

SOUND AND IMMERSION IN THE FIRST-PERSON SHOOTER

Mark Grimshaw
University of Wolverhampton
WOLVERHAMPTON
United Kingdom
E-mail: mark.grimshaw@wlv.ac.uk

KEYWORDS

First-person shooter, sound, immersion, realism.

ABSTRACT

One of the aims of modern First-Person Shooter (FPS) design is to provide an immersive experience to the player. This paper examines the role of sound in enabling such immersion and argues that even in 'realism' FPS games, it may be achieved sonically through a focus on caricature rather than realism. The paper utilizes and develops previous work in which a conceptual framework for the design and analysis of run and gun FPS sound is developed and the notion of the relationship between player and FPS soundscape as an acoustic ecology is put forward (Grimshaw and Schott 2007a; Grimshaw and Schott 2007b). Some problems of sound practice and sound reproduction in the game are highlighted and a conceptual solution is proposed.

INTRODUCTION

It may be stated that player immersion in the First-Person Shooter (FPS) game is one of the goals of the FPS developer. This being mental immersion (and not yet full physical immersion), the goal may be defined as the player's perception that she is within the game environment, that she is the character whose hands she sees before her. Player immersion, then, may be supposed to be primarily perceptual and is manifested by a shift of perceptual focus, from an awareness of 'being in and part of' reality to 'being in and part of' virtuality such that, in the ideal case, virtuality becomes substituted for reality. This immersion is, in part, enabled through a system of sonic perceptual realism which is technically enabled through the FPS game engine's sonification capabilities.

For the player and developer there are many processes leading to FPS immersion and perhaps the first takes place before the game has even been installed. Back stories, minimal though they are, and promotional material for FPS games typically address the potential player in the second-person singular and situate her within the game-world: "[Y]ou are U.S. Army Ranger B.J. Blazkovicz [...] You are about to embark on a journey deep into the heart of the Third Reich" (Gray Matter Studios and id Software 2001), "you lunge onto a stage of harrowing landscapes and veiled abysses" (id Software 1999), "[y]ou are a marine [...] Only you stand between Hell and Earth" (id Software 2004).¹

¹ This form of direct address occurs not only in FPS games as Burn and Parker (2003, p.45) note.

Advances in computer technology are used to bait further these lures where "incredible graphics, and revolutionary technology combine to draw you into the most frightening gaming experience ever created" (id Software 2004).

The images on screen can only be a part of a virtual environment as they are a 2-dimensional representation of 3-dimensionality. Sound, though, exists and operates both in reality and in virtuality; it has a real volume and dimensionality that is a 3-dimensional representation of the 2-dimensional representation of the 3-dimensional world of the game.² Yet, in managing this feat, sound is also illusory not solely because it refers to a virtual resonating space (Grimshaw and Schott 2007b) but also because it may make use of caricature and convention rather than (necessarily) authentic sound to represent a variety of paraspaces in the game.

Unlike graphics, sound rarely rates a direct mention in digital games marketing material – claims for graphical superiority over other games can be made with images (often rendered with a detail and realism that are never replicated in the game), but the game box and packaging are incapable of providing a similar siren call for sound. However, it is my argument that sound too plays a part in the game's perceptual realism that forms a basis for player immersion. In this, my argument parallels claims made for sound in other media. As Anderson (1996) states, "sound is seventy percent of the illusion of reality in a motion picture" (p.80). Although I am not as willing to provide such a precise figure, my contention is that sound is of great importance, if not the greatest importance, in creating the perceptual realism of the FPS game that leads to immersion.

THE FPS GAME ENGINE AS SONIFICATION SYSTEM

Kramer *et al.* (n.d.) provide a definition of sonification as the use of a sound generator to transform non-audio data into sound in order to facilitate, or perhaps provide new, understanding of that data (p.3). The purpose of sonification is to monitor and comprehend data which might otherwise, and in another form, be difficult to note and understand.

² It is possible to add further layers to this particular conceptual onion or matryoshka doll by suggesting that sound will always carry artefacts of the user space and equipment that is inhabited and used by the player in order to partake in the game and that this adds another real space with any other real and illusory spaces already contained in the sound.

