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UNDERSTANDING IMMERSIVE AUDIO: A HISTORICAL AND SOCIO-CULTURAL EXPLORATION OF AUDITORY DISPLAYS

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ABSTRACT

This paper examines the historical and socio-cultural underpinnings of immersive audio seen from the paradigms of Acoustic Ecology and Acoustic Communication. The paper offers the view that in order to understand the many implications of immersive sound, both from a design perspective and from a cultural studies perspective, we need to first examine its social and technological histories. The paper explores examples and concepts of immersive sound from the natural, electroacoustic, digital and interactive domains, and presents a case study of Ec(h)o - a real audio-augmented immersive museum installation.

1. INTRODUCTION

Interactive systems, especially ones that involve auditory displays, are becoming more and more integrated in today's public and private environments. Such systems range from simple computing and/or communication devices to complex gaming simulations and other still experimental physical interactive environments. In each case, sound design plays an important role in generating a sense of place, movement, and interaction, providing aesthetic affect, and giving a tangible cultural context for the activity at hand.

Yet such recent developments in auditory display (AD) systems and immersive audio have not occurred in isolation from other social, cultural and technological changes over the last century. Advancements in sound reproduction, electroacoustics and multimedia are only one part of a larger equation. Scientific developments in acoustics, psychoacoustics and sound engineering, together with a greater understanding of audition and perception, comprise another part. The ensuing socio-cultural changes in the patterns of listening, modes of perception, and interaction with our technologically-extended world, all comprise the foundation of the development, popularity and ubiquity of modern auditory displays. In turn, our ready acceptance of electroacoustic sound as a means of communication and a banal necessity of life, contributes to an increased blurring of boundaries between public and private, reality and virtual simulation. These interlinked processes not only affect the practice of AD design, but need to be considered within its very framework and context, as they embody its implicit history.

This paper aims to briefly survey major events in the emergence and acceptance of electroacoustic sound in the 20th century, and to comment on the socio-cultural processes surrounding these changes. Specifically, I will look at the emergence of background music and media as a ubiquitous social environment, new architectural acoustics and disembodied sound, the emergence of digital technology, immersive audio in cinema and games, and finally – sound design in complex interactive AD systems. These phenomena will be discussed within the framework of acoustic communication as a way of conceptualizing and understanding complex auditory display systems, and summary tables will be provided after each major section to emphasize and define core concepts. By understanding the history of embedded sound and surrogate sound environments, and employing a communication-based sound approach to conceptualize them, we will be better equipped to understand more recent phenomena, such as immersive audio. Here it must be noted that while sonification constitutes another important research area in the filed of designed environments and immersion, for the purposes of brevity, this paper does not address sonification directly. Instead, it discusses the more general concept of designed and immersive auditory display systems.

1. SOUND-AS-ENVIRONMENT

Before immersive audio, there is immersive sound. Before embedded auditory displays in surrogate environments, there are naturally embedded sounds in the acoustic environment. Our preoccupation with technology often allows us to forget or ignore the 'analogue' processes in nature that constitute the foundation of digital events and simulations. There are certain modes of listening that operate in a natural acoustic environment and provide us with information about our surroundings while we employ a complex set of skills to interpret these signals. There is no reason to think that these processes do not continue to operate in technologically-mediated AD environments [1]. Immersive audio models the way we hear, listen, perceive and respond to sounds in our natural sound environments. Yet immersive AD displays often rely on a less than comprehensive understanding of acoustics, communication and ecology of sound. The two models presented here attempt to build a more solid framework for understanding the acoustic environment and our relationship to sound in situated contexts. As such, these approaches are valuable tools in forming design practices and concepts associated with immersive audio.

1.1. Acoustic Ecology Model

A pioneer in the field of Acoustic Ecology, R. Murray Schafer first defined the notion of a *soundscape* to mean a holistic system of sound events constituting an acoustic environment and functioning in an ecologically balanced, sustainable way [2]. Born out of the threat of urban noise pollution, Schafer's ideas centre on conceptualizing an ecological balance in the acoustic frontier. Around his work in the World Soundscape Project, he develops the terms 'hi-fi' and 'lo-fi' to describe different states of aural stasis in the environment. A hi-fi soundscape, exemplified in Schafer's work by the natural environmental soundscape, is one where frequencies occupy their own "spectral niches" [3] and are heard distinctly, thus creating a high signal-to-noise ratio [4]. A lo-fi soundscape, on the other hand, often exemplified by modern urban city noise, is one where [amplified] sound, traffic and white noise, *mask* sound signals and obstruct clear aural communication, creating a low signal-to-noise ratio [4].

