Game Sound from Behind the Sofa

An Exploration into the Fear Potential of Sound & Psychophysiological Approaches to Audio-centric, Adaptive Gameplay

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Dedicated to my wife and son; Hayley and James Garner. Thank you to the former for tireless support and encouragement and to the latter for (almost!) waiting until I'd finished before being born.

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Preface:

My foray into the study of computer video games, in many ways, feels much like a predetermined event. Although I cannot make claim to being present at the birth of first generation home entertainment gaming systems or the arcade machines that predate them, I can be grateful for a personal gaming timeline that has almost traversed the complete history, or at least an abridged version. As a child, games consoles were prohibited items within my family home and whilst my friends enjoyed the spoils of Commodore 64s, Sega Master Systems and Nintendo Entertainment Systems (some even had retro Atari systems, giving me an addiction-laden appreciation for Pong), I was frustratingly restricted to playing them during fleeting visits to friends' homes. Then fortune favoured me and Amiga were kind enough to release the 500, and better yet, market it as a multi-function personal computer with educational benefits. So, one Christmas, my parents presented me with a word processor and animation/art designer and I certainly remember learning a significant amount from *Bart Simpson vs. the Space Mutants* and *Lemmings*, although my educational odyssey was unlikely to have corresponded to my parents' intentions. From then on I resolved to explore games further and somehow managed to buy my own Gameboy and Nintendo 64 by saving up with a two-pound per week allowance; something I'm still rather proud of.

Games technology is a testament to the way in which humans have transcended the pace of evolutionary development to accelerate progress in a truly dramatic way. As computing power doubles roughly every 18 months the dreams we have standing by, ready to implement, are soon to be realised. Much as in physics we are getting closer to manipulating our world at a sub-atomic level, in computer technology we move ever nearer to creating artificial life, extending our own (perhaps indefinitely), and recreating our existence as a virtual construct. To have the opportunity to be a part of the process is a great honour and unmistakeably exciting.

Sound has always been an essential part of the computer video game experience, drawing the player deeper into the virtual world and creating iconic and instantly recognisable games moments, from the wonderfully relieving sound Sonic the Hedgehog makes when he takes a breath from an underwater bubble, to the levelling up sound of World of Warcraft that haunts the dreams of many a raider. Nevertheless, audio still remains secondary to vision, despite being a significantly more heavily utilised sense. Sound supports our immersion and sense of presence within both virtuality and reality yet is arguably taken for granted in many circumstances. I therefore hope that this work (and continuing associated research) will support efforts to elucidate the value of sound (both within and beyond computer games) and garner appreciation for sound as an invaluable aspect of existence.

Contents:

Thesis Abstract:

The central concern of this thesis is upon the processes by which human beings perceive sound and experience emotions within a computer video gameplay context. The potential of quantitative sound parameters to evoke and modulate emotional experience is explored, working towards the development of structured hypothetical frameworks of auditory processing and emotional experience. Research relevant to computer game theory, embodied cognition, psychophysiology, emotion studies, fear processing and acoustics/psychoacoustics are reviewed in detail and several primary experimental trials are presented that provide additional support of the hypothetical frameworks: an ecological process of fear, a fear-related model of virtual and real acoustic ecologies, and an embodied virtual acoustic ecology framework.

It is intended that this thesis will clearly support more effective and efficient sound design practices and also improve awareness of the capacity of sound to generate significant emotional experiences during computer video gameplay. It is further hoped that this thesis will elucidate the potential of biometrics/psychophysiology to allow game designers to better understand the player and to move closer towards the development of an automated computer system that is capable of interpreting player-emotion and adapting the game environment in response, to create a continuously evolving and unique, player-centred game experience.

Glossary & Regularly Abbreviated terms:

Affective value – Abstract differentiation between stimuli in terms of both their potential to evoke emotional responses and the intensity of said response.

Affective realism – Approach to creating more immersive and ‘realistic’ virtual environments that focuses upon emulation of the emotional interactive processes that exist is reality.

Biometrics – Characteristically refers to systems that utilise physiological data to identify an individual for security applications. Within the thesis, biometrics refers simply to the physiological data, regardless of application.

Biofeedback – Presentation of personal biometric data to the individual, typically as visualised representations.

Biofeedback loop – A circular system in stimuli influence physiological data and, in turn, physiological data influences stimuli in a continuous loop.

Computer Video Games (CVG) – Digital interactive media encompassing home entertainment, mobile, hand-held, internet-based and arcade-based systems. For the purposes of the thesis, the focus is upon home entertainment (consoles, PC/MAC) systems.

Embodied Cognition (EC) – Concept of human cognition, asserting that thought cannot be detached from the immediate environment or the physiology/memory of the individual.

Electrodermal Activity (EDA) – Psychophysiological measure of electrical activity conducted via the skin and related to sweat secretion. The term is commonly used throughout to refer to skin conductance response.

Electroencephalography (EEG) – Psychophysiological measure of electrical activity released during communication between neurons in the brain.

Electromyography (EMG) – Psychophysiological measure of electrical activity during muscular activity. The term is used throughout the thesis to refer to surface EEG techniques collecting signal data from facial muscles.

First-person Shooter (FPS) – Computer video game genre utilising a first-person perspective as game display. Gameplay activity characteristically revolves around projectile weapon combat.

Geographical Distance – The physical distance (space) that exists between an individual and a specific entity/event.

Hypotheticality – A measure of whether an entity/event is concrete/inevitable or abstract/hypothetical/unlikely to occur

Physical realism – Simulations of physical processes (gravity, collision, photorealism, etc.) that supports the creation of virtual environments, that are indistinguishable from reality.

Psychological Distance (PD) – Concept asserting that perception of entities and situations is highly susceptible to the influences of geographical distance, temporal distance, hypotheticality and social distance

Psychophysiology – Studying the relationships between psychological manipulations and resulting physiological activity (measured in living organisms) to understand mental and bodily processes and their relation to each other.