Furthermore, the transposing of data to the sonic domain allows the specialized abilities of the auditory system to be brought to bear on that data in an attempt to discern meaning from it. As an example, the ears are finely attuned to minute temporal and frequency changes, more so than the eyes, and, for the purposes of constant monitoring, the ears, unlike the eyes, cannot be shut (there being no earlids) and need not be oriented in any particular direction to sense sound.

Kramer defines two further terms related to sonification. Firstly, audification (or 0th order sonification) is a “direct translation of a data waveform to the audible domain for the purposes of monitoring and comprehension” (1994, p.186). Secondly, audiation relies on human experience and imagination whereby a person mentally invokes a sound when presented with an image — an image of a dog may provoke an audiated yap.

The audio samples typically provided with FPS games are used by the game engine for audification purposes. Because these audio samples are not sounds but are representations of the original sound stored as bits within the game system, in order to be heard, they must be organized by the game engine during game play and processed by audio transducers. Higher order sonification is represented by the mapping of game events to particular audio samples prior to their audification. These game events may be initiated by players or bots as they partake in the gameplay and interact with the game world. Examples include the firing of weapons, movement, the collection of various game items or more significant and global events such as the capture of a flag in a capture the flag scenario. They may also be initiated by the game engine itself as ambient sounds or as audio samples audified in response, for instance, to the amount of time remaining for play.

In all cases, FPS game sonification is predicated upon player presence and action. Audification of audio samples occurs only in response to player action or, at the very least, to player presence within the game world.³ For many game engine-initiated sounds, the player may exercise a kinaesthetic control over the sonification by moving her character in relation to the sound source. For example, by moving away from a sound source, the sound becomes attenuated until the point at which it ceases to play. In technical terms, the game engine tracks the character’s position within the virtual space of the game world in relation to the sound source and decreases the volume of the audio sample until it is stopped altogether.

Sonification techniques, therefore, are intimately concerned with expressing meaning in sound. The FPS game engine, in conjunction with the appropriate hardware, may be viewed as a sonification system in that it translates non-audio data (the game status or player actions, for example) into sound thereby providing sonically interpretable data to the player. By this process, game engine sonification provides a perceptual conduit from game and character status to player.

³ Similar to Böhme’s (2000) suggestion that atmospheres in acoustic ecologies require a discerning subject to be present.

Furthermore, in a multi-player scenario, such sonification is an important mode of player-player communication. Sonification provides a relational framework for the player to begin to contextualize herself within the spaces of the game world or in relation to events and other characters — ultimately, in a multiplayer game, this framework enables her to establish relationships with other players.

IMMERSION THROUGH SOUND IN THE FPS GAME

Paraphrasing Pine and Gilmore (1999), Ermi and Mäyrä (2005) state that “immersion means becoming physically or virtually a part of the experience itself” and, as part of their ‘four realms of experience’, they define digital games as an escapist experience because the medium includes both active participation and immersion.⁴ Following their analysis of a variety of digital games (in which the FPS *Half-Life 2* (Valve Software 2004) had the highest overall immersion rating), they posit three types of immersive hooks: *sensory immersion* where sensory stimuli from the game (auditory and visual) override sensory stimuli from reality; *challenge-based immersion* requiring motor and mental skills and *imaginative immersion* where players identify with the game’s story and characters.

All sound in the game has the ability to provide Ermi and Mäyrä’s sensory immersion but, because this is sensory rather than perceptual, the degree of this type of immersion is, in large part, dependent upon the type of audio interface the player uses and, for example, the relative volumes and relative frequency bandwidths (and overlap) between the game environment’s sounds and the player environment’s sounds. However, it is almost certainly the case that sensory immersion is increased through the wearing of headphones (as most FPS players do) because these serve to block out sounds from the user environment (Morris 2002). Where, according to Ermi and Mäyrä, immersion includes becoming *physically* a part of the experience, this is achieved, in the case of the FPS game acoustic ecology, through the process of the player becoming physically immersed in the real resonating space (Grimshaw and Schott 2007b) and so sensory immersion is a physical immersion.

Many FPS sounds provide challenge-based immersive possibilities. These are typically weapons-based sounds (sounds providing threat or opportunity affordances) or game status signals (in team games particularly) which potentially require mental and/or kinetic skills when furnishing a response. It is also the case that audio beacons requiring navigational listening provide a similar immersive potential especially where a game or level is being learnt and the player is constructing navigable mental maps (Grimshaw and Schott 2007a).

