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The Resonating Spaces of First-Person Shooter Games

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ABSTRACT
In previous work I have provided a conceptual framework for the design and analysis of sound in First-Person Shooter games and have suggested that the relationship between player and soundscape in such games may be modeled as an acoustic ecology. This paper develops these ideas further and uses them to describe and define a variety of sonic spaces within the First-Person Shooter and their relevance for player immersion in both the acoustic ecology and the wider gameworld.

Categories and Subject Descriptors
H.5.5 [**Information Interfaces and Presentation**]: Sound and Music Computing – *modeling, systems*.

General Terms
Design, Human Factors, Theory.

Keywords
Acoustic ecology, FPS games, Immersion, Spaces.

2. INTRODUCTION
The images of a First-Person Shooter (FPS) game help define spaces with which a player may engage and through which her character navigates. This paper explores how the spaces in which the gameplay takes place are related to a variety of spaces represented by the FPS game sounds and outlines the consequences of this for player immersion and its role in acoustic ecology of the FPS game.[1] Images in the game world are 2-dimensional and any 3-dimensionality they imply is purely illusory. Sound, though, can only exist in a 3-dimensional form and this, as argued here, is the reason why sound is of prime importance to the perception of spaces, both within the acoustic ecology and within the wider game world, and to player immersion in these spaces. An ecology comprises a set of spaces in which the components are contained or are active. I suggest that the FPS acoustic ecology may be understood as an acoustic space comprising a set of resonating spaces and paraspaces and this, I argue, is the reason why spatiality is an essential requirement for any discussion of player immersion in the FPS game. 'Paraspace' follows Parkes and Thrift's [14] terminology and so is a space that, within the acoustic ecology, describes and provides immersory and participatory affordances to do with location, time and cultural and social factors. These help to anchor the player in the perceptual reality of the FPS game world by providing the immersive cues that enable the player to become an integral part of the game's acoustic ecology, thereby affording the perception of that ecology and the components within it, and by inviting participation in the creation of that ecology.

Although Parkes and Thrift contrast paraspaces with universal spaces (which are dimensional or volumetric spaces that must be discussed alongside time), within the concept of the FPS game acoustic ecology, the word 'universal', where there is more than one of these types of spaces, is fraught with difficulty and confusion. Thus, I propose the term *resonating space* because it implies a number of properties and functions which relate to the idea of an *acoustic* space. Although it may imply other quantities, 'resonating' has a particular affinity to acoustics and, in this sense, it implies reverberation, localization and the notion of sound propagation from a source through air as the soundwaves expand in the volume of the containing or reflective spaces[2] represented in the images on screen. In other words, volume and time are two integrated and important components of this resonating space and thus this spatial concept is admirably suited to discuss sound. Furthermore, in its recognition of volume, the

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[1] In other work, I have argued that ecology is a preferred term to environment when describing the totality of FPS game sound because, among other reasons, ecology encompasses the notion of time, of player activity within the game and that the acoustic ecology will change over the duration of the gameplay [8].

[2] Although sound can certainly propagate through an 'open field' where there is no such containing space or reflective surfaces, such situations are extremely rare (so rare in nature that they may, in fact, not exist). Furthermore, due to technical constraints in the real-time production of graphical components during the gameplay, FPS games are often full of such virtual spaces and surfaces.

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resonating spaces of the FPS game acoustic ecology are a perceptual reification of the Cartesian coordinate system embedded in the game engine and, in its recognition of the temporal element, such a spatial concept recognizes not only the temporal dimension of sound but also the essential dynamic nature of the acoustic ecology — FPS spaces change.

Breinbjerg, uses the terms *architectural space*, *relational space* and *space as place* [1] when analyzing sound use in *Half-Life 2* [20]. The latter two terms relate to the concept of paraspace and it is in this sense that they are discussed here. However, architectural space, while it does imply the notions of volume, containment and, in the context of sound, reverberation, is a problematic term in the context of modeling an acoustic ecology. There is no implication of a temporal property and, furthermore, it is explicitly tied to architecture, to human industry, and therefore makes no allowance for the fact that such a space may also be found in natural ecologies (sound can resonate through valleys and reverberate off mountains). Although a minor point, it is important to take into consideration the range of non-architectural constructions that may be found in many FPS games and this, the more neutral term resonating space does. Breinbjerg, however, does state that architectural space is a quantitative phenomenon while relational space and space as place are qualitative phenomena and this important distinction may be applied to the spatial terminology I utilize. Thus, resonating space is a quantitative space whose dimensions may be measured[3] whereas paraspace is a qualitative phenomenon recognizing, in this case, player knowledge and socio-cultural experience when defining the qualities of such a space.

This paper, then, explores the import of sound to the perception of a number of spaces within the FPS game. This exploration helps to provide further answers as to how and why players might become immersed within and participate in the acoustic ecology and so aids their immersion within and participation in the gameworld. I begin with an outline of the localization and reverberation of sound in the FPS game, as these are the main tools for the game sound designer with which resonating spaces may be designed, before proceeding to discuss resonating space, acoustic paraspace and acoustic time.