Quantitative Acoustic Parameters – Characteristics of sound that can be differentiated via quantitative measures (hertz, seconds, decibels, etc.)

Social distance – A psychological distance concept asserting that the closeness of social relationships may influence an individual's perception towards a relevant entity or event.

Survival-horror – A classification of computer video game that most commonly refers to aesthetic and mood as opposed to gameplay mechanics. Games characteristically incorporate horror-theme mythologies, characters and scenarios. Their aesthetic is commonly dark, uncertain and threatening in efforts to imply danger and evoke fear.

Temporal distance – The distance (measured in time) that separates an individual from an entity/event.

Web experimentation – an online task that requires participants to interact with web-based materials and provide real-time and/or debrief responses.

Chapter 1

Introduction and Thesis Structure

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Chapter 1: Introduction

The central focus of this thesis is upon the methods by which human beings perceive sound and process emotions during computer video gameplay. The overarching aim is to address the following questions: ‘can quantitative acoustic parameters modulate an emotional experience’, ‘can the processes of sound perception and emotion be realised as mechanically structured frameworks comparable to computer programming code’ and, as an extension of the previous question, ‘can psychophysiological data be processed in a way that would enable a computer system to accurately determine a player’s emotional state during play?’ In concise terms, the intended contributions to knowledge of this thesis are: to support more effective and efficient sound design practices, to position sound as a critical element to generating emotion and therefore as a central element of computer video games, to develop game experience measures that allow the game designer to better understand the player and, finally, to progress the development of an automated computer system capable of interpreting emotional status (by way of psychophysiological and contextual data) and manipulating the game environment in response, creating a continuously adaptive game experience and making games capable of incorporating many innovative, emotion-centred, gameplay mechanics. This opening chapter outlines the principal aspects of study with a view to elucidating the key perspectives relevant to the thesis. Commencing with an outline of relevant terminology and continuing with a testament to the projected contribution of the thesis, current problems in game sound design, emotioneering, fear assessment, and emotion classification are discussed, alongside ways in which this study could potentially support developments across these fields. The chapter concludes with an outline of the thesis structure.

THESIS OVERVIEW

Understanding emotionality is a crucial aspect of human-computer interaction and sound is a critical component to consider when developing emotionality as it is directly associated with the user’s experience of emotions (Alves & Roque, 2009). This PhD thesis documents theoretical research and associated experimentation within the study of acoustics and fear. The work produced is continuously framed within the context of computer video games. The aims of the thesis are to assess literature from a range of disciplines to develop a framework of virtual acoustic ecology within the context of fear, to develop our understanding of the role sounds (excluding musical and vocal) play in eliciting fear during computer video gameplay and to provide quantifiable evidence in support of the hypothesis that manipulation of acoustic properties can affect the nature of a fearful experience.

The primary overarching hypothesis of the thesis states that game sound, biometric data and qualitative game experience descriptors have the potential to operate as a psychophysiological feedback loop within which affective data, in response to crafted game sound events/soundscapes, can be encoded into adaptive game parameters by way of an automated emotionally intelligent system.

The above hypothesis is founded upon two more general hypotheses that are currently being explored in academia. The first is that human emotion (specifically fear) can be understood as arrangements of quantitative variables that exist within the brain and body. It is further postulated that such developing biofeedback technology enables researchers to observe and record many of the parameters of these variables to the degree that they can not only distinguish between discrete emotional states, but also identify variations within individual emotions. Within the context of fear in a survival horror game, this translates to the capacity of an automated system to recognise if a player is feeling fear and establish the nature of that experience. It is asserted that although the progressive psychophysiological equipment is rapidly approaching this goal, biometric technology is not yet capable of meeting such aspirations. Nonetheless, the hypothesis of this work asserts that automated affect assessment can be attainable within a computer video game application, by way of qualitative descriptors synchronised to game events and scenes that enable biometric data to be contextualised, thereby supporting greater accuracy of recognition.

The second foundational hypothesis states that quantitative acoustic parameters (characteristics of sound that can be measured in established units such as hertz, seconds and decibels) have the potential to modulate the affective value of a sound without contextual support. For example, a loud sound with an immediate attack, presented in a previously quiet or silent environment, will always evoke a comparable shock response irrespective of semantic properties, scenario or differences between individual listeners. Furthermore, it is theorised that a comprehensive understanding of the association between sound parameters and player affect has the potential to enable sound designers' effective control over a player’s emotions during play. If the primary hypothesis of this thesis could be conclusively supported, such concepts could be applied to technological developments. Computer video game engines could automatically recognise and learn effective fear-evoking strategies to develop an awareness of the individual player’s personal fear profile that could improve gameplay immersion and enjoyment, contribute significantly to replay value and ultimately (if embedded into the platform architecture rather than an individual game engine) could translate across multiple games to consistently maximise the affective potential of any experience undertaken utilising that hardware system.