Schafer's answer to noise pollution and the unbalanced urban soundscape is a combination of aural education, sound awareness and a new public approach to the sound environment through soundscape composition [2]. His central thesis is that the acoustic environment could and should be heard as a musical composition and we must acknowledge our own responsibility for its composition [3]. This responsibility has both positive and negative embodiments – soundmaking and music, or noise and signal masking. As Schafer's colleague and acoustic communication theorist, Barry Truax points out that, "the necessity of the ecological concept springs from the context of loss, or at least from the present threat to survival. The question for us now is whether a new balance can be regained. Can we – with consciousness – be part of a new eco-system?" [5]. In light of soundscape design, we have to be informed by the past, and maintain an ecological balance of sound components. To start, we have to understand design as a system that "comprises the knowledge and the techniques that we understand and can put into practice," [5] and that it involves everyone as listeners and soundmakers, not just the designer/composer.

Based on his work for the World Soundscape Project, which began in the 1970s, Schafer developed several core terms to describe soundscape components. *Keynotes* are ambient, background sounds that are present a large portion of the time in a space; *sound signals* are foreground sound events that transmit information about the environment, and *soundmarks*, similarly to landmarks, are unique sounds typical for local community soundscapes and often characterize them [4]. Yet these terms are not set categories, but characteristics of sound, as each individual listener's perception will determine the class to which the sound belongs.

Another important idea that Schafer develops in his 1993 book *Voices of Tyranny, Temples of Silence,* is the concept of 'acoustic space'. His conceptualization has many implications for soundscape design and auditory perception studies, because it emphasizes the multi-directionality of the sound field and the complex, almost unpredictable nature of sound behaviour. *Acoustic space* consists of many sounds and is coloured by all physical properties of the environment, including the listener, thus creating a unique atmosphere of sound and place [6]. Along with acoustic coloration - the audible properties of sound produced by their interaction with the physical environment - these soundscape components characterize an acoustic community [3].

1.1. Acoustic Communication Model

Following Schafer's work, Barry Truax developed a multi-disciplinary framework for understanding sound based in notions of acoustic ecology. This framework – acoustic communication – moves away from the energy-transfer view of sound, where the focus is on the mechanical transmission and reception of sound vibrations. Instead, it models sound, listener and environment in a holistic interconnected system, where sound mediates a two-way relationship between listener and environment [4]. This new understanding of sound allows us to bring considerations of culture and political economy into the soundscape paradigm alongside auditory perception and cognition. Drawing on cultural and sociological histories of sound, as well as major communication theorists, Truax creates a rich perspective of the role of sound before and after the emergence of electroacoustics, and of shifts in listening patterns. Using the acoustic communication model, the soundscape can be seen as a multi-faceted framework of reference representing the many relationships that sound mediates between environment, society, listeners, culture, public and private domains, class, status and politics.

The acoustic communication model also extends to a new understanding of psychoacoustics, listening and perception. Traditional models of auditory perception conceptualize listening as a process of neural transmission of incoming vibrations to the brain [7]. In fact, as pointed out by Truax [5] and others, listening is a complex activity involving multi-levelled conscious attention and higher cognitive functions, including memory, template matching, foregrounding (attentive listening) and backgrounding (holistic listening based in Gestalt pattern recognition).

Two major groups of listening are 'everyday listening' - [8], [9], [10], [1] – omni-directional, semi-distracted, adaptive-interactive listening that focuses on immediate information-processing of sound, and 'analytic listening' [4] – attention to detail, 'expert' activity focussed on an aesthetic or analytical experience. Based on these patterns, Truax has developed a number of terms exemplifying major listening modes and processes. *Listening-in-search* involves a determined seeking of a particular sound template in an aurally busy environment. *Listening-in-readiness* involves background listening with an underlying expectation for a particular sound or set of sound signals (such as a baby cry) [4]. The 'cocktail party effect,' conceptualized by many AD designers, is a special mode of listening-in-search, which involves a 'zooming in' on a particular sound source – often semantic-based (speech) - in an environment of competing sound information with the same spectrum.