3. LOCALIZATION AND REVERBERATION

The two qualities of sound that prove to be important in the perception of spaces defined by that sound are localization and reverberation.[4] The localizing properties of sound are evidence of the 3-dimensionality of sound and reverberation is an effect of the dimensions and disposition of objects in the space in which it sounds as well as the material properties of that space. This section, therefore, is a brief discussion of these two qualities as preparation for more focused debate on the spatializing properties of sound in the FPS game acoustic ecology.

One of the key factors that must be considered in relation to a conceptualization of participation in the FPS game acoustic ecology is the ability to identify the direction a sound is coming from and, thereby, to determine the location of the sound source. This ability, if the sound source is unseen (perhaps behind the player's character), is the basis for kinaesthetic interaction with sound objects within the game (the possibility to acousmatize or de-acousmatize sounds) which itself is one of the gateways to understanding participation in the acoustic ecology. Additionally, localization of sound presupposes that there is a 3-dimensional space in which sound sources are positioned and thus the ability to localize sound in the FPS game is strong evidence of at least one resonating space extant in the game.

Localization of sound, disregarding synchresis and related audio-visual proximity effects, is mainly dependent upon the auditory system. Where the eyes provide stereoscopic vision for the perception of depth, the ears provide binaural hearing for the perception of location. The study of sound localization cues and localization perception constitutes a large part of the literature of both classical acoustics, ecological acoustics and the design of auditory interfaces and virtual reality.[5] The ability to localize sound is deemed to be of great importance for virtual environments or any system attempting to synthesize and implement an acoustic space or to represent some non-audio spatial data set in the audio domain. Where sound is juxtaposed to image, synchresis, or the audio-visual proximity effect, can have an influence on the perceived location of sound. However, in the context of an article on audio-only games, Röber and Masuch suggest that the "most important quality to explore acoustic spaces is the ability to determine the origin of sounds and speech" [15] and I suggest that this is particularly import in the 'hunter and the hunted' context of FPS games. While this paper does not investigate audio-only games,[6] audiovisual FPS games generate resonating spaces that the player's character inhabits and in which the ability to localize both looping sounds and discrete sounds is of great importance.

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[3] Not necessarily exactly, but it is possible to say, for example, that the volume represented by a resonating space is large, small or larger than that one. Propagation times may, however, be quite accurately measured from source to listener.

[4] There are other qualities too. Amplitude, for example, and the frequency components of sound are an indication of depth and the material qualities of the physical space in which the sound sounds. For the purposes of this discussion though, these are subsumed under the qualities of localization and reverberation. Additionally, strictly speaking, localization is not a property of sound in the sense that it is a parameter of sound *per se*. Localization is something that affects the manner in which sound is sensed and perceived though, and it is for this reason that the more encompassing term *quality* is used.

[5] A larger treatment of the subject may be found in any good acoustics or psychoacoustics text book (such as Everest [5]; Howard & Angus [9]).

[6] Those interested in this may consult a range of articles and links at *Audiogames.net* (http://www.audiogames.net/)

There are several technical difficulties which limit the availability or effect of both localization and reverberant cues. The unknown factor of the player's use of stereo loudspeakers, surround sound systems or headphones presents problems for designing sound localization cues in FPS games. Nutating (of the head) will have some effect in both front and rear discrimination with surround sound speakers[7] but will only have a supererogatory effect for stereo speakers. Lateral localization will only occur on a small frontal plane when listening to stereo speakers and both speaker systems will exhibit similar difficulties in the provision of elevation localization cues while headphone usage negates the effect of nutation.[8] Given the almost infinite possibilities for the positional relationship between a player's in-game character and any one sound in the game, an infinite pre-reverberated number of variations of that one sound (such as a game character's footsteps in different locations, on different surfaces and at different speeds) cannot be added as part of the game data without presenting insurmountable problems of data storage. Modern FPS game engines (such as that used for *Half-Life 2*), surmount this problem by the use of ‘acoustic shading’ techniques in which material and spatial properties of the character’s locale are used to process audio samples in real-time.

Typically, environment sounds that are not kinaesthetically controllable by the player and various globally sounded game status messages are not localizable (nor, given their function, need they be). For some sounds, localization may be treated as their most important function while for others, their low frequency means they are inherently difficult to localize. As Schafer puts it, in the context of music: "Localization of the sound source is more difficult with low-frequency sounds, and music stressing such sound is […] more directionless in space. Instead of facing the sound source the listener seems immersed in it" [16]. In this case, the very fact that such a sound is difficult to localize contributes to the perception of being immersed within a womb-like acoustic space.

While localization guarantees that there is a resonating space in which the audio samples sound, it does not delineate the boundaries of that space. The relative intensities of different sounds or decreasing or increasing intensity of sound as the source object moves relative to the listener help to provide this. However, as a vital component in the perception of depth in the acoustic space, the reverberation of sound should not be ignored in this respect. Furthermore, reverberation helps to provide information about the game environment's material properties (cues to the game's paraspaces) and aids in immersion in the acoustic ecology by the process of externalization.