The academic review within this thesis brings together core concepts of embodied cognition (see Wilson, 2002), acoustic ecology (see Truax, 1978), virtual acoustic ecology (see Grimshaw & Schott, 2008) computer video game experience (see Grimshaw, 2007) and fear processing theory (see Massumi, 2005) to construct an acoustic ecology of fear within a virtuality framework. Beginning with an overview of emotion theory and fear conceptualisation/processing from contrasting perspectives; the thesis examines perception, specifically: the six main concepts of embodied cognition (Wilson, 2002), thrownness, construal level theory and psychological distance (Heidegger, 1927; Lieberman & Trope, 2008; Winograd & Flores, 1986). These concepts are strongly advocated within the thesis and influence the conclusions that inform both the preliminary experimentation and hypothetical frameworks documented later within the thesis. Existing empirical and conceptual research concerning acoustic parameters, sound classes and modes of listening are also amalgamated and refined via the survival-horror game context. This research also includes a consolidation of literature relevant to internet-mediated experimentation and a rationale is put forward, advocating the internet as a reliable and powerful resource for empirical investigation within this field. Empirical investigation includes several experiments measuring players' experience of fear by way of both innovative qualitative analysis (real-time intensity vocalisation) and quantitative biometrics. Obtained data reveals that changes in the acoustic parameters of game sound can have a significant impact upon the player's emotional (fear) experience. Both empirical data and secondary research are consolidated to produce a hypothetical process of fear that is re-contextualised into a gameplay relevant acoustic ecology. The framework of sound-emotionality presented within the thesis leaves room for further developments. Future work could explore the concepts presented in more highly specified detail, most specifically, the variances in fear elicitation that can be observed in response to a comprehensive range of parameters within individual acoustic effects. Increased specification will address the impact of parameter settings, for example: high-pass filtering within reverberation, degree angle within localisation, and individual frequency bands within equalisation. Such detail would enable the development of a comprehensive framework of subjective emotional experience and quantitative acoustic manipulation within a computer video game context.

DEFINITIONS OF RELEVANT TERMINOLOGY

The term *computer video game* (CVG) is applied throughout in reference to the electronic medium that embodies and contextualises the acoustic, emotion and psychophysiology research explored within the thesis. This term is favoured above alternative descriptors as it is a comprehensive term that accommodates the two most common terms presented within recent relevant literature: *computer game* (for example, Grimshaw & Schott, 2008; Parker & Heerema, 2008; van Reekum et al., 2004) and *video game* (Perron, 2004; Ravaja et al., 2008). For the purposes of the thesis, CVG will refer to commercially available electronic software and incorporates most modern platforms of gaming (including handheld/portable devices, home consoles, personal computers, mobile devices/phones and internet gaming). Although arcade, gambling/public house and early years children's toy machines are not explicitly removed from reference, they are not directly relevant to this study.

The first-person shooter (FPS), like several other genres (and indeed entertainment mediums), cannot be fully encapsulated within a general framework, notably in terms of the finer details. As discussed in more detail, later within the thesis, the FPS genre is evolving substantially and the nature of this study itself is to further support this progression. The foundations of the FPS however, remain relatively constant; integrating a 360^{o}/3 axis first-person perspective, visible avatar arms/hands/weapons, a real-time rendered 3D virtual environment and gameplay mechanics centred primarily upon exploration, shooting and survival. Some recent, innovative titles do oppose these characteristics, including *Amnesia: the Dark Descent* (Frictional, 2010) and *realMyst* (Sunsoft, 2000) that involve no weapons or combat despite the former being largely considered a survival horror game.

The distinction between CVG genre classifications is discernibly vague and it has been asserted that the survival-horror genre is itself a subgenre of action-adventure (Boyce, 2011). Fahs (2009) posits that survival-horror games are 'one of the only genres not defined by gameplay mechanics, but by theme, atmosphere, subject matter, and design philosophy', several aspects that are discernibly more abstract, and variations in such features are more difficult to differentiate between. Consequently, relatively few titles share a common framework. Common variations between horror-themed games include perspective (first or third-person) and combat system (firearms, melee weapons or unarmed) but direct comparison of most modern titles frequently reveals significant differences between approaches to the more subtle aspect of game parameter settings (health, weapon damage, ammunition availability, enemy frequency, enemy health, etc.). Within this study, survival horror therefore refers to any computer video game that crafts atmosphere, environment and circumstance to evoke fear-related affect during gameplay irrespective of gameplay mechanics or perspective.

With regards to sounds within a CVG context, the term *game sound* is favoured over *game audio* only in response to the greater commonality of the former within analogous research (see Collins, 2008; Grimshaw & Schott, 2008; Wu, Li & Rao, 2008, etc.). Collins (2008, p. 3) separates game sound into four categories: dialogue/speech, music, sound effects (typically representative of an individual entity/event) and ambient sounds (characteristically background sound, slow evolving and to establish scene). This research is concerned only with these latter two classes and to support efficiency and transparency throughout the text, the idiom *sound effects* is employed as a blanket-term incorporating both ambience and sound effect classes. Both sound effects and soundscape ambiences are themselves sub-categorised into numerous divisions of game sound throughout the thesis to accommodate the various functions and traits that distinguish sounds within a computer video game.

THE 'FEAR PROBLEM' WITH COMPUTER VIDEO GAMES AND OTHER RELEVANT AREAS OF DEVELOPMENT

At the time of writing, the AAA (referring to premium commercial game titles) games industry appears divided with regards to how horror themed games should approach the concept of frightening their audience, the most notable divide being between action-orientated and exploration/puzzle types. It is not possible to accurately determine a game's approach to horror from its broader design choices, for example, whilst *Amnesia: the Dark Decent* (Frictional Games, 2010) and *F.E.A.R 2: Project Origin* (Monolith, 2009) both share first-person perspectives, the former precludes a combat system altogether whilst the latter presents the player with an array of standard FPS weapons and plentiful ammunition supplies.