⁴ Defining absorption as “directing attention to an experience that is brought to mind”, the other three realms of experience are: *entertainment* (absorption and passive participation); *educational* (absorption and active participation) and *aesthetic* (immersion and passive participation).

Sounds affording imaginative immersion help the player identify with the characters and action in the FPS game. Proprioceptive sounds, like the character's breathing, are especially potent immersory cues particularly if the game engine allows for a change in breathing rate following the speed and exertions of the character. Exteroceptive sounds, such as footsteps, provide similar affordances as they respond directly to player input.

Developing Fencott's (1999) system of cues and surprises, McMahan's discussion of immersion in digital games (2003) describes cues as sureties; mundane cues conforming to the player's expectations. Her three categories of surprises (attractors, connectors and retainers) either provoke an action on the part of the player or are an aid to navigation and orientation. As realism is one of the defining elements of immersion, sureties and surprises are part of a system of perceptual realism that, for McMahan, combines with a social realism to foster immersion.

There are a range of sounds in the FPS game working to provide this system of perceptual realism. Environment sounds such as ambience, the sounds of doors being opened and closed, weapons fire and footsteps are examples of mundane sureties especially if the latter three are initiated by the player herself.⁵ Such actions may simultaneously be classed as surprises when initiated by another character leading to challenge-based immersive possibilities.

This system of cues and surprises may be paralleled by Malaby's (2006) description of a digital game as a system of multiple contingencies, contrived and calibrated, leading to both predictable and unpredictable outcomes (p.9). In this sense, the interpretation of aural cues and surprises is (on one level and as a simple example) contingent upon user experience of such sounds or not. These are contrived and calibrated by the sound designers and game designers in an attempt to produce the desired mix of both predictable and unpredictable outcomes of player responses that provide the patterned, yet differing, gameplay experiences each time the game is played. This contrived and calibrated mix must be carefully judged. As Steve Johnson states: "If games are too hard they're boring, and if they're too easy they're boring, but if they're right in the zone they're addictive" (quoted in Wasik 2006, p.33). Although this statement is applied to game elements in general, it may also specifically be applied to the affordances of the FPS acoustic ecology; such affordances are not accidental but are designed.⁶

An important point made by McMahan is one of her three conditions for an immersive experience: "[T]he user's actions must have a non-trivial impact upon the environment" (pp.68-69). The non-trivial environmental impact of a sonically-active player is demonstrated in Figure

⁵ In some scenarios, sounds from team mates may be sureties as may sounds from enemies in the distance.

⁶ Designed, it is to be hoped, with some thought but I accept that, in some cases, that thought may be cursory and based solely on an acceptance of popular commercial cinema sound conventions.

2 and is compared to that of the inactive player in Figure 1.

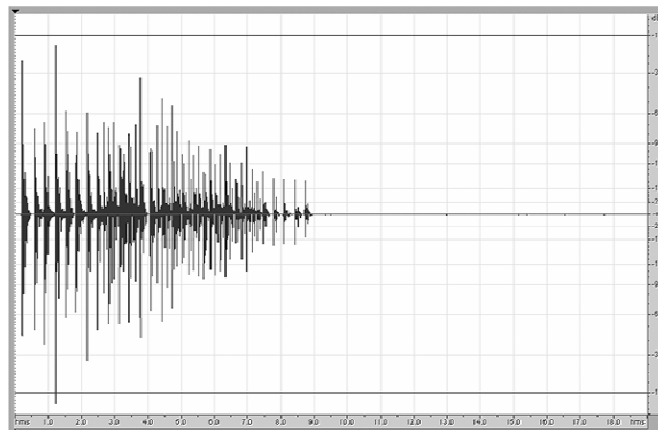


Figure 1. The sound heard by an inactive FPS player in *Urban Terror*.