[7] Assuming the game engine fully supports the use of such a system.

[8] The development of head-tracking devices, as described by Murphy and Pitt [13], may well enable nutation to be coupled with headphone use if the tracking can also be mapped to sound localization cues as provided by the game engine.

Shinn-Cunningham, Lin and Streeter suggest that reverberation has a use in avoiding the internalizing effect of In-Head Localization (IHL) [17]. IHL is a subjective phenomenon where the sound heard over headphones is not externalized by the listener and appears to come from within the head. In part, this is due to the ineffectuality of nutating or otherwise changing the listener's physical position in relation to the sound sources. Wenzel suggests that IHL may be mitigated by the addition of environmental cues [21]. It is not clear what these 'environmental cues' may be but if, in addition to discrete sounds, we may surmise reverberation, then the proposition of Shinn-Cunningham, Lin and Streeter appears to support Wenzel's suggestion that sound is more likely to be externalized through the addition of such cues. Furthermore, placing the listener at the centre of a universe of externalized sound is a fundamental requirement for player immersion, a position strengthened by the notion that the FPS player is a first-person auditor. This immersion cannot happen if the acoustic ecology itself is perceived to be inside the player's head through the process of IHL. Despite Schafer's hyperbole that the headphone listener *is* the sphere, *is* the universe of sound [16], the player should not *be* the universe but should be the *centre* of that universe and, therefore, *within* a sphere of moving sonic elements. With the player as first-person auditor, this universe of game elements does, in technical terms, revolve around the player — it is the game engine that rearranges these elements, both visual and sonic, around the static position of the character so creating the illusion of movement in a 3-dimensional game world.

One final role that reverberation plays in the creation of both resonating spaces and paraspaces within the FPS game is in its affordance of the surrounding environment's material and spatial properties. Long reverberation times[9] are dictated, in the main, by two factors. One is the volume of the physical space in which the audio sample sounds and the other is the absorbent qualities of the materials off which sound may be reflected (reverberation is the sum of all sound reflections as opposed to the direct sound reaching the listener straight from the sound source). Hence the long reverberation time of cathedrals which are very large, enclosed volumes and which are usually made of reflective stone or plasterwork.[10] Thus, in the FPS game, a highly reverberant sound is typically used to indicate that the player's character is within a large, reflective space as opposed to being in an open sound field (such as outside). The length of reverberation is also indicative of the virtual material in the game world off which the sound is apparently reflecting. In this case, it is not just the length (in part indicating the absorbent properties of the material) but also the timbral quality of the reverberation — sounds reflecting off metal surfaces tend to be quite bright as opposed to sound reflecting off wooden surfaces for example. In this way, reverberation helps create the perception of paraspaces in the game such as specific types of locales and buildings as indicated by their materials.

[9] T_{60}, the time in seconds that it takes for the reverberation intensity level of a sound to decrease by 60dB.

[10] Anechoic chambers are typically small and comprise highly sound-absorbent materials.

Modern FPS games localize almost all diegetic sound by placing each sound in a particular position in the audio field (stereo or multichannel) with respect to a central point in the game world which, for each player, is the player's character's location in that world. In other words, sound revolves around the player as first-person auditor. The act of sonic localization creates the basics of a 3-dimensional acoustic ecology that (in addition to paraspaces which I discuss below) comprises at least two acoustic resonating spaces: the one that exists in reality and the virtual acoustic space that mirrors and expands in all directions the visual space seen on the screen. Reverberation aids in externalization, depth and distance perception and, because any reverberant part of sound is founded upon the characteristics of that sound, it also plays a part in the causality and indexicality of that sound because a sound may be characterized by its source object and source action [7]. As reverberation is dependent upon the physical characteristics of the surrounding environment, its materials and volume, it is also a significant factor in the perception of these materials and volumes. As Chagas states: "Reverberation becomes an instrument of the *deconstruction* and *re-construction* of space" [2] and thus it helps to conceptualize the variety of resonating spaces and paraspaces that are found in the FPS game acoustic ecology.

4. RESONATING SPACE

In the introduction to this paper, I defined the term resonating space as an acoustic space comprising a volume and time in order to distinguish such a space from acoustic paraspaces. This section expands upon that definition and uses it to discuss those acoustic spaces differentiated in the FPS game ecology which are defined in terms of volume and time and which, therefore, provide spaces in that ecology for players to be immersed within. I argue that there are at least two resonating spaces to be differentiated when modeling the FPS game acoustic ecology and that the player is physically immersed in that resonating space which is real (and which exists in the user environment) and that this real resonating space acts in conjunction with the graphical spaces depicted on the screen to create the perception of a virtual resonating space which is a sonic reification, or sonification, of the spatial elements of the game engine. Finally, I provide terminology with which to classify those sounds that contribute to the perception of the resonating spaces.