One notable trend, observable whilst considering development of modern horror games titles, is the tendency amongst franchises to gradually move the focus away from generating fear and towards increased action quotas. This progression can clearly be observed within the *Dead Space* (Visceral Games), *F.E.A.R* (Monolith) and *Resident Evil* (Capcom) series all three of which have significantly increased frequency of action set pieces, ammunition/health supplies and/or enemy spawns and have also introduced local cooperative play options. The original *Resident Evil* (1996) title utilised many gameplay mechanics that epitomised the survival-horror genre, including awkward camera angles, latency suffering controls, inaccessible combat systems and overwhelming enemies that often required the player to flee and regroup (Boyce, 2011). However, later incarnations of the series have strived to remove such characteristics in favour of an *over-the-shoulder* perspective (interestingly popularised by the 2005 sequel, *Resident Evil 4* [Giant Bomb.com, 2012]) plus more smooth and intuitive combat. Although such changes are, in some ways, notable improvements (*Resident Evil 4* received a 96/100 Metacritic score [Metacritic.com, 2005] in addition to several games awards) they may also be responsible for attenuating the *fear-factor* of survival-horror by removing aspects of the game design that reduced player coping ability and raised tension (Boyce, 2011). Increased accessibility of modern games arguably increases appeal in many circumstances but has unfortunate consequences in horror-themed gaming. Howell (2011) describes *schematic game design* as a consistency in mechanics between games that supports access, navigation and interaction. Howell asserts that whilst such an approach has some merit, there remains a risk of players feeling a lack of challenge in response to essentially being escorted through game levels and, consequently, they are less inclined to explore any innovative aspects of a game. Instead their experience is limited by their assumptions and 'they will often attempt to play other similar games based on those expectations without exploring the nuances of the individual title'. These concerns are with regards to modern gaming in general and therefore the consequences for games that wish to elicit horror are arguably more severe with schematic game design causing once innovative approaches to fear elicitation to become predictable and even comical. Whilst the above issue is a genuine concern for game designers who wish to evoke fear, it could be argued that such characteristics were destined to be challenged and removed, leaving a requirement for immersion-based diegetic sources to supersede game mechanics as more continuously effective sources of gameplay fright.

Modern horror-themed games can also be classified into two sub-groups, *action horror* and *psychological horror*. Boyce (2011) asserts that the former is a largely western horror tradition, based primarily around shock and gore, whilst the latter is characteristically eastern and focuses upon narrative, atmosphere and unease. This certainly has been an apt differentiation (e.g. the *Silent Hill* series [Konami, Japan] in comparison to the *Doom* Series [ID software, USA]). However, recent game developments are beginning to blur the distinctions as some eastern games take increasing action-orientated approaches (e.g. *Resident Evil 6* [Capcom, 2012]) whilst some western-developed games have employed a distinctly eastern approach to atmosphere and pacing (e.g. *Alan Wake*, [Remedy, 2010]).

From a game sound perspective, the above differentiation between design approaches is crucial to sound design that intends to evoke a fearful response in the player. Whilst psychological horror dictates steady pacing and therefore slowly evolving, unnerving atmospheres; action horror requires shocks, disgust-laden horrific revelation and against-the-clock tension devices. This points to significant differences in sound design, with the former approach more likely to employ dissonance, uneven rhythmic structures, uncomfortable ambiences slow-building rises in pitch and tempo, distorted and sharp equalisation, etc. In contrast, an action-horror theme would be expected to require short attack bursts of sound, high contrast volume changes and aggressively quick tempos. Whilst psychological horror deals in sounds that connote the unknown or the uncanny, action horror sounds signify immediate, characterised danger and disgusting imagery.

To better understand the potential for sound to elicit discrete emotional states it is crucial that the evidence collected be obtained from a multi-faceted approach and consequent inferences made in response to concurrent patterns of data. Qualitative psychological responses provide detailed and contextualised information but retrospective analysis lacks temporal accuracy, cannot reliably differentiate more minute changes in affective valence or intensity, and is susceptible to false response, suppression or accentuation based upon participant agenda. The opposing approach of quantitative physiological analysis cannot accurately reflect upon circumstantial nuances and there is currently no relevant system that does not have a question mark positioned above its translation process from physical measure to emotional experience. Quantitative psychophysiological analysis does however present a solution to subjective approaches, circumventing participant agenda and obtaining precise temporal and signal resolutions, allowing researchers to accurately observe when a change occurred and calculate the size and statistical character of that change. Psychophysiological approaches further provide opportunity for the development of automated, artificial emotion recognition systems in which physiological data can be contextualised and emotional states ‘understood’ by a software intelligence. Such progress reaches beyond our understanding of the affective potential of game sound to the concept of emotion-biofeedback loops: automated systems capable of amalgamating physiological responses with game data logging data (from individual events to overarching situations and surrounding virtual environments) to accurately and reliably infer emotional states during computer gameplay and feed that information back into the system. The game engine can then respond with changes to, potentially, any conceivable parameter of the game; from generating a sunrise in response to a player’s happy state, to increasing the avatar’s physical action statistics (run faster, jump higher) in response to a player’s aggressive state. If such a system were utilised within modern games titles: increased concentration could enable the bullet-time function in *F.E.A.R* (Monolith, 2006) or *Max Payne* (Remedy, 2001), elevated relaxation could increase your speed and chance of success in defusing a bomb in *Rainbow Six: Vegas* (Ubisoft, 2006), and angry emotional response could unlock additional ‘renegade’ conversation options in *Mass Effect* (Bioware, 2007).

In addition to such game-specific mechanics, biofeedback systems facilitate the potential for radically improved artificial intelligence systems that could empower non-player characters (NPC) with emotional intelligence. NPCs could react appropriately in real-time to player-emotion states enabling the player to interact with characters like never before and simultaneously opening up a world of possibilities for new game mechanics. Biofeedback has the potential to allow a player to: intimidate or calm a suspect during an interrogation, barter with a passing traveller over the cost of a new plasma rifle, or convince a friendly character to believe in and join your crusade, all by way of feeding physiological information into the game engine that is then translated during gameplay into an appropriate NPC response. Biofeedback emotion recognition systems also present a valuable contribution to the development of serious games projects. Emotional intelligence in NPC characters could support person to person communication training (e.g. sales and marketing industries), stress management training for high-risk and cognitively demanding tasks (emergency services, military, etc.) or emotion training (relevant to psychotherapists, social workers, teachers, etc.) to name a few.