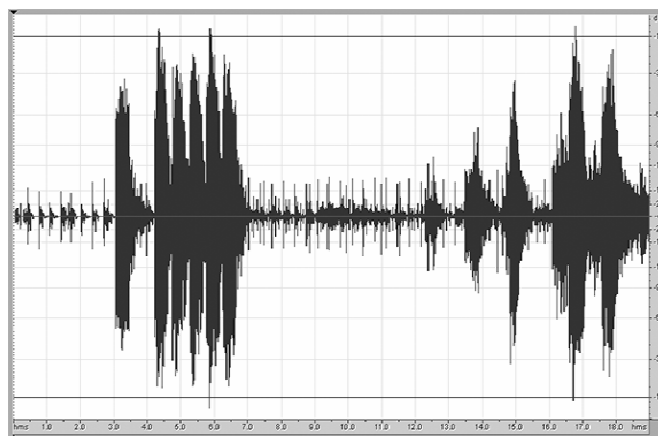


Figure 2. The sound heard by an active FPS player in *Urban Terror*.

Both of the soundscapes shown in Figure 1 and Figure 2 show the sound heard by an FPS player during the first 19 seconds of an eight-player capture the flag game in *Urban Terror* (Silicon Ice 2005) on the *Abbey* level. In the first, the player is doing nothing and the only sounds heard are the soft twittering of birds and the receding footsteps of teammates as they move towards the game action. In the second, the player is running around and firing weapons. The difference between these two soundscapes demonstrates that the intervention of an active player has a great effect upon the acoustic ecology of which that player is a part thereby fulfilling one of McMahan's three conditions for an immersive experience.

There is one further aid to immersion through sound that has not yet been discussed so far and it is one that relates to the design peculiarities of the FPS game. A character and player in the FPS game are, in so far as the perception of sound is concerned, one and the same due to the first-person (visual and sonic) perspective.⁷ To compare this to another medium,

⁷ In fact, a player almost never sees her character other than as a pair of hands or a single hand, when the FPS game features mirrors within the game environment, in overhead

where film sound practice has moved from the notion of impossible auditors through to external and internal auditors (Altman 1992) and where none of these silent observers have an active role in the film diegesis, there is no such distinction in FPS games where the immersive, 3-dimensional nature of the game posits the player as *first-person auditor* (Grimshaw and Schott 2007a). If the diegetic, sonic world of the film exists solely for the characters on screen, then the diegetic sonic world of the FPS game extends from the screen to physically encapsulate the player in the acoustic ecology's real resonating space. This is particularly the case where the player is using headphones because they serve as an extension to the player's proprioceptive auditory system greatly attenuating, and in some cases entirely blocking out, sounds external to the game world such that, for example, the sounds of the character breathing become the sounds of the player breathing.⁸ Thus, FPS game diegetic sounds extend the game environment from a flat, 2-dimensional screen to the 3-dimensionality of the external world. The player's proprioceptive sounds are replaced by the character's proprioceptive sounds and all other game world sounds envelop the player as part of the game's real resonating space. These sounds form part of not only the real resonating space but also the virtual resonating space of the game and thus help to immerse the player, both physically and mentally, in the FPS game acoustic ecology.

Carr (2006), summarizing definitions of immersion as provided by other writers, states that there are two categories of immersion: "[P]erceptual immersion, which occurs when an experience monopolizes the senses of the participant, and psychological immersion, which involves the participant becoming engrossed through their imaginative or mental absorption" (p.69). Although the use of the term 'perceptual immersion' is confusing as it refers solely to sensory systems,⁹ Carr's description of these two categories of immersion bears strong similarities to Ermi and Mäyrä's sensory immersion and their challenge-based and mental immersion. Both categories of Carr's immersion are usually at play in all digital games but the differences in affordances offered by different genres of digital games will tilt the balance in favour of one or the other. FPS games, I would suggest, operate more (but not solely) at the level of visceral, sensory immersion compared to Role Playing Games, for example, which, with their strongly narrative and socially interactive bent, accomplish any immersion mainly by psychological means. These two categories are also similar in many respects to McMahan's systems of perceptual realism and social realism.

PERCEPTUAL REALISM THROUGH SOUND IN THE FPS GAME

Many FPS game designers attempt emulations (or at least high-level simulations) of reality in their games. Sound in the FPS game is (currently) the only way of inserting real-

shots of the player's dead character while waiting to respawn or in rare game-specific uses of third person perspective.

⁸ A form of sensory immersion.