Key Concepts from the Acoustic Ecology and Acoustic Communication models:	
Hi-fi	A high-information environment with a high signal-to-noise ratio
Lo-fi	An environment with a high degree of masking and low signal-to-noise ratio
Keynote	An ambient sound, present in an acoustic community most of the time and cognitively backgrounded by listeners
Sound signal	Foreground sound events, providing information
Soundmark	Unique sounds, characterizing a community

Soundscape Composition	The process of recreating a soundscape using electroacoustic techniques of sound manipulation
Everyday Listening	Omni-directional, semi-distracted, adaptive-interactive listening that we engage in on a daily basis with the goal of immediate information processing
Analytical Listening	Attentive, foreground listening, usually to the finer details of sound
Cocktail-party effect	An aural 'zooming in' in a busy acoustic environment
Masking	The result in perceptual loss due to white, traffic, or other broadband noise prominently present in the environment
Acoustic Space	A sound field of propagation and interaction between sound and environment

1. MUSIC-AS-ENVIRONMENT

Every historical shift in the sonic environment helps contextualize and determine the directions in which subsequent acoustic environments are heading. In this section, I discuss the critical transition from sound-as-environment to music-as-environment, where music, especially background music, becomes the 'normal' ambient environment, and new listening patterns emerge.

1.1. Listening Before Electroacoustic Reproduction

Walter Ong's extensive work on orality and communication points to many of the characteristics of listening prior to print literacy and the recording and stockpiling of speech/sound [11]. The ephemeral quality of sound - the fact that nothing could be repeated or reproduced in the exact same way again - contributed to an active, feedback-oriented 'everyday listening' [4], where sounds mediate the communication between people and the environment that surrounds them. Albert Bregman, James Ballas and other theorists of sound, have focussed precisely on this 'everyday listening' of environmental sounds, and their work points to an understanding of auditory perception in terms of *sound events*, emphasizing the functional ecology of this interaction [12]. This balance is reinforced by another important condition of the period before electricity and amplification – that sounds can only be as 'loud' as it is physically possible for the sound source to transmit energy, so problems of masking and obstructed communication are minimized [4].

In terms of musical expression and soundmaking prior to electroacoustics, Jacques Attali gives us his account of the different relationships that music mediates between people and society before and after the mass reproduction of sound. In the stage of 'sacrifice,' music is simply a means of "channelling society's violence" [13]. In other words, music reaffirms order and counteracts chaos, exemplified by noise. In this regard, music, much like sound in the acoustic communication model, is a mediator of social relationships in the context of the environment and community. In the period of 'representation,' starting in the 17th century in Europe, music begins to embody more than just sounds. It becomes a symbol of power, status, cultural expression [13]. It starts exhibiting use/exchange value as an object, and with the emergence of virtuosity, concerts and opera for a paying audience, it becomes situated in make-believe surrogate environments [14]. In the era of individualized representation, as Attali argues, "music can no longer affirm that society is possible. It repeats the memory of another society" [13]. This new status of music as an object, and not an everyday activity, helps shape a new type of listening – a more attentive, analytical listening, focussed on the individual elements of sound, rather than on a holistic perception.

1.1. Listening in the Electroacoustic Era

Attali's theory of mass music, based on Adorno and Horkheimer's texts on mass culture, proclaims the destruction of cultural meaning. "The absence of meaning is the necessary condition for the legitimacy of a technocracy's power," he announces grimly [13], describing the era of "repetition," the stockpiling of music and the emergence of copyright - music as intellectual property. In addition, the era of mass music turns the idea of silence into a "death in the heart of life" [13]. Schafer [2] also comments on the vilification of silence in the contemporary soundscape as a 'dead space' and a negative force in society. Repetition symbolizes uniformity, compliance and 'programmed events', as Ursula Franklin [16] argues in "Silence and the Notion of the Commons". She describes the disappearance of silence as an "enabling environment" and its replacement by "the silencing that comes when there is the megaphone, the boombox, the PA[1] system" [16].