Biometrics within computer video games are currently at a developmental stage it is anticipated that within ten years the technology will become mainstream, the central application being to create an adaptive system, capable of learning the preferences, motivations, and emotional temperaments of individual players and, with that information, creating unique and evolving gameplay experiences (McAllister, 2011). Whilst this particular application is far from an established technology within contemporary gaming, games production companies are currently utilising biometrics for usability and user experience (quality control) testing (Tychsen & Canossa, 2008). Developers of current commercial-grade biometric headsets (www.emotiv.com, www.neurosky.com) advertise gaming as a key application of their hardware. On May 9th, 2012, several websites published rumours that Microsoft was preparing to patent a pressure-sensitive game controller design, capable of recognising an individual user form their unique hand pressure patterns (Greene, 2012). Patel (2009) discusses the *Wii Vitality*, and adaptation of the current Wii motion controller that detects heart-rate and Sony has been reported to have recently patented a bespoke biometric controller capable of measuring muscular movement, heart rate and sweat secretion (Humphries, 2011). With the three primary powerhouses of games development all revealing openness to the technology but yet to take the proverbial plunge, there is clearly a sense that biometrics is not currently perceived to be commercially viable. However, the production of such devices as concept suggests that biometrics as a future potential is great and these manufacturers are all very keen to be the forerunners in marketing biometric games technology successfully.

Cultivating a better understanding of sound within a computer gameplay context is not without substantial merit. Until recently, sound has been perceived as being of secondary importance in virtual reality and computer video games systems (Murphy & Neff, 2011). Alves and Roque (2011) concisely state the chief concern with regards to development of sound in games, stating that it ‘remains the craft of a talented minority and the unavailability of a public body of knowledge […] leads to a mix of alienation and best-judgement improvisation in the broader development community’. Approaches to game sound design vary significantly and this fragmented character lacks cohesion, even within genres, and ultimately is slowing development. Alves and Roque (2011) suggest a holistic and multi-disciplinary approach to game sound that could support the eventual creation of guidelines to unify progression between developers and researchers. Murphy and Neff (2011) posit that game sound is still commonly treated as window-dressing, accentuating the immersive capacity of the visuals and not yet fully appreciated as of equal importance in creation of truly immersive virtual worlds. Although specifically referring to spatial sounds, Murphy and

Neff also assert that one of the key issues with game sound is that it ‘remain[s] focussed on a generalized listening experience’ and does not attempt to recreate the individualised listening that we experience every day. Hug (2011) suggests that game sound, as a growing entity, lacks independence and ‘in many ways still seems to live with its parents, Mrs Film Sound and Mr Realism’. Hug also raises an important question regarding the ultimate aspirations of VR and game sound, noting that a conflict exists between desires to develop a filmic, hyper-real aesthetic and intentions to emulate reality, creating a virtual soundscape indistinguishable from the real. Hug places the representative sound design of the survival horror genre within the former category, as is logical when considering that many of the entities and phenomena contained within the genre exist beyond the parameters of our natural universe and, as such, numerous sounds associated with such entities cannot originate from an emulation of reality. Hug accepts, however, that sounds within this context are afforded acceptance by the listener if they are appropriately *representative*. This requirement is complicated by the definition of this term as it could refer to convention as established by proceeding games or comparable motion pictures (extending even to sounds that reflect a description within a novel) or expectation based upon prior experience of analogous physical interactions.

The motion picture *Jurassic Park* (Spielberg, 1993) presented a complete sonic characteristic for the Tyrannosaurus Rex based entirely upon conjecture inferred from the sparse evidence available. The acoustic attributes (intensity, relative pitch, timbre, ADSR [attack, decay, sustain, release], etc.) of the beast’s mighty roar are based upon assumptions of the physical properties of the animal, surmised from the skeleton, yet the roar is believable because it matches expectations drawn from the listeners’ own suppositions (drawn primarily from visual analysis). This extends even to sounds that have significant (but not complete) grounding in reality, such as the earth-shaking stomp of the dinosaur. Whilst some elements of the physical interaction can be proven (nature of the surface being walked upon, acoustic properties of the surrounding environment, etc.) the intensity of the sound is inferred as is the weight of the creature, the typical velocity of its steps, the contours and shape of the foot, etc.; all are estimates.

Survival horror games clearly do not have a fixed position between fantasy and reality. For example, a modern-day, zombie-themed title may contain many sounds analogous to the real word (gunshots, limbs being severed, carcasses being consumed, etc.) whilst a science fiction horror title may contain comparatively more fantastic sounds (plasma rifle shots, tractor beams, teleports, etc.). As a result, this genre is (arguably) particularly difficult to approach with an established consensus on sound design, but conversely, to effectively produce such a system would be an impressive and substantial step forward.

FEAR AND SOUND FROM A FIRST-PERSON PERSPECTIVE

The recent developments in computer video games have consequences for the first-person shooter (FPS). Specifically, the *run and gun* association to FPS games has arguably now become a stereotype. Critically acclaimed and commercially successful first-person perspective titles have begun to move away from the ‘mindless shooter’ generalisation by means of intricate narrative and character development, more sophisticated problem solving, moral choice, strategic cooperative multiplayer and role-playing elements such as weapon upgrading, item management and open-world questing. The changes being witnessed here are not part of a linear progression but rather a branching of the FPS into a number of sub-genres, developing in parallel.

Although the first-person shooter game type is arguably not representative of the survival horror genre, several modern titles exist that utilise this perspective (e.g. *Darkness Within: Pursuit of Loath Nolder* [Zoetrope Interactive, 2007] and *Call of Cthulhu: Dark Corners of the Earth* [Headfirst Productions, 2005]). The FPS genre has topped the global sales charts between 2009 and 2011 (Independent.co.uk, 2009; Guardian.co.uk, 2010; Guardian.co.uk, 2011), supporting assertions that the format is both extremely popular and substantially profitable. With relevance to the thesis, several practical considerations position the FPS format above the various alternatives, most notably the availability of powerful graphic user interfaces (GUIs) that enable high levels of customisation and world building tools without requiring substantial programming ability. First-person source development kits (SDK) are arguably the most advanced toolsets for modern game creation, incorporating the latest technological developments in sound, graphics, artificial intelligence systems and scripting. FPS game modification communities are substantial with individuals and groups experimenting with the engines and sharing results. As a result FPS-SDKs provide a wealth of opportunities to develop bespoke test-games tailored precisely to the desired research methodology.

