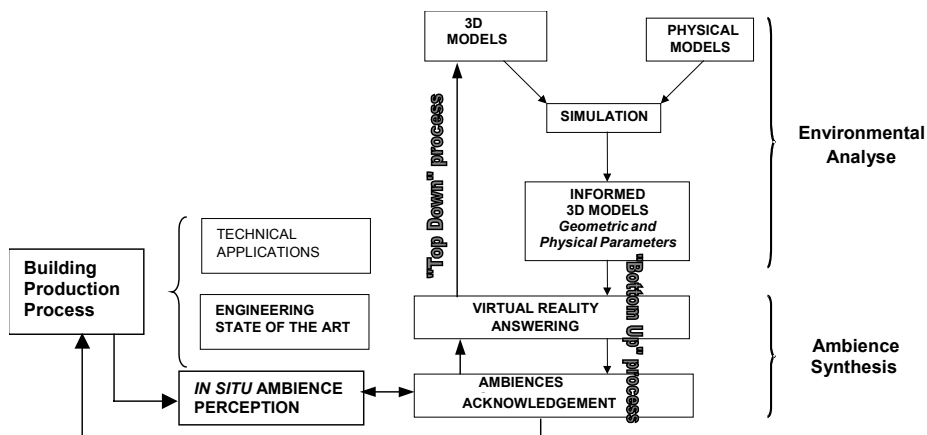
An immersion with a total interaction will allow a free moving and a dynamic parametering, permitting a total independence between each side of the triangle figure 4. This moving and sensing degree of freedom is important for space conditioning, and, consequently, for exploration acknowledgement.

Imagination characterises interpretation of the parameters resulting from the virtual reality experimentation. Those descriptive parameters are related to the physical phenomenon with replacing them in the perceptual context. Several known methods can be applied to this aim, and the results shows a “zoning ratio” for each perceptual characterisation, implemented from the starting point of the perceptor to the rest of its evolution during a walktime.

### 5 Building constraints: from project to technical solutioning

Environmental simulation is fed between a 3-D geometrical model of the town and the associated physical data, in order to provide a specified ambience perception condition through technical applications. This psychophysical method, consisting to compare engineering solutions with subjective judgements is known as the “Bottom Up” process of sensorial data treatment (Dubois, 1993).

Virtual reality technical applications allows a feedback to this methodological approach, with including the human being at the beginning of the process. An interrogation of the pre-constituted engineering database provides an ambience acknowledgement through immersion, in order to inform the geometrical model with human environmental needs (Figure 5):



**Figure 5.** Ambiences synthesising scheme: “Top Down” and “Bottom Up” processes

This “Top Down” processing model constitutes a new answer for integrating semio-physical parameters into the built environment engineering, through discursive (verbal) expression of environmental needs. The ambience 3-D scheme used in immersion process synchronously links “Top Down” and “Bottom Up” physical dimensions to perception shapes, into a spatio-temporal dynamic, traducing the physical shape of a phenomenon into a technical solution to be integrated through the building engineering process.

Considering this process as a part of the building production finality, we propose a new triangular scheme, synthesising this methodological convergence between Virtual Reality, ambience acknowledgement and built production (Figure 6).