The FPS player's prosthetic limbs, extend away from her from reality into a visual space that, in graphical terms, is a representation on a 2-dimensional screen of a 3-dimensional space. In visual terms, the space into which the player thrusts her prostheses is completely illusory; it makes use of Western artistic perspectivist conventions, scaling, simulations of parallax (for depth) and light and shadow to simulate a 3-dimensional space such as those found in reality. The game engine aids in this simulation, for example, by mimicking some of the effects of gravity and other aspects of the game such as 'solid' surfaces or by the ability of characters to wander into doorways, around objects or up and down stairs. All of these aspects are merely simulations because their effects and actions cannot be sensed (bar some primitive feedback device which smears with a broad brush the nuances of the human tactile system) but only perceived as something that is happening to a screen character the player is asked to identify with.

Sound though is different. It is not a simulation of 3-dimensionality — it cannot be as sound must be heard in reality to be sound. In other words, sound cannot be sound unless it exists and is propagated in a 3-dimensional space and that space is within the space of reality not the space of the game world — it can only be heard when the data encoding the sound is freed from the 2-dimensionality of the game by being audificated. Whereas a representation of a street on the screen exists solely as a flat, 2-dimensional representation that is created from data stored within the computer (until the holodeck becomes an actuality), FPS game sound (indeed any game sound) must be audificated into an audible analogue of the audio data stored within the computer. Sound, therefore, possesses spatializing affordances which are quite distinct to those of image and these, I suggest, better fit sound for the purposes of conveying the spatial characteristics of the FPS game world to the player than the use of image. Because sound is 3-dimensional (indeed the only truly 3-dimensional component of the FPS game), I suggest that FPS game sound is the physical gate through which the player enters the virtual world of the game.

The creation of the resonating spaces found in the game makes use of localization cues, reverberation cues indicating room size, depth cues (such as direct sound to reverberant sound ratios) and other cues such as doppler shift indicating speed and direction of travel of the sound source (indicating, in other words, that there is a volume for sound source objects to move about in). As with the direct sound produced without spatial processing from the FPS game's audio samples, these spatial cues can only be heard as a propagation of a soundwave through 3-dimensional space. The conclusion therefore, is that whereas the visual aspects of a FPS game are a 2-dimensional simulation of a 3-dimensional space, the sound elements are a (re)creation in 3-dimensional space of another 3-dimensional space. To a certain extent, this (re)creation is only partially successful because of the separation of sound from the apparent cause as seen on the screen (especially when headphones are not used). Sound that appears to be coming from the objects on screen actually comes from loudspeakers and this introduces some limits in our sensing and perception of the sound. These limits relate to the inability of the player's movement (the player, not the character) to have the same effect on depth and localization cues as would be expected were the sounds to issue from the environment outside the world of the game and the loudspeakers.

The real resonating space issues out of the game world into the real-world space of the user environment through the agency of audification and this space provides the only form of physical immersion which digital games currently offer.[11] Another space is the virtual resonating space that is a recreation of the spaces suggested by the image on screen that is mapped onto the image through a process of synchresis and, in so doing, both amplifies and confirms these suggested spaces. The player may be considered to be physically immersed in the real resonating space but is perceptually immersed in the virtual resonating space and that it is the conjunction between the former space and the images

[11] Disregarding a variety of arcade game frames which, in most cases, may be viewed as add-ons to the game.

of the game world which brings this about. In becoming immersed within the virtual resonating space (and therefore immersed within the FPS game acoustic ecology), the player is making use of sonic affordances and uses listening modes (particularly causal listening but also navigational listening because the resonating spaces in the ecology are spaces which can be navigated).

The perception of the sound will be different for each player. There are several reasons for this. Firstly, every player perceives the same sound sensation differently because of different physiology and other causes such as the absorptive or reflective qualities of the clothing worn (if not wearing headphones). Secondly, the sound sensation changes between player to player if, for example, player A is further from the sound source than player B or if player A is positioned in a more sound-absorbing area than player B (assuming a game engine capable of ideal acoustic shading). Thirdly, the perceptual and cognitive faculties of each player will categorize and provide meaning to sound differently. These differences may be manifested by varying intensities of sound at each player, different frequency spectra, different ratios of direct to reverberant sound, by different localization cues or by different responses to the sound — a shotgun blast will have different meanings and responses required for different players.

There is a significant difference between the acoustic spaces created in films and those created in FPS games. In film, offscreen sound that "enlarges the film space beyond the borders of the screen" [19] does not invite or allow exploration into that space because the film spectator is an immobile participant in the film's space unable to discover the offscreen sound source unless the director wishes it. With few exceptions, the source of a sound from an object not in sight in a FPS game can be discovered by turning towards the direction the sound is coming from (that is, altering the screen view) and, if necessary, moving (the character) towards it; a kinaesthetic interaction. Whereas we can only imagine "the reality [...] of a larger world stretching on indefinitely" [19] beyond that which we see on the cinema screen, in the FPS game we can explore the space, guided by our ears, and confirm the world implied by the 'offscreen' sound.