With regards to game sound, the current available technology of the FPS engine presents a wealth of opportunity for experimentation. At the time of writing, the two principal competitors in this milieu are the *Unreal Engine* (Epic Games, 1993-2012) and the *CryEngine* (Crytek, 2004-2012). Currently in their third incarnations, these game engines both exist as free to use internet-based versions (regularly updated fully downloadable SDK, incorporating all the features and technology but providing minimal content [models, sounds, textures, etc.]) and game-based versions (bundled SDK that includes access to all content present in the accompanying game but cannot be updated and thus the technology can become out-dated). Both engine SDKs provide impressive arrays of audio manipulation tools that transform basic sounds into integrated *sound events* (an individual or group of sounds integrated into a game via digital signal processing native to the engine). Sounds can be accurately localised within 3D space (multi-channel playback compatible); attenuated in response to physical objects within the virtual environment, looped and randomised to enable greater length ambient sounds without large numbers of varied source recordings; and modulated in terms of pitch, volume, equalisation, etc. to enable a single repetitive source sound to appear as many. Both engines also support audio optimisation and are compatible with modern compression algorithms (mp2/mp3, Ogg Vorbis, etc.) allowing the sound designer to implement complex sonic landscapes and events whilst remaining resource-efficient (Mycryengine.com, 2012; Unrealengine.com, 2012). Although both the Unreal and CryEngine systems are comparable in many respects, the latter arguably provides greater functionality and control due to full integration with the FMOD middleware program, a professional-grade toolset designed as a middle-ground between digital audio workstation (DAW) and game sound implementation tool, ultimately offering a larger number of options, parameter settings and features than the Unreal Engine’s native audio system (fmod.org, 2012).

As a genre, the first-person shooter provides the desired tools and commercial appeal. Furthermore, it is the nature of the first-person perspective that supports the fear and sound contexts of this thesis. Third-person perspectives may effectively elicit fear as an empathetic emotion (Perron, 2004), analogous to typical filmic approaches. Sound design, however, arguably connects more directly with the audience/player as a result of the immersive quality of sound. This is particularly true when considering extra-diegetic sound design (voice-overs, music, hyper-real effects) but acoustic treatments of diegetic sounds are also ordinarily intended to affect the audience directly (for example, an extended period of silence followed by a jolting, intense sound). Whether playing a computer video game or watching a film, sound exists within a three-dimensional environment within which the viewer is also placed, the energy waves travelling through real spaces and reflecting off real surfaces (Grimshaw, 2007). Film sound designers commonly mix sounds to a first-person perspective, with the audience (as opposed to a diegetic character) as the central point of reference, often with the intention to facilitate immersion (Massey, 2004). The same is true in the majority of survival horror games’ sound design, within which third person visuals are paired with first-person sound. Logically, it could be assumed that the intention here is to combine immersive impact within one aspect with the empathetic effect of another. This thesis does not attempt to assess the truth in this assumption nor compare first and third-person perspectives for fear elicitation effectiveness and instead acts upon the assumption that immersion and presence, consolidated by both sound and visuals, have greater potential to successfully evoke fearful responses from players.

The potential value of better understanding fear, both in general and within a game sound context is discussed in chapter 3. However, the thesis is intended to present frameworks integrating computer gameplay and sound that could be expanded upon in future research to study discrete emotions other than fear. The foremost reasoning for selecting fear as the particular emotional state under inspection is that fear is debatably the sole emotion, outside of those intrinsically associated with gaming as an activity (frustration, excitement, pride, etc.), that has defined an entire genre. Fear can also be ostensibly described as a relatively more concrete emotional state, with a greater consensus regarding metaphor and simile. Consequently, fear is potentially a more suitable candidate for quantitative analysis in comparison with a more abstract emotion such a joy. This thesis retains focus consistently upon fear-related assessment of game sound and does not explore alternative emotional states but suggests such a route as a viable future extension.

Throughout the thesis, there is a distinct emphasis upon sound as opposed to visuals or mechanics and the intentions of the study are to support developments exclusively in sound effects (non-speech/non-musical) for computer video game applications. Within CVG studies (and indeed several related disciplines) sound, particularly sound effects (as opposed to speech and music) are underrepresented when compared to specialities such as graphics, artificial intelligence and game mechanics (Collins, 2008) and the technology surrounding game sound is equally overshadowed by graphics and artificial intelligence (Parker & Heerema, 2008). This in itself is a valid reason to pursue a study in game sound but additional motivations include improving accessibility and experience for visually impaired audiences and capitalising upon the immersive, three-dimensional nature of sound as a solution to the shortfalls of current visual displays. It is arguably appropriate to assume that successful development of virtual worlds indistinguishable from our own, that elicit deep and genuine emotional states akin to reality, cannot be attained by way of a single developmental aspect. Ultimately, equivalent breakthroughs across all relevant areas will be required to achieve such goals and it is therefore crucial that sound not be left behind.