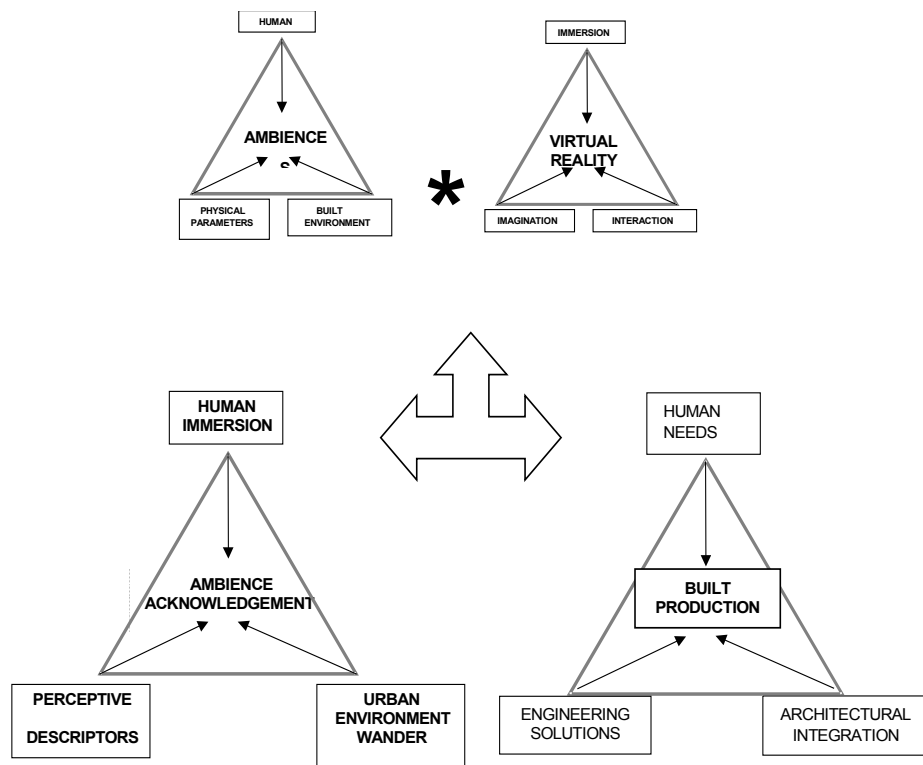


Figure 6. Ambience production scheme



This production process supposes the rendering of three classes of ambiances parameters:

- the human factor parameters associated to the verbal expression of environmental needs,
- the engineering parameters directly linked with the technical imagination,
- the architectural parameters in mean of material and built principles integration.

## **6 Application: an acoustic ambience study by spatial immersion**

The method presented here constitutes a fore-shadowing tool for ambience production. Actually developed in the Cerma Laboratory, the following application is based on a coupling principle between space characterisation and sound recognition (Nathanail *et al.*, 1997); the applied method supposes an acoustic ambience study relative to an identified architectural location.

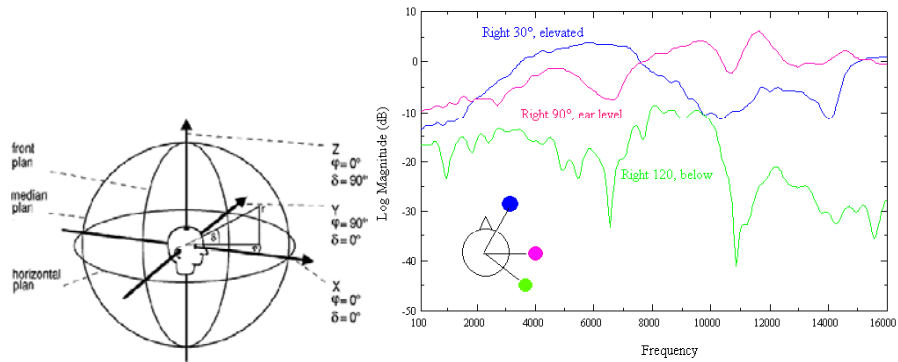
### **6.1 Ambiences phenomenon prediction**

The topic for ambience representation will be solved both with a realistic human placement in the 3-D town numerical model and with the use of pertinent perceptive descriptors. For this purpose, we will associate the acoustic shape/phenomenon relationship we have previously described, taking into account the structural organisation of the sound stimuli that built the perceptual representation of sonic ambiances.

Furthermore, our interests for ambience characterisation is motive for the importance of sound in architectural and urban spaces, denounced through the sonic pollution increasing. This fact has made up the capital rule of acoustic parameters for our environment, so that architects are more and more interested in sound propagation phenomena in built spaces.