⁹ Strictly speaking, this is actually *sensory immersion*.

world causality into the virtuality of the game. For example, recordings of real-world weapons which are triggered whenever the player shoots a gun within the game. Ward (2002) has the view that there are elements of digital games which tend towards mimetic realism (as close a mimicking of reality as possible) and aspects that tend towards abstract realism (pp.124—127). I would suggest that, in general, the use of sound for realism purposes in the FPS game falls somewhere between the two poles. Specifically, though, there are some sounds that are mimetic in their representation of realism (Doppler effects, recordings of real weapons, for example¹⁰) and others that are more abstract in such representation (caricature sounds). 'Realism' games and mods such as *Urban Terror* have a majority of audio samples which may be ascribed a mimetic realism. In more advanced game engines, this is often combined with real-time 'acoustic shading' of audio samples for depth or reverberation cues depending on the materials and spaces of the game in an effort to emulate the reverberant qualities of soundscapes found in the real world.

However, several authors suggest that, for the purposes of immersion, a reduced realism may be all that is required. In order to provide a perception of realism, it is not necessary to provide first-order reproductions of materials or phenomena from reality within the game environment. First-order reproductions of materials and phenomena refer, in the case of images, to photographs of game object correlates taken from reality and, in the case of sound, to audio samples (taken from reality) of the objects and actions of the game. Chion, writing about film sound, states that what is necessary to provide a sense of realism may in fact be quite opposed to any state of reality and is often the subject of convention. There are sound conventions and "specific codes of realism" that produce anything but the sound that exists in reality but rather provide "the impression of realism [and these conventions become] our reference for reality itself" (Chion 1994, p.108). This comment about the nature of reality and the role played by sound in the creation of realism is supported by other writers on film sound and by those writing about sound design and use in other audiovisual media. Lastra (2000) states that: "Decades of tin-sheet thunder and coconut shell hooves prove [...] that fidelity to source is not a *property* of film sound, but an *effect* of synchronization" (p.147). He views the recording and compilation of stock sound effects to be later used for dubbing purposes as symptomatic of the move from the fidelity of the original to a constructed representation of reality (p.207). In other words, the synchronization, meaning and verisimilitude of the sound are more important than fidelity to the original — more important than providing and using an authentic sound — and this may be extrapolated as a hypothesis to the context of FPS sound.

Similar comments have been made by a range of writers (including Laurel (1993), Back and Des (1996) and Fencott (1999)) discussing realism and the uses of caricature sound

¹⁰ Here, there are parallels to film sound FX such as the shotgun in *Terminator 2* (Cameron 1991) which is actually produced from a recording of two cannons (Palmer 2002).

in virtual environments and computer desktops. It may be supposed, therefore, that realism in the FPS game may best be sonically achieved through a system of perceptual realism based on verisimilitude and simulation; a realism of theme in which there is “plausibility of characterization, circumstance and action” (Corner 1992, p.100) that is supported by convention and sound-use consistency as opposed to an attempt at realism that strives for an emulation of real-world objects and actions.

CONCLUSION

It may well be a mistake, then, to strive too hard for an emulation of reality when designing the sounds of an FPS game with a view to their immersive possibilities. Perhaps what is more important is to create a reduced realism, operating at the level of convention, consistency and verisimilitude in its efforts to persuade the player of its reality, but that is coupled with the predication of (most) sounds upon player action and all the other codes of realism extant in the game (social realism and simulations of gravity, for example). A desire for realism should, perhaps, be balanced with the recognition of the very visceral qualities for which sound may be used especially in FPS games — the SPAS shotgun of *Urban Terror* or the shore-based artillery of *Battlefield 1942* (Digital Illusions 2002), with the right audio hardware¹¹ have an immediate, physical impact as a result of enhanced bass frequencies coupled with a high amplitude.¹² This reduced realism then, may be balanced by sensory enhancement (increasing sensory immersion, therefore) such that the resulting soundscape falls between van Leeuwen's (1999) naturalistic and sensory coding orientations for sound (pp.177—182), between an accurate representation of what one would hear were one physically present in the game world and an increased emotive impact at the expense of natural realism. Thus, as far as realism is concerned, a reduced realism, a perceptual (rather than naturalistic) realism may be what is required as a foundation for player immersion within the FPS game acoustic ecology.