OUTLINE OF THESIS STRUCTURE

The overarching structure of the thesis can be separated into three segments, the first of which provides literature reviews relevant to the four primary areas of study: emotions (chapters 2 and 3), acoustic ecologies (chapter 3 and 4), virtuality/game theory (chapter 4) and psychophysiology (chapter 5). A discussion regarding the nature of web-mediated experimentation environments is also presented as part of the methodology chapter (6), providing additional background research in preparation for a related preliminary trial. The second segment encompasses the methodologies (chapter 6) and results/discussion (chapter 7) of three preliminary trials that assess the fear-related affective potential of various different sounds and digital signal processing (DSP) parameters. The final segment consolidates the conclusions raised throughout the thesis and presents a set of hypothetical frameworks intended to reflect the conclusions of the preceding chapters and visualise the conceptual processes that occur during sound perception and emotion processing in a computer video game context. These frameworks are the primary contribution this thesis makes to knowledge and go some way to supporting the primary research hypothesis by proposing a set of models that present auditory processing and emotional experience as intrinsically linked to physiology and psychology, revealing how influencing one area of the framework will have significant and potentially dramatic effects upon another.

The thesis closes with an overview of future study and, in the appendices, documents raw data obtained from the preliminary trials and presents a design document for *Xpresenc*e, a bespoke biofeedback software program intended to manipulate game parameters in response to user-affective data.

The next chapter commences the literature review with an overview of emotions, both within general and CVG contexts. The importance of human emotion throughout our evolutionary history is considered and key perceptions are documented. In preparation for further discussion regarding automated emotion recognition, classification methods are also evaluated alongside an account of current neuroscience perspectives and an introduction to relevant concepts of fear.

Chapter 2

Understanding Emotion and the Nature of Fear in Games

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Chapter 2: Understanding Emotion and the Nature of Fear in Games

INTRODUCTION

A comprehensive and precise understanding of emotion, both in terms of evocation and recognition, could signify a substantial landmark in games advancement. Emotionality in gaming already plays a pivotal role in the design and development of new games titles (Lazarro, 2004). This chapter provides an introduction to the thesis by way of outlining one of the key areas of study it builds upon. Beginning with a testament to the value of research concerning human emotion, this chapter then presents an overview of relevant concepts relating to general emotion theory. Later sections increase specificity, discussing human emotion within a computer video game context; and finally, the experience of fear is outlined to pre-empt more detailed discussion within later chapters.

THE IMPORTANCE OF HUMAN EMOTION

The original debate concerning the function of human emotion would discuss whether a formal function of emotion existed at all. Stoic philosophers who proposed enlightenment through logic and reason would argue that emotions arose from false judgements (Baltzly, 2010). Contesting Athenian philosophies asserted that emotions were not irrational, but were instead a function of cognition (Konstan, 2006: 421). Descartes (1649) believed that emotions could be both function and dysfunctional depending upon the context. Darwinian theories (see Darwin, 1872) asserted the functionality of emotion: insisting upon an evolutionary basis for emotion origin within which emotions have developed to become crucial to our ecological adaptation and survival. Oatley, Keltner and Jenkins (2006) document several specific emotion functions that relate to evolutionary thought: orientation (prioritisation of attention towards imminent threats/opportunities), organisation (emotional influence upon physiological processes to support survival-related action) and communication (supporting social interaction and ultimately, reproduction). Contemporary research into mirror neurons (neurons that fire both when performing an action and observing the same action in others to promote empathetic understanding [Keysers, 2011]) supports communication as a pivotal function of emotion.

The concept that successful interaction between humans relies heavily upon emotional communication and understanding has been applied to human-computer interaction (HCI) by Reeves and Nass (1996), who argue that both natural and social factors are prevalent during interactions between man and machine. Picard (2000) posits that a lack of emotional understanding between humans inexorably leads to frustration and the same effect is possible in certain human-computer interactions. Emotional interactivity between software and user has influenced the consumer sales of computer technology (Norman, 2004) and existing research has revealed significant positive correlation between user enjoyment and emotional excitement (specifically, suspense) within a computer video game context (Klimmt et al., 2009).

Emotionality is now an established component of many computer video game (CVG) titles and a growing body of research supports its importance (Freeman, 2003; Holbrook et al., 1984). Perron (2005) asserts that emotional experiences resultant of gameplay have a great potential for improving player experience and that the more intense the emotion, the greater the perceived experience. Perron also describes the experience of fear within a survival horror game as a pleasure and a significant incentive to play. In addition to a positive influence upon immersion, performance and learning (Shilling et al., 2002), emotionality has the potential to grant players access to a wider spectrum of emotional states than cannot be easily achieved in reality (Svendsen, 2008: p.74). As Wilde (1891) suggests:

"Because art does not hurt us, the tears that we shed at a play are a type of the exquisite sterile emotions that it is the function of art to awaken." (Oscar Wilde, 1891)

It could be asserted that the majority of the populations living in developed nations are currently fortunate enough to exist in an environment within which many of the evolutionary functions of our being are not fully required to ensure our survival. For us, survival denotes something quite different from that which evolution first developed our emotions for. To an extent, we are capable of going far beyond utilising our emotions to survive an environmental scenario (such as fear engaging a flight response to escape a predator) to actively manipulate our environment in a way which may remove the possibility of a threat even occurring. As such, we are equipped with emotional functionalities that exist somewhere between under-exerted and redundant. One particular theory is that, in many ways, artistic creation has sought to fill this void by way of engaging our most intense emotion processes and enabling us to fully immerse ourselves within the human experience without the traditionally associated physical risk. The latter sections of this chapter will explore this idea further in an attempt to elucidate why we desire emotional experiences, including those perceived to be inherently negative.

EMOTION: ORIGINS, DEFINITIONS & PERSPECTIVES

This section presents a brief history of emotion research and outlines the developing nature of emotion theory; both in terms of what emotions are and where they originate from. More contemporary literature is presented that makes reference to emotions and affect, specifically within a computer video game context, to better elucidate some of the central concepts that this thesis will build upon.