#### **6.1.1 Ecological validity**

From a physiological acceptance, human ear localisation capability is optimal in horizontal plane, depending on two major physical factors: phase and intensity. If phase synchronisation permits a good localisation process for frequencies <1.5 kHz, due to significant inter-aural time difference (approximately 700 microseconds), inter-aural intensity difference is the only way to localise frequencies up to 3 kHz. Moreover, as seen figure 7, frequency localisation accuracy depends on the relative situation of the incident source (Botte *et al.*, 1989).



**Figure 7.** *Physiological localisation indices (Botte & al., 1989)*

Experimental restitution has to be *ecologically valid*. In other words, acoustical ambience reproduction has to provide a real functioning referential illusion. In physics, acoustic phenomenon is parameterised through emission, propagation and reception modalities. Consequently, stimuli used in this restitution should enforce the initial conditions of the real reference situation, in terms of sound source physical characterisation, spatial propagation laws and reception conditions. Those “ecological conditions” would be modelled on the background studies concerning relationships between acoustical characterisation and aural perception (Hoc, 2001).

Correspondence between physiological organisation and electro-acoustical restitution conditions enable an ecologically valid immersion system aimed to test real ambiances *in labo*, without contextual pollution, in order to obtain the twin data types necessary to join physical properties and perceptual effectiveness through ambiances characterisation as follow:

- sensitive data provided trough subjective answering to sound stimuli,
- physico-spatial attributes obtained through signal analysis.

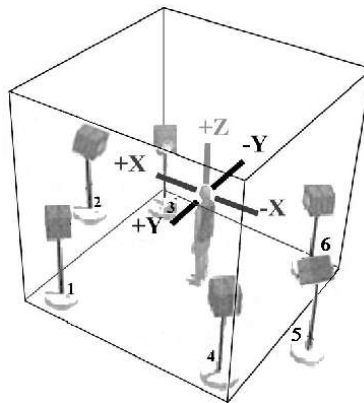
Correlation between these data-types will provide the psychophysical descriptors.

### 6.1.2 *Judgement criterion formalization*

Comparison between space physical characterisation and sensitive exploration leads us to define psychophysical parameters for soundscape prototypic categorisation, entered on semantic rendering of the subject’s brainwork. In this way, symbolical information treatment involves the subject into the interactional

emergence construction process. This cognitive approach means that ambience complexation is no more reduced to environmental information treatment, but constituted with preliminary representations organising the perception action. Moreover, the soundscape exploration process, combining physical properties and perception actions, will enable the “space producer” (architect, urban planner...) to translate the “space-users” needs and representations of the involved environment into its physical properties to be implemented through engineering solutions.

In the aim of environmental prediction, the use of virtual reality immersion techniques enables the identification of pertinent indicators used for urban ambience subjective evaluation. Immersion conditions for ambience restitution has to proceed with a rigorous protocol, involving precise subject placement and total sound geometrical control. For acoustic virtual rendering, space impressions such as *localisation* have to be ecologically valid. In that aim, figure 8 shows part of the immersion protocol, exploiting an 6-channel sound reproduction Ambisonic® system, lying under controlled acoustic restitution conditions through variable reverberation time of the immersion space.



**Figure 8.** *Audio-spatialisation with Ambisonic® diffusion system.*

## 6.2 Acoustic immersion experiment in an architectural space : Sound dynamical spatialisation

### 6.2.1 Experimental description

Physiological localisation properties of voice have been tested through the participation of a professional actor, declaiming poetry (“*lettre à Mr. Capucin*” from Rainer Maria Rilke) during two successive walks in a building hall, as described on figure 9. Then, the walkthrough spatial signatures have both been described through acoustical spatial measurements (tridimensional sound level pressure “3-D Leq”) and subjective graphical evaluation (sketch of the actor’s displacement made under hearing by immersion).