Mass reproduction of music exists long before electroacoustics with opera and instrumental concerts [14]; however, electroacoustic technology makes possible the exact replication of any sound and its independent recollection thereafter. This *schizophonic sound* [2] is disembodied from its source, context and time of occurrence, and becomes an abstract 'aural object' of representation [17]. Sound comes to symbolize power, control, use and exchange value, and private ownership [13]. Electroacoustics also puts sound under unprecedented scrutiny as well as aesthetic appreciation, fostering *analytical listening* [4]. Alongside the move towards clean, non-reverberant sound in architectural acoustics [15], electroacoustic technologies, especially digital sound, further remove any perceptual reference to *space* by eliminating acoustic coloration. The transition facilitates the easy transfer of sound/music *objects* into a variety of different surrogate environments – restaurants, concert halls, stadiums, malls, schools, etc. This fluidity in turn results in the acceptance of music-as-environment in both the private and public spheres of life, and leads to the blurring of the lines between the two. Background music, defined by Satie as music "like furniture," [18] not only becomes part of the environment, but *is* the environment. It builds invisible surrogate relationships between people sparing them from obligatory interaction and "filling up heavy silences between friends" [18].

Similar to the Telharmonium of 1906, which provides 'atmosphere music' in restaurants using the telephone line [19], the Muzak Corporation was created in 1922 to first provide music over the telephone [13], and later to 'program' music in various public spaces by use of market research patterns. Muzak is perhaps the first materialization of complex soundscape design. Hildegard Westerkamp's research in background music solidifies the views put forward by Attali and others – that music in the era of schizophonic mass reproduction becomes a "soundtrack for

[1] Public Announcement

consumerism" [20]. Sound "becomes associated in our memories with environments and products. In essence it becomes the 'ambiance' of the media environment" [5]. However, the new fluidity and flexibility of sound freed of its source does not result in endless diversity of spaces and sounds, but in the emergence of archetypal surrogate environments. These most often commercial spaces come with pre-packaged sound quality – compressed, narrowband dynamic range and dry digital sound, as well as content standards – slow light rock for the department store aisles and fast pop at the restaurants. These emerging sound environments foster "passive listening" [20] and superficial disengagement from the social environment. As Westerkamp argues, the phenomenon of background music also results in the inevitable silencing of spontaneous human soundmaking, and with it our active interaction with place and time [20].

Key concepts from the Music-As-Environment framework:	
Music as an object of representation	Music has use and exchange value, and it symbolizes power, status, etc.
Background music	Ambient music programming such as Muzak, radio, TV flow, etc.
Schizophonic sound	Electroacoustic sound that is separated from its source and played at another space/time
Passive listening	Inattentive, background listening, lack of active interaction with sound
Surrogate environment	A re-created environment, into which a chosen sound or an auditory display system is inserted

1. MEDIA-AS-ENVIRONMENT

Archetypal sonic spaces such as concert halls, malls, and restaurants, initially defined as public environments, gradually move into people's private lives with the emergence of the phonograph, the telephone, and especially the radio. The private space becomes another sound-programmed surrogate environment, usually designed for passive, background listening. This shift is not unrelated to the trend of development of mass media and mass production/consumption. In a society where urban alienation and post-industrial capitalism shatter traditional forms of community and social interaction, media becomes a surrogate social milieu for the 'masses,' and binds people together in imaginary relationships. Radio is a particularly important cornerstone in mass media development and plants the roots of contemporary media language, such as temporal flow, structural density, foregrounding-backgrounding cues, advertising language, audience as product and media's overall relation to consumerism. When wireless radio technology first emerged it was praised as a web of interconnection, universal communication and utopian democracy – "house of our dreams" as named by Gaston Bachelard [21].

Mendelsohn's work focuses specifically on the characteristics of radio programming, conceptualising the cultural changes ensuing from its introduction in the private and public social worlds. Radio literally 'educates the consumer' and creates a new language of media consumption, aural sensitivity, listening and cognition. One of the major functions that radio fulfils is "bracketing the day" through program flow – that is, providing structure to daily activities by setting predictable patterns – news at noon, followed by music, announcer, advertising, then more news, etc [22]. In addition, as with background music in malls and restaurants, radio 'sets the mood' for the day and "lubricates" social relations [22] in alienated urban settings. As such, radio functions as a shared aural environment and implied shared physical and mental space. Similar to background music, radio settles as a predictable 'accompaniment media' to daily life, first confined to the home, and soon invading the streets and offices [23]. This transgression of public-private boundaries leads way to portable, personalized sound accompaniment in the age of the 'Sony Walkman,' as characterized by cultural theorist Paul du Gay [24]. Accompaniment media becomes a standard sonic companion, and listening habits adjust accordingly, as we become the perceived composers of our public and private electroacoustic experience.