This mimics one of the functions of sound in reality that is not provided by film sound — in reality too, a person may actively investigate the physical space that is hinted at by 'offscreen' sounds — and in this way, in the FPS game, the provision of a teasing acoustic space with New World promise[12] as an analogue to the acoustic spaces of reality provides some of the required preconditions for immersion as described by McMahan [12]. For example, gunfire at various points of the FPS acoustic space may be classed, at a first level, as perceptual sureties if the player is in the midst of a fire-fight. They may be classed as perceptual surprises of the attractor and connector variety if the gunfire, perhaps in conjunction with rapidly approaching footsteps, suddenly sounds to one side of a player in the lull of a battle — attractors because there is an action expected on the part of the player (perhaps turn and face the potential enemy or run away) and connectors because they help orientate the player in the visual space depicted on screen.

As mentioned in the introduction to this paper, Breinbjerg posits three dimensions of space as defined by sound in the game [1]. Architectural space is defined by simulations of materials used and the construction and dimensions of the space and is a quantitative phenomenon. Additionally, he makes the point that such space must be sonically indicated by objects that are not part of the architecture but whose sounds are nevertheless affected by it (for example, the reverberation of footsteps in a large, cavernous hall as the hall itself makes little or no sound). Relational space is defined by distance and position of sound sources in relation to the listener and is subjective, non-quantifiable and dynamic — listeners hear differently, are in different locations and use different audio systems — because sound sources and the listener may move in relation to each other.

The use of the term 'space' (architectural and relational) by Breinbjerg is perhaps misleading as it suggests at least two distinct forms of space relating to volumes that are perceived by the listener. In terms of FPS game sound design, the distinction is a valid one especially when viewed as quantitative and qualitative because the first is relatively simply implemented in code (a simple reverberation algorithm for sound reflecting off a brick texture in a large room is a relatively trivial matter to code) and the second is more difficult to design because of the larger quantity of unknown factors (for example, the position of the character in the game, the use of surround sound or stereo playback).[13] However, in terms of player experience, I suggest that it would be more correct to label these as spatial components. The sounds heard in Breinbjerg's relational space are affected by his architectural space that requires the provision of other sounds that act in conjunction with the architectural properties to create the resonating spaces of the game. Any such architectural space requires a listener to be present within that space in order to hear the sounds — if there is no sensing auditory system present, there is no sound. Placing a listener in the architectural space immediately creates relationships between that listener and the components of that space and so the two spaces that Breinbjerg proposes are simply two facets of the same form of space — resonating space.

Within the acoustic ecology of the game, sounds that enable the perception of the game world's resonating spaces (whether they are pre-reverberated audio samples or the sound heard after processing by the game audio engine), I define as *choraplasts* to indicate their ability to fashion the perception of a resonating

[12] This conceit is a comparison to the *terra incognita* of early cartographers and the sense of wonder and imaginative surmise that contributed to the age of exploration.

[13] Increasing computer processing power will mean that relational space in the game will become more quantifiable as game audio engines become more sophisticated allowing the fine tuning, for example, of sound to player location in the game.

space [7].[14] Sounds become choraplasts through the use of techniques such as localization and reverberation thereby providing the aurally perceived parameters of height, width and depth for the resonating space. It must be stressed here that any resonating space created by sound not only has volume but also has time. This dimension is important as it is through time that sound sounds and over time that the ecology changes. This change reflects the integration and participation of players in the acoustic ecology because it is an expression of the relationships, based on sound, between players and between players and the game engine.

I suggested previously that there are at least two resonating spaces in the FPS game. The first, in which the player is physically immersed,[15] provides an example of sensory immersion in which the sounds in the user environment are overidden by the sounds of the game environment [4]. The second, which sonifies the 2-dimensional screen image in three dimensions, is an example of perceptual immersion and, comprising as it does a number of perceptual immersion 'hooks', serves to lure the player into the game world inhabited by her character [8]. I suggest that the real resonating space is mapped onto the game world by a process of synchresis and that this process is what creates the perception of the virtual resonating space. This is a type of meta-synchresis in which the entire soundscape (consisting of many individual sounds and which exists in a different location to the screen within the player's user environment) is perceptually mapped not only to the image on screen but to the entire surrounding locale of that particular point in the game world (including the parts which are unseen). This meta-synchresis provides the affordance by which synchresis may then occur between individual sounds within the acoustic ecology and individual objects which are seen on the screen.

This section, then, has explored the idea that sound has a role in the creation of at least two resonating spaces in the FPS game, that these spaces physically immerse the player in one space and invite perceptual immersion in the other and that meta-synchresis, whereby the real resonating space is perceptually mapped to the game world despite being in a different physical location, is the process by which the virtual resonating space is perceived. Additionally, the term choraplast is useful for accounting for those sounds having the function of creating resonating space.

Schafer notes that sound can be used to define a space that does not necessarily have any visible boundaries [16]. In this case, sound is typically used to mark territory; for example, the territorial calls of birds or the sound of a parish church bell marking the purview of the parish. This is sound defining a social place or locale, a paraspace, and is the subject of the next section.