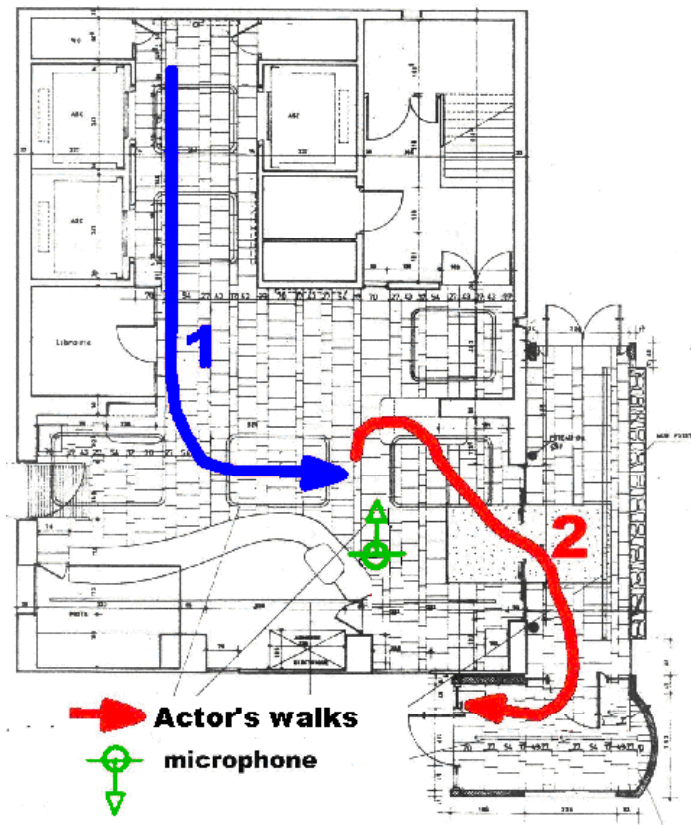
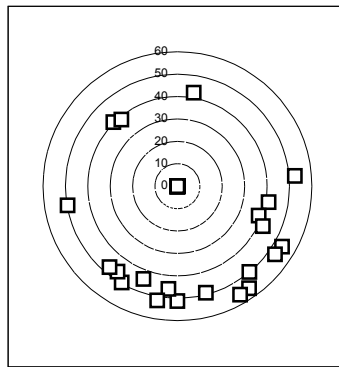


Figure 9. Actor’s walkthrough in the hall and microphone placement

6.2.2 *Quantitative and qualitative characterization*

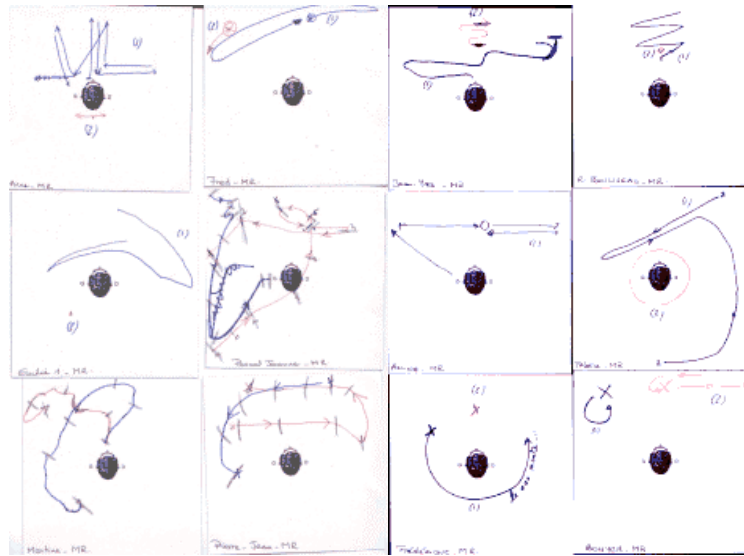
Acoustical spatial measurements of the actor’s walk are using a new tridimensional sound level pressure measurement technique called “3-D Leq”. This technique use the “Ambisonics®” recording system, providing sound spatial visualisation through sound level pressure “Bubbles” cartography in the horizontal hearing plan at every moment of the walks. In our experiment, the “instant” involved corresponds to a 186 ms Level equivalent (“Leq”) share time. Each actor’s displacement has been divided into six segments, so that we can analyse a time segment of twenty “instants” of the two walks, for an approximately 4 sec duration, as represented on figure 10.