Combined with structured programming, radio changes the listening experience from background listening to *media listening*. An important aspect of *media listening*, also characteristic of TV flow as an extension of radio flow, is the pattern of amplitude flow. That is, the majority of normal programming is broadcast in narrow bandwidth at relatively constant amplitude, designed to blend with the background of daily activities, while advertising and other special elements are broadcast with a broader spectrum and greater dynamic range, demanding foreground attention from the listener [4].

In effect, media sound does not merely foster a dependent kind of listening, but it tells us *how* to listen. It trains us to increase or decrease our auditory attention by use of carefully crafted cues, until they become second nature. These gestalts of auditory perception then seamlessly integrate in cinema sound, carrying the promise of total immersion, suspension of disbelief, and realistic experience design. Ultimately, as our environment changes and we become more saturated in media flow we start to experience sonic phenomena such as radio, TV, portable audio and Muzak as environmental sound. This dramatically changes our relationship with the acoustic environment, as electroacoustic and acoustic sounds become intertwined and blend into each other, rendering the modes of listening that we use for these two sound milieus interchangeable. As a result, we begin relying less on active, engaged, information-processing listening, and more on habitual background and media listening in all of our surroundings. It is perhaps the emergence of interactive sound design that finally shifts the attention back to a more holistic perception of sound and active engagement with it, relying on a more locative, communicational 'everyday listening' mode.

Key Concepts from the Media-As-Environment framework:	
Structured Flow	Media programming creating a predictable pattern of sound/information for commercial benefit
Media listening	A new perceptual language of distracted listening and media perception

1. DESIGN-AS-ENVIRONMENT

As discussed above, background music is the earliest fully designed and controlled surrogate sonic environment, which, through interaction with other phenomena in sound technologies and media, continues to shape the contemporary listening experience. Other modern examples of immersive audio are film sound, video game sound and interactive auditory display installations. These interactive systems can be either virtual – where sound is entirely engineered and usually delivered via personal headphones to the exclusion of other acoustic sounds; or physical – realized through computer programming but embedded in a shared physical and cultural space. These alternate sound environments are made possible by advances in digital audio, virtual reality, the Internet and computer programming.

1.1. Sound in Cinema

In its basic definition, an immersive sound space is a carefully and intuitively designed surrogate environment that creates a more full-bodied experience involving the senses to a fuller capacity than traditional media. Sound in cinema is an important cornerstone in soundscape deisgn because it simultaneously builds and draws on media and background sound, as well as influences and feeds into more sophisticated virtual and multimedia environments. Using Barry Truax's acoustic communication model for sound design, an immersive environment contains three major elements: speech, music and soundscape [4]. In cinema, these break down to vocal material, composed musical score and sound effects grid, including spatialization and/or interactive-adaptive programming. Hearing these sounds in a darkened auditorium and in combination with larger-than-life visuals promotes the experience of immersion. However, it is important to note that the idea of immersion as virtual or "augmented" reality is not only an extension of earlier electroacoustic technologies but also capitalizes on media listening and decoding. As Truax comments, "once background listening becomes a habit, it is ready for exploitation by the media" [4]. The cinema soundscape is reduced to "easily recognizable sound objects" [21] and even though realism is increased through sound, "this realism is not born of the 'real' [but is] constructed through other media" [21] - radio and television. Sound, is thus hyper-real rather than real. This view is also echoed by Christian Metz in his *Aural Objects* essay, where he describes film sound as being based in sound *objects* – individual representations of real life sounds, and signifiers in a larger conceptual media language [17].

1.1. Listening and Virtual Audio

Virtual Reality (VR) is a special type of surrogate environment based in digital audio, 3-D animation, rich graphics and audio coding. In VR spaces, sound is a virtual 'aural object' of representation, carefully designed to elicit recognition, action and response, or create an emotional-psychological mood. As such, virtual audio builds on the patterns of listening and recognition created by previously existing media and aural phenomena, yet it also results in new sensitivities and cognitive modes of interaction. Following from McLuhan's conceptualization of the electronic world as oral [6], virtual audio creates a new kind of aurality in technological environments. Using this virtual "aural medium," one can "enter a space of no space" and be immersed in a compelling, increasingly tangible experience [21].