[14] This has resonance with Kristeva's use of the term *chora* as a mobile and ephemeral articulation giving rise to, but preceding, spatial geometry [11].

[15] In the case of headphone use, one might say physically encased.

5. ACOUSTIC PARASPACE

In addition to defining resonating spaces, and potentially in conjunction with vision, sound defines acoustic paraspaces. The acoustic ecology of the FPS game may be viewed as a particular form of paraspace in that it is a space which enables social interaction between players, on the basis of sounds, and an interaction between players and the game engine. Here, though, the emphasis will be on the perception of locational paraspaces; that is, those paraspaces that indicate particular locales within the game world and that are characterized, in the main, by parameters other than spatial volume.

Location may be general or it may be specific. Thus, to use examples from the real world, the sounds of traffic (car and bus engines, honking horns, for example), the footsteps of pedestrians on a hard surface, and muzak issuing from opening doors indicate that the location is a row of shops lining a street in a town or city. If the listener also hears the bells of Big Ben and a particular language (English) and accent (Cockney), this marks the location specifically as London. This may be compared to the locations found in FPS games although they typically have less specificity. For example, the Bach organ fugue and the birdsong audio samples in the *Abbey* level of *Urban Terror* [18] suggest that the location of the level is that of a Christian religious place in a bucolic setting.

Writing about film sound, Chion identifies sound types that help define a setting of a film (in this case he refers to location as 'space' or 'locale'). These he divides into discrete sounds emitting infrequently and more pervasive, permanent background sounds; thus "elements of auditory setting [which] help create and define the film's space" [3]. They may be synchronized to specific sound sources on the screen or not and his examples include a dog barking or an office telephone ringing. What Chion calls *ambient sound* is "sound that envelops a scene and inhabits its space [...] birds singing, churchbells ringing. [Although lacking a visual source they] identify a particular locale through their pervasive and continuous presence" [3].

The same rationale may be applied to some of the sounds in the FPS game. The location may or may not have an equivalent in reality; the sound of Big Ben chiming in a level that represents London is an example, the sound of traffic in an urban environment is a more generic example and sundry more imaginative sounds indicating fantastic locations[16] are examples

[16] During the design of the *Quake III Arena* [10] *Grim Shores 3: Atlantis* user level [6] (which was set in an underwater Atlantis complete with hieroglyphs and statues of Egyptian deities), my chosen ambient sound for a certain dark subterranean chamber was a susurration of voices created by recording myself chanting in Italian (an appropriately sibilant language), reversing the audio sample, multitracking it back on itself with a range of delays, applying a long, dark reverberation and finally discarding the direct sound in favour of the reverberant

of locations having no correlate in reality.[17] Such sounds are interpreted via cultural experiences or (and sometimes in addition to) the experience and training gained in playing the particular game or level. There is no appropriate term classifying such sounds and so they will be termed *topoplasts* because of their ability to signify a place or location [7].

FPS game sounds that help create locational paraspaces are usually environment sounds or pervasive keynote sounds (for example, continually ringing church bells indicating a church in the vicinity or singing birds and the continuous sound of wind rustling through leaves indicating a forest). But they may also be more discrete sounds or Schafer's signal sounds that players actively attend to but, nonetheless, because of the identifying properties of the sound, help to perceptually define that particular location. These types of sounds may also have the function of aiding in the creation of resonating spaces if the game engine processes them with cues indicating localization, reverberation and depth. Such sounds are able to function in this manner within the game because of the raw (that is, not processed in real-time) characteristics of the audio sample (for example the metallic ringing that indicates the tolling of a bell) or because the raw audio sample may be processed to serve as an indicator of place by adding, for example, a long reverberation to indicate a cavernous, reflective place (such as a cathedral) which also serves as an indicator of resonating space.

The game world of the FPS game is a compilation of acoustic locational paraspaces beginning with the general setting of the game level (docks, for example) and comprising various locations within that (quayside, warehouses, railway yard, for instance). Such paraspaces are contained within the real resonating space and, like the virtual resonating space, are meta-synchretically mapped onto the images on screen to become part of the gameworld. Sounds with a topoplastic function are key to enabling the perception of such locations and may work together with the image on screen for this purpose or, as 'off-screen' sounds, may function alone in guiding the player to a perception of locations beyond the limits of the screen.

6. ACOUSTIC TIME

It was pointed out at the start of this paper that time is a fundamental component of any discussion of resonating space or acoustic paraspace. However, simply noting this does not describe how the temporal components of sound in the FPS game acoustic ecology work with other sonic parameters towards the creation of these types of spaces. This section, therefore, discusses parameters of sound which contribute to perceptions of time in the game and defines further taxonomies in order to describe the temporal functions of FPS game sounds. Some of this discussion compares perceptions of time in films to perceptions of time in digital games following the example of writers such as Wolf [22].