The results provides the sound pressure dynamical behaviour into the 2-D space during the actor’s displacements in the hall.



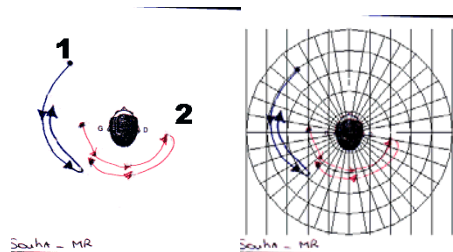
**Figure 10.** Sound level pressure “Bubbles” in the horizontal hearing plan for a 4-sec duration sequence

The same dynamical sound recording has been diffused in the immersion equipment, and the subject was asked to reproduce the spatial dynamic of the two successive walks in a graphical way, through line-drawings into a square representing the immersion space. The obtained drawings figure 11 underscore the difficulty to correlate spatial sensation with the real displacement of the actor’s voice. Moreover, the gap between the sketches seems to indicate a misadjustment between reality and cognitive representation of the walk dynamical spatialisation.



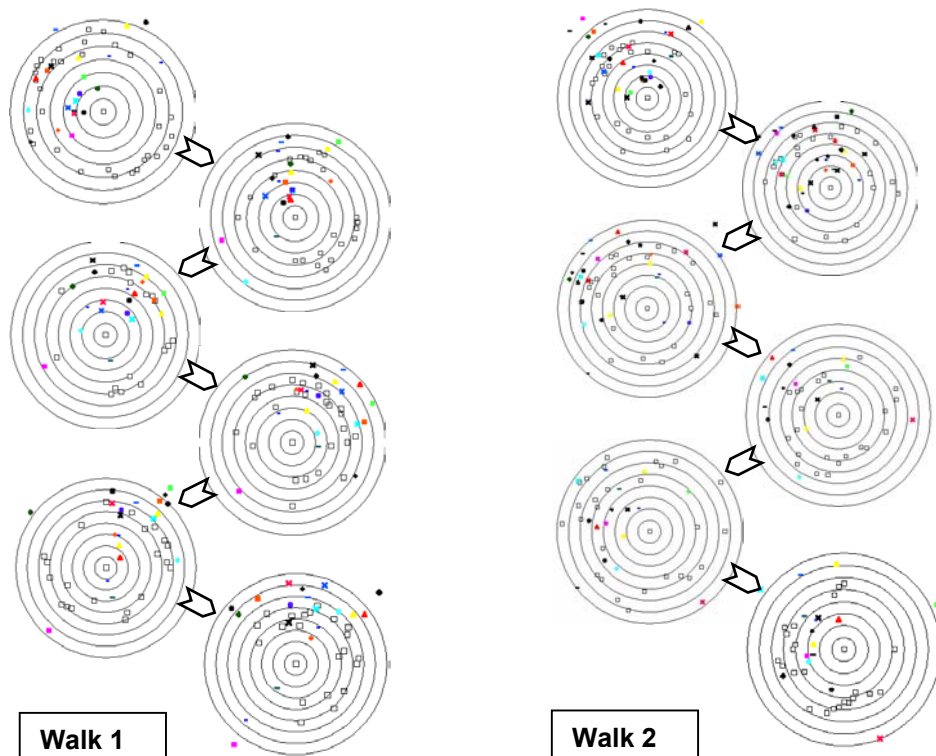
**Figure 11.** *Different perceived localisation into immersion conditions*

In order to compare the perceived localisation with the sound pressure dynamical behaviour, we operate a partition of the graphic representation of the dynamical spatialisation of the walk, through the hypothesis of equivalence between sketch segment length and walk duration. In that aim, we divide the actor's displacements sketch into the same twelve segments used for quantitative approach, so that we can analyse equivalent 4-sec duration sequences. Spatial representation of the sequence involves an angle-distance vector coding centred on the subject spatial situation in the centre of the immersion square, as shown figure 12:



**Figure 12.** *Angle-distance vector coding of the displacement sketch*

Scatter plots represents spatial positions judgements and measures at every moment of the actor's walks. With representing each 4-sec duration sequence in the horizontal hearing plan, the scatter plots animation underlines the good correlation between sound level pressure "Bubbles" dynamical behaviour and discreet displacement sketch. This behaviour is illustrated figure 13:



**Figure 12.** Comparative results between sound pressure bubbles (white squares) and displacement sketch points (mixed dots)

### 6.2.3 Sound dynamics emergent structures of perception

The "self-organised" characterisation of the perception process is revealed through the subject graphical sketch partition. This dynamical behaviour confirms the principle of approximation continuity (Carey, 1995): the process denounces this

perceptive experiment as a complex action, readable through successive instant localisation attempt, which global description formalises an unreal schematisation through the drawing action. This supervenience principle (Davidson, 1970), stating that mental properties and facts supervene on physical properties and facts, underlines the microstructure of sound information. This non-reductive determination principle states on inductive inference between psychological and physical description of the same phenomenon. In our case, the resulting interlevel theory, psychophysics, may infer that psychic behaviour of the subject is both determined by the physical properties of his environment and the relationships between their constituents, leading to a global set called “ambiences”.

This ontological dependence states psychophysical laws on general principles of rationality, as mental and physical properties can define an event if and only if mental change in an object’s properties-the supervening properties-entails *and* is the consequence of a change in its physical properties. Each step of a psychophysical experiment is empirically supported both by observations of relevant correlation and by the empirical adequacy of psychophysics principles, which unifies the two levels of the observed phenomenon, psychology and physics. Following this principle, sonic shape recognition proceeds to a connectionist approach, treating information as a discontinued process, successively slicing the perceived objects, in order to reference them in an allocentric way during the perception action.

#### 6.2.4 *Towards psychophysical indicators of acoustical quality*

Finally, one can conclude on the behaviour aggregation principle, as the global behaviour model, in our case spatial dynamical sound description, is totally independent from individual behaviours. In other words, the object of this research does not concern here the perceived shape of sound, but the approach of “psychophysical super-shapes”, that is cognitive modelling of behavioural aggregation. In the aggregate, perceptive complexions of a soundscape is denoted through the generic qualitative word *Phonicity*, representing the homeomorphism between the perceived sound object and its evocation. This word describes both the quality of the identification of all the soundscape’s components by listening (through properties as localisation, presence, intelligibility...), and the capacity for the listener to find there a sense, that is to recognise a natural and relevant organisation of its constitutive elements for identification. In that aim, specific time/space descriptors, such as *localisation*, will help clearing the soundscape stimuli complexity, in order to proceed to its taxonomic description.

## 7 Conclusion

This method constitutes a step-over for simulation or measure data analysis obtained in the field of environmental studies. In this way, virtual reality allows



interaction characterising with use of interlevel indicators in the cross-fields of urban built environment, physical phenomenon and human perception *in virtuo*. Additionally, the use of virtual reality as a rendering tool offers an alternative to methods based on survey realised in real cities. With taking scaling and human factors into account, this method would be able to compare different urban and architectural frameworks, in order to identify their ambience characteristics. This leads to a new urban built typology related to the human perception parameters.

In this way, sonic effects indicators, but also ambient ones will be described through evaluation of the corresponding psychophysical “Ambience attributes”. Those attributes, such as localisation, presence, dispersion or intelligibility, should provide pertinent indices for building production, with coupling cognitive representation, based on the virtual reality scene judgement, to technical characterisation of a specified ambience. Thus, sensorial immersion of projected environments allows a real operational expertise according to urban inhabitant’s perception, with exploring their reactions to architectural or urban planning.

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