There are two predecessors to virtual audio that shape and influence its authenticity and perceptual-listening framework. One is the microphone, which, similar to radio, provides surrogate intimacy and "a spiritual and atmospheric nearness of broadcaster and listener" [21]. The microphone eradicates implied physical distance in the demolition of metaphorical distance between real and representation. Another predecessor of virtual reality is the headphone technology. The possibility of bringing the outer world into the inner world and creating a personalized surrogate sound environment has many cultural critics fascinated. In his book *Doing Cultural Studies*, Paul du Gay looks specifically at the phenomenon of the Walkman and terms the experience of listening to portable audio a "soundtrack to life" [24]. Headphones literally immerse us in a designed soundtrack of imaginary space, and mediate relationships between the listener and that space, establishing a new VR phenomenology.

Audio technology creates a "sound field" designed to sound as if it occurred naturally in the environment, however, the very existence of digital media has implications for the role of virtual audio. Sound is divorced completely from a physical source, and is controlled entirely by code. It is technically abstracted – sound attributes, distances and behaviours are de-constructed, mapped and coded, and then reconstructed to fit a virtual space. This way, algorithms represent sound and sound behaviour, rather than expressing its physical characteristics, similar to Attali's argument that musical code is a "language without meaning" [13]. Ultimately, the abstract nature of virtual audio and the limitations and opportunities brought by the technology of headphones and program code create a "new space of perception and embodiment" [21].

1.1. Immersive, Interactive and Adaptive Audio

In traditional AD design, concerned with alerts and notifications, there are important considerations about the environment or context in which sounds are heard and perceived. Aside from issues of auditory perception and streaming, there are challenges with masking in busy sound environments. With physical interaction systems, specifically responsive environments, where almost every parameter of the experience is technology-driven, mediated and controlled, the AD system *is* the environment. Not only is the sound, and hence – the experience – designed in minute detail, but users most often experience the space via headphones, further minimizing acoustic sounds and colorations.

With the development of 3-D audio the restrictions of stereophony are finally transgressed. Binaural recording and precise ITD (Interaural Time Delay), ILD (Interaural Level Difference) and HTRF (Head-Related Transfer Function) digital filters take headphone-based virtual audio to a new perceptual level. By applying multidimensional streaming techniques, sound can effectively be reproduced anywhere in virtual space simulating a tangible sound source [25]. In addition, multi-channel speaker systems, commercially known as 'surround sound,' provide a shared immersion experience, where, ideally, each speaker functions as a sound source on its own. In effect, AD design has finally shifted back to a more 'acoustic' model of aurality, sound distribution and perception. As McLuhan argues, quoted by Schafer, "the electric world" is aural, and it moves us back to an acoustic space of preliterate cultures [6]. In this type of approach, sound has a strong connection to the environment

and mediates a relationship between the listener and space, reinforcing acoustic communication.

Interactive sound design, thus, attempts to use our senses in a more physical, *embodied* act of listening, engagement and interaction. It extends the existing soundscape within the surrogate sound environment by drawing attention to itself, rather than passively 'filling up' a space to create a mood for consumption. It does so by asking us to relate to, orient ourselves through sound, locate other objects within a space and give and receive feedback about actions and events. Interactive audio also provides variety and coloration by creating adaptive algorithms for sound behaviour and allowing active modulation and interaction with its listeners.

Key Concepts from the Design-As-Environment framework:	
Immersive Space	An environment that simulates real-life multi-modal interaction with space. Audio immersion simulates a natural sound field
Aural objects	Sounds that symbolize real sources or events, and have meaning outside of their actual characteristics and application
Virtual Audio	Sound designed to simulate reality using sampled or digitally produced sound, and presented in stereophonic or multichannel format
Augmented Reality	A term used in physical interactive installations, describing added technological aspects to the space