Almost all modern FPS games make use of audio samples which are typically recordings of the real-world objects and actions represented in the game. This method of sound production is the source of a potential problem: audio samples require large amounts of system resources and this is compounded by a desire to provide ever more samples in pursuit of a realist aesthetic. As Boyd (2003) notes, a film sound designer suffers no such handicap but the game sound designer works to a non-linear, multi-branched script: “It isn't possible to make every gunshot sound unique if you don't know how many gunshot sounds are needed!” A game such as *Urban Terror*, based on the *Quake III* game engine, must therefore strike a balance between providing an audio sample for every sonic possibility and keeping a tight control on storage and memory. Later game engines, such as that of *Half-Life 2*, partially solve this problem by performing real-time processing of audio samples to match the acoustic

features of the character's environs. With this ‘acoustic shading’, one audio sample may feasibly do multiple duty as differing sounds. However, it still makes use of resource-intensive audio samples and, significantly, provides a solution solely for the acoustic properties of an audio sample. As the name implies, it takes no account of other possible encodings in sound, its emotive aspects for example.

The answer may perhaps be found by turning to real-time synthesis of sound coupled with the understanding that verisimilitudinous caricature is the paradigm rather than accurate sonic emulation. Whereas physicists precisely describe sounds by frequency and amplitude, this is not the approach of the everyday listener. Indeed, as Gaver (1993) notes, sounds are typically described by the source's material properties or its actions (p.310). Thus a sound may be a metallic clang, a wooden thump, having a scraping action or being like a glass shattering. Dimensions too may be relatively assessed in sound with larger or longer sound sources typically having relatively lower frequencies.

Gaver suggests, therefore, that an object's dimensions, material properties and actions may be modeled through sound synthesis techniques and, to demonstrate this, he provides examples of algorithms that are designed to model salient characteristics of the object or action. Thus, they produce caricature sounds that provide the minimum acoustic information required to enable their identification — simulation rather than emulation. If this or similar caricature synthesis were to be used in the FPS game, it may also be enhanced by real-time signal processing according to the game locale.

This is not to say that the use of audio samples should be dropped entirely. Some sounds are so unique (despite recent developments in its synthesis, the human voice remains just such a candidate) that they may be reproduced closely only with audio samples. Rather, it may be the case that foregrounded sound, vocal sounds, or unique sounds of the real world should continue to be represented by audio samples. Sound synthesis may instead be used for background sounds, abstract sounds and more-or-less repetitive sounds (such as footsteps) — anything for which caricature provides the minimum required perceptual realism. Assuming the processing power is available for multi-channel, real-time sound synthesis, such a system is a potential solution to the expense and limitations of audio samples whilst still being able to maintain the perceptual realism required for player immersion.

REFERENCES

- Altman, R. 1992. “Sound Space”. In *Sound Theory Sound Practice*, R. Altman, ed. New York: Routledge.
- Anderson, J.D. 1996. *The Reality of Illusion: An Ecological Approach to Cognitive Film Theory*. Carbondale and Edwardsville: Southern Illinois University Press.
- Back, M. and D. Des. 1996. *Micro-Narratives in Sound Design: Context and Caricature in Waveform Manipulation*. [Available Online] [cited March 12, 2004] Available from <http://www2.hku.nl/~audiogam/ag/articles/micronaratives.ht>

¹¹ That is, having a large dynamic range.

¹² One of the reasons why *Terminator 2* uses a recording of cannons for the shotgun sound.