Chion suggests that sound in film can have a temporal function when a montage or sequence of, at first sight, unrelated images is presented on screen. Without sound, these images can be read as either synchronous or sequential. However, "the addition of realistic, diegetic sound imposes on the sequence a sense of real time [...] a sense of time that is linear and sequential" [3]. Additionally, because sound is 'vectorized', that is, it has a definite start, middle and end, sound with moving images imposes a "real and irreversible time" — although many sequences of images are reversible without being noticeably reversed, sound in a reversed film always discloses that the film has been reversed [3]. This is an important point, sound with moving images indicates that real time[18] is passing by and progressing forwards and this also relates to the progression of the diegetic time of the medium.[19]

As far as concerns the audio and visual reproduction systems of films and digital games, there are inherent technological differences between the two media affecting the perception of time. Staring at a 'still' image on the cinema screen (where neither the camera nor the subject move yet the film continues), the impression of time passing is cued by grain, flicker and other anomalies in the image such as scratches or hairs moving between the projector's light and the film screen. There is no equivalent in digital games (or, for that matter, in digitally produced and reproduced films). As Wolf states: "[G]rain, hiss and flicker are nondiegetic indicators of time passing [...] video games usually do not have the same nondiegetic indicators of passing time" and other elements, such as sound, must be added to indicate this [22].

Some sounds have a function of marking and segmenting time in the present (whether 'present' in reality or the 'present' of film or game time). For these, there is a range of sound types such as clock-tower bells, marking the hours or fifteen minute divisions of the hour, or the ticking of a watch marking seconds.[20] These types of sound tend to be rarely used in FPS games other than as a musical or chordal flourish or similar when the gameplay ends or starts, and they segment time into large chunks relating to the completion of a level and the start of the next. An example of a shorter division of the gameplay time is found in *Quake III Arena* where various powerups are set to respawn at set time intervals at which point they will be signaled by a unique sound; the astute player will note the passage of time by such sounds positioning herself to take advantage of the powerup right at the respawn time.

sound only. By no means was the speech intended to be intelligible despite being recognisable as some form of vocal utterance; it was designed for affect and to sonify the volume of the chamber depicted on screen.

[17] Although they may well have cultural resonance, be re-imaginings of historical or mythical places or be interpretations of locations imagined by popular convention.

[18] The perception of 'real time' is used advisedly and is not necessarily a quantifiable amount as anyone who has lost themselves in a digital game only to later emerge discovering that several hours have flown by in the real world would recognize.

[19] With the exception of flashbacks in film.

[20] Heard less and less today.

For a sound which affects the perception of chronological time, its most important property is its macro-temporal property *viz.* its amplitude envelope. Thus a sound may have a *slow* attack, a *long* sustain and a *quick* release; all perceived and measured in terms and units of time and therefore having an effect upon the perception of chronological time. Additionally, the rate of repeating of the sound will potentially have a similar perceptual effect. For a sound having functions to do with the perception of resonating space, the paraspaces described above or a historical timeframe, its micro-temporal properties come to the fore as these will be perceived less in terms of time units but rather in terms of their effect upon the density of reflections that make up reverberation, for example, or the timbre and spectral fluctuations that result from changing temporal relationships between the partials of the sound.

Sound also has the ability to indicate a point or period of time in the past, present or future as pointed out by Schafer quoting line 501 from Book II of Virgil's *Georgics*: "Such was the life that golden Saturn lived upon earth: Mankind had not yet heard the bugle bellow for war, Nor yet heard the clank of the sword on the hard anvil" [16]. Hence certain sounds are redolent of particular historical periods; mechanical sounds, particularly metallic sounds, are indicative of the industrial and post-industrial ages and, by the same token, the absence of metallic sounds such as the 'clank of the sword on the hard anvil' can be indicative of the pre-Bronze Age period. The addition of some sounds, such as the sound of a jet aeroplane in a game environment meant to represent the mediæval period, can be anachronistic. In addition to the use of particular sounds, the density, loudness and frequency of occurrence of sounds can also indicate the time period — it is a common modern plaint that the background sound levels to which mankind is now exposed have increased significantly.

A final temporal function of sound, in conjunction with visuals, is one that indicates distance (and in this, it also has an effect on the perceived dimensions of the resonating space). Many of us are familiar with using the time between seeing a bolt of lightening and hearing the clap of the thunder to judge how far away the storm is. Because light at these small distances is perceptually instantaneous with the event, the distance of the storm is calculated from the speed of sound — as sound travels at c.344ms^{-1}, a delay between sight and sound of three seconds indicates a distance of approximately one kilometre. However, there are no FPS games that significantly use this phenomenon to indicate distance; this is strange as it would be a simple matter to code.[21] This squashing of time, or discarding of one form of distance perception cue, is an unusual feature of digital games. It is difficult to justify why this should be the case especially if the rules of immersion require the provision of expected cues or if the game designers are attempting simulations of aspects of reality. It may be an oversight brought about by a subconscious acceptance when designing the game that, despite the artifice of perspective and parallax in emulating visual depth, objects on the screen really are all on the same plane just a few centimetres in front of the player's eyes. Perhaps there is a recognition that digital games should not be overly complex and therefore difficult to engage with and learn at first exposure — allowing a player to hear a sniper's bullet *before* it hits gives a chance to that player — or perhaps there is a requirement for an immediacy of the effect of in-game actions complicated by multiplayer configurations bringing the added complication of network latency.