1.1. Ec(h)o: A Case Study

As an example of 'ubiquitous computing' and interactive-adaptive algorithm coding, Ec(h)o is multi-modal sound installation for the *Museum of Nature* in Ottawa, Canada. It is "an audio augmented reality interface utilizing spatialized soundscapes and a semantic Web approach to information" [26]. In this sound-enhanced exhibit the visitor navigates through several layers of audio – ambient soundscapes, location-based soundmarks, hierarchical audio icons for selection and audio narratives relating to the artifacts at hand. This interactive museum installation is an example of design-as-environment providing a multi-modal shared surrogate environment in a physical space. Individual motion-tracked headphones deliver the immersive sound experience, and the interaction takes place via an ergonomic colour-coded cube, connected to visual recognition software [26]. The soundscape elements are modelled upon the acoustic ecology and acoustic communication models, where sound, environment and listener create a 'feedback loop' of interaction [4] (see Figure 1 for a floor plan schematic – small circles represent *soundmarks* and big circles represent *keynotes*). The acoustic functionality of this system is defined by sound behaviour that is "adapted to its environment and understands beauty as a value expressed through people's attitudes [4]. As shown in the diagram below, there are several thematic soundscapes, localized in a radius around a relevant exhibit and broadcasted over FM frequencies. These soundscapes are modulated in real time by the visitor's movements, fading in and out of each other. In addition, soundmarks, chosen specifically to reflect important aspects of a given set of artifacts are incorporated into the soundscapes. Another element to the audio experience is a number of recorded narratives, that can be recalled via three aural 'prefaces' appearing in the left, centre and right speakers of the headphones, utilizing sound localization techniques. All of these elements: speech, soundmarks and keynotes interact with each other creating an 'acoustic space' that characterises the present community.

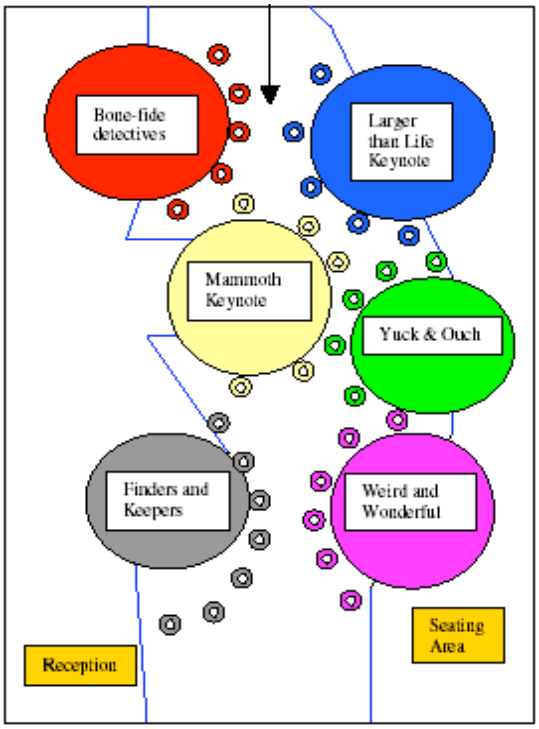

Figure 1. *Ec(h)o floor plan of the Museum of Nature in Ottawa*

While this auditory display installation does not take ownership of solving all the complex problems in soundscape design put forward in this paper, it does nevertheless, provide an example of a design, which makes use of both *everyday listening* modes for communicational, information-processing purposes, and *background listening* modes for creating a sense of place, cultural context and atmosphere of meaning.

6. CONCLUSIONS

Immersion creates a new mode of perception and embodiment incorporating a history of listening and cultural memory. AD systems have come a long way from pure tone beeps and alarms to complex hierarchical audio menus, rich immersive cinema and video game sound, and interactive and adaptive audio in 'total immersion' installations. Along the way many listening patterns have influenced sound design, including a variety of 'everyday listening' patterns, as well as 'background' or 'distracted' listening in the electroacoustic era, and 'media listening' in the age of structured flow and mass reproduction. The conceptualisation of sound design has also changed significantly from seeing sound as an *object* of representation to focussing on sound *events* by grounding them in a source and generating a more variable, un-correlated sound field. Ultimately, contemporary interactive-immersive audio systems make a return to more holistic notions of sound perception, acoustic community and space. In an ecological, communication-based system, sound is

well adapted to its environment and not only communicates useful information and a richer multi-modal experience, but it mediates the very relationship between listener and that interactive environment. In addition, immersive sound design as *composition* is a way of taking control of the soundscape and counteracting the distracted listening that the media world promotes. Through electroacoustics, we can deconstruct the elements of a sound environment, re-construct and re-conceptualize them through sound design, and partake in soundmaking rather than sound consumption.

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