- m.
- Böhme, G. 2000. "Acoustic Atmospheres: A Contribution to the Study of Ecological Acoustics." *Soundscape* 1 (1):14—18.
- Boyd, A. 2003. "When Worlds Collide: Sound and Music in Films and Games." [Available Online] *Gamasutra* [cited September 6, 2004] Available from http://www.gamasutra.com/features/20030204/boyd_01.shtml
- Burn, A. and D. Parker. 2003. *Analysing Media Texts*. London: Continuum.
- Cameron, J. (Director) 1991. *Terminator 2: Judgement Day*. J. Cameron (Producer). USA: Tri-Star Pictures.
- Carr, D. 2006. "Space, Navigation and Affect." In *Computer Games: Text, Narrative and Play*, Cambridge: Polity.
- Chion, M. 1994. *Audio-Vision: Sound on Screen*. C. Gorbman, trans. New York: Columbia University Press.
- Corner, J. 1992. "Presumption as theory: 'realism' in television studies." *Screen* 33 (1):97—102.
- Digital Illusions. 2002 *Battlefield 1942* [Computer program]. Electronic Arts.
- Ermi, L. and F. Mäyrä. 2005. "Fundamental Components of the Gameplay Experience: Analysing Immersion." Paper read at *Changing Views -- Worlds in Play*, June 16—16, at Toronto.
- Fencott, C. 1999. *Presence and the Content of Virtual Environments*. [Available Online] [cited August 4, 2005] Available from <http://web.onyxnet.co.uk/Fencott-onyxnet.co.uk/pres99/pres99.htm>.
- Gaver, W.W. 1993. "How Do We Hear in the World? Explorations in Ecological Acoustics." *Ecological Psychology* 5 (4):285—313.
- Gray Matter Studios and id Software. 2001. *Return to Castle Wolfenstein* [Computer program]. Activision.
- Grimshaw, M. and G. Schott. 2007a. "A Conceptual Framework for the Design and Analysis of First-Person Shooter Audio." Paper read at *Third International Conference on Games Research and Development*, September 10—11, at Manchester.
- Grimshaw, M. and G. Schott. 2007b. "Situating Gaming as a Sonic Experience: The Acoustic Ecology of First Person Shooters." Paper read at *Situated Play*, September 24—28, at University of Tokyo.
- id Software. 2004. *Doom 3* [Computer program]. Activision.
- id Software. 1999. *Quake III Arena* [Computer program]. Activision.
- Kramer, G., B. Walker, T. Bonebright, P. Cook, J. Flowers, N. Miner, J. Neuhoff, R. Bargar, S. Barrass, J. Berger, G. Evreinov, W. Tecumsah Fitch, M. Gröhn, S. Handel, H. Kaper, H. Levkowitz, S. Lodha, B. Shinn-Cunningham, M. Simoni, and S. Tipei. (n.d.). *Sonification Report: Status of the Field and Research Agenda*. [Available Online] [cited September 1, 2005] Available from <http://www.icad.org/websiteV2.0/References/nsf.html>.
- Kramer, G. 1994. "Some Organizing Principles for Representing Data with Sound." In *Auditory Display: Sonification, Audification, and Auditory Interfaces*, G. Kramer, ed. Reading MA: Addison-Wesley.
- Lastra, J. 2000. *Sound Technology and the American Cinema: Perception, Representation, Modernity. Film and Culture*. New York: Columbia University Press.
- van Leeuwen, T. 1999. *Speech, Music, Sound*. London: MacMillan Press.
- Malaby, T.M. 2006. "Stopping Play: A New Approach to Games." [Available Online] *Social Science Research Network* [cited August 11, 2006] Available from <http://ssrn.com/abstract=922456>.
- McMahan, A. 2003. "Immersion, Engagement, and Presence: A New Method for Analyzing 3-D Video Games." In *The Video Game Theory Reader*, J.P. Wolf and B. Perron, eds. New York: Routledge.
- Morris, S. 2002. "First Person Shooters -- A Game Apparatus." In *Screenplay: Cinema/Videogames/Interfaces*, G. King and T. Krzywinska, eds. London: Wallflower Press.
- Palmer, I.J. 2002. *How Realistic is the Sound Design in the D-Day Landing Sequence in Saving Private Ryan?* master's thesis, Bournemouth University.
- Pine, B. J. and J. H. Gilmore. 1999. *The Experience Economy: Work is Theatre & Every Business a Stage*. Boston: Harvard Business School Press.
- Silicon Ice. 2005. *Urban Terror* [Computer program]. version 3.7.
- Valve Software. 2004. *Half-Life 2* [Computer program]. Electronic Arts.
- Ward, P. 2002. "Videogames as Remediated Animation." In *Screenplay: Cinema/Videogames/Interfaces*, G. King and T. Krzywinska, eds. London: Wallflower Press.
- Wasik, B. 2006. "Grand Theft Education: Literacy in the Age of Video Games." *Harper's Magazine* September, 31—39.

BIOGRAPHY

Mark Grimshaw has an MSc in Music Technology from York University, UK and a PhD from the University of Waikato in New Zealand. He currently heads the Division of Digital Media at the University of Wolverhampton, UK. In addition to his work in Games Studies, he is also the lead developer of the open source bibliographic software WIKINDX.