Because sound has time as a function of itself, that is, sound is heard in and may therefore be analyzed in terms of time, all FPS sound indicates the passage of time. Analyzing sound in this manner is an indication of the passage of real time where a sound has a certain length from start to finish or has a certain frequency (that is, cycles per second). There is also, however, a game time that is not always synchronized with real time if the game designer so wishes it and, additionally, there are other perceptions of time, some more individual than others.[22] The ability to hear sound requires a length of time and so sound is indelibly linked to the passage of time. Furthermore, sound can also reference a certain point in time and, in this case, cultural and societal experience is required. Sounds that influence the perception of the passage of time I define as *chronoplasts* and sounds that create the perception of the temporal period an FPS game is set in are termed *aionoplasts* [7].

Sound also serves to fit the playing of an FPS game level into a temporal container with beginning, middle and end (not to be confused with the classic three-act restorative narrative structure). This may be defined by the density of sound (increasing as players hunt out and fight each other and decreasing as characters die and await respawning), it may be defined by particular types of sounds (sounds indicating the beginning, middle and end of the level) or by other methods depending upon the game engine and mode of play. This is clearly indicated by the graphical sound wave presented in **Figure 1** which describes the course of the gameplay of a free-for-all *Urban Terror* match with eight characters:

[21] The relative size of an object displayed on screen is already derived in the code by its distance from the character's position so the same parameters used to calculate this can also be used to calculate and introduce an appropriate delay.

[22] My personal experience is that real time tends to pass more quickly when playing a particularly involving FPS match; whenever I wish to kill time, I play an FPS game.

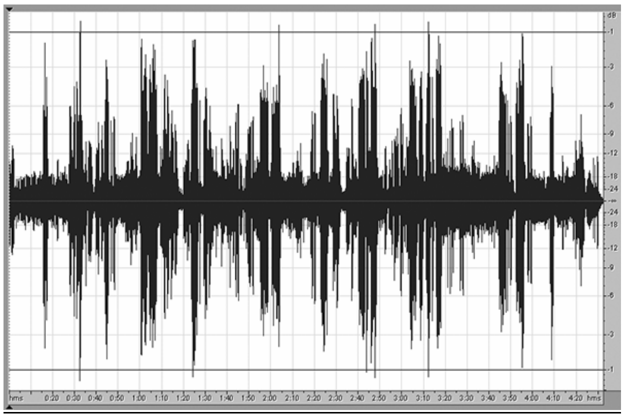

Figure 1. A visual representation of an Urban Terror soundscape over the course of a level.

This represents the sound heard by one player as she moves through the game hunting out and killing other characters or dying herself. The higher amplitude sounds represent the firing of guns at close quarters (the loudest are the player's own weaponry) and the points of increased density of such sounds are indicative of bouts of fighting interspersed with quieter periods during which the player is resting and bandaging wounds, waiting to respawn after in-game death or is moving towards the sound of distant activity in order to engage with the enemy once more.[23]

7. CONCLUSION

Whereas image in the game makes use of artistic conventions, artificial parallax and scaling in order to represent a 3-dimensional world on a 2-dimensional screen, sound alone exists in three dimensions and, for this reason, is the primary perceptual enabler of the illusory space represented by the image on the screen. This real resonating space is audificated by the game engine from the audio samples stored on the installation medium and, where the game engine allows, is further enhanced by real-time acoustic shading. A second virtual resonating space is perceived through the meta-synchresis that occurs when the real resonating space is perceptually mapped to the image provided on screen. This is a particularly important affordance offered by the real resonating space and, in this way, the real-time-created resonating space provides the affordance of believing that the objects on screen are occupying or moving within the virtual resonating space (perceptually created by the FPS game) rather than within the plane area defined by the four sides of the monitor. These two spaces continually morph around the player adapting not only to the player's actions but also to other players' actions, players who are within virtual hearing range (a range that is dictated by the game engine). In doing so, they continually provide new affordances for player perception and response and this, combined with the afore-mentioned meta-synchresis, is a key perceptual hook used to immerse the player within the FPS game world.

In addition to resonating spaces, FPS game sounds also create a set of paraspaces of which the more relevant are locational paraspaces and temporal paraspaces (of these, there are two important ones — those contributing to perceptions of temporal period and those contributing to temporal progression). Furthermore, the functional ability of sound to provide spatial information may be combined such that any one sound may have, for example, both a resonating spatial function and a locational paraspatial function. Additionally, understanding the paraspatial locational properties of a sound is often a matter of socio-cultural experience. Ringing church bells may have little meaning to those who have never heard such a sound before but will have a host of connotations (perhaps different for different listeners) beyond the specific denotation to those who are familiar with the sound.

[23] Note that in this case, the resonating spaces, any paraspaces and the historical period cannot be inferred from the visual representation of the soundscape in the same way that it demonstrates the passage of time and player activity.

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