In terms of etymology, emotion can be differentiated from commonly associated terminology: affect, feeling, temperament and mood. For the purposes of the thesis, affect is utilised as the blanket-term, encompassing all associated vocabulary. Positioning affect as an overarching term takes influence from Fleckenstein (1991: p.448), who describes affect as 'an extricable element of cognition'. Watson and Clarke (1994) distinguish emotions from moods, asserting that the former are event-related, reactionary responses to individual triggers whilst the latter are repetitious, cyclic and better thought of as emotional summarisations of a more prolonged period. Gray and Watson (2001) suggest that emotions are responses to external stimuli whilst mood refers to responses to both external and internal bodily processes. They also suggest that whilst emotions may be of a full range of intensities, mood is characteristically low to moderate intensity. Thayer et al. (1996: p.5) connects the term mood to *feeling*, describing mood as 'a background feeling that persists over time'. Terms such as feeling and *temperament* appear largely to function as synonyms, whilst emotion and mood help clearly differentiate immediate and prolonged affective response.

Consideration for human emotion reaches back to Greek philosophy. Aristotle's conceptual approach documented theories that arguably remain pertinent in modern research. Emotion was perceived to be dependent upon our belief structures, associated with bodily action and able to give an argument a perceived truth. Emotions were, however, argued to be capable of generating irrational behaviour and were characterised as a component of the human condition that one must take responsibility for. A suitable, encompassing hypothesis that notably resonates with modern theory (discussed later within this thesis) is the concept of an interrelationship existing between emotions, cognition and behaviour; within which emotions may manipulate perception (or action, judgement, etc.) whilst conversely, these entities may also manipulate emotion. Descartian philosophy expands emotion theory further, presenting six fundamental discrete emotions (wonder, desire, joy, love, hatred and sadness) and perpetuating the notion of regular interplay between emotions, physiological factors and the environment. Descartes (1649) also proclaimed the existence and involvement of a soul within an emotion framework and argued that conscious thought cannot entirely regulate emotion, but can suppress it to an extent. Descartian theory posits that all emotional states have inherent function, however; in correspondence to Greek philosophy, particular emotional states within certain contexts are described as dysfunctional. Darwin's work (1872) may have been one of the pioneering scientific explorations of emotion; nevertheless the conclusions of Darwinian thought still largely resonate with the philosophies that preceded it. What could arguably be depicted as Darwin's primary contribution to emotion theory was his notion of an evolutionary origin and development process for human emotion. Within this framework, emotions develop steadily over time in response to changing environments that necessitate emotional activity/processing for survival. Figure 1 (below) outlines a comprehensive, albeit not exhaustive, list of emotion perspectives and notions that are separated into macro (more general, overarching) and micro (more specified, component) theories to provide a concise overview of general emotion theory. Many of the theories detailed here are described in greater detail within *Changing Minds: in Detail* (Straker, 2010) and *Understanding Emotion* (Oatley, Keltner & Jenkins, 2006).

Figure 1: Consolidation of relevant emotion theories

Macro Theories	*Description*	*Citation*
James-Lange theory	Emotions are in response to bodily changes that are themselves, responses to the environment.	James (1884)
Cannon-Bard theory	Bodily changes are in response to emotions which are more directly tied to the environment.	Cannon (1931)
Singer-Schachter / Two-factor theory	Emotions are equivalently susceptible to physiological and cognitive factors.	Schachter & Singer (1962)
Situated Emotion theory	Emotions are not completely internalised. Emotion is the product of an organism's investigation of its environment.	Griffiths & Scarantino (2009)
Affective Events theory	Emotions exist within a timeline and are influenced and caused by events (emotion episodes).	Weiss & Cropanzano (1996)
Appraisals theory	Emotions follow appraisal (or evaluations) of an event and relational (relate self to object).	Arnold (1954)
Component Process theory	Emotions are broad entities that exist as a series of synchronised physiological and cognitive components.	Scherer (1988)
Dramaturgical theory	Life is a drama within which emotions support our 'roles' and enable a dramatic performance built around strategy and rules.	Hochschild (1979)
Drive theory	Emotions are amplifiers of drive (hunger, lust, etc.) which define action choices via motivation or repulsion.	Tomkins (1962)
Evolutionary theory	Emotions originated and developed via evolutionary processes and can transcend behavioural and cognitive influence to be compared across different cultures and species.	Darwin (1872)
Neuro-physiological theory	Emotion is a valence-related mental state organised within the limbic system.	Gainotti (2000)
Micro Theories	***Description***	***Citation***
Affect Perseverance	An emotional bias/preference may continue after the initial appraisal has been invalidated.	Sherman & Kim (2002)
Durability Bias	Tendency to over-estimate the duration of a novel emotional state.	Wilson et al. (2000)
Focalism	Emotional state may cause fixed attention upon a specific entity, causing a false assumption that our current emotions are completely dependent upon that entity.	Erber & Tesser (1992)
Impact Bias	Tendency to over-estimate the overall impact of a novel emotional state.	Gilbert et al. (1992)
Mood-Congruent Judgement	Judgements are inescapably affected by emotion.	Isen et al. (1978)
Mood-Congruent Memory	The presence of emotion supports the passage of information into the long-term memory (LTM).	Eich, Macauley & Ryan (1994)
Mood-dependent Memory	Recollection of emotional memories is more likely to correspond to the emotional state being experienced.	Eich, Macauley & Ryan (1994)
Opponent-Process theory	Emotions act in opposing pairs (e.g. Pleasure – pain). Experience of one will suppress the other.	Solomon (1980)
Emotional Contagion	Emotional state can spread quickly through large crowds.	Jones & Jones (1995)

Nearing the turn of the 20th century, researchers with expertise exclusively related to emotion theory began to emerge. James (1884) prescribed to the philosophy that a clear correlation existed between emotional experience and physiological changes, but in addition, proposed a causal pathway through which such physiological effects preceded (and were directly responsible for) emotional experience (the James-Lange theory of emotions). In response to the lack of conclusiveness presented within this explanation, a reverse-theory unsurprisingly surfaced, claiming the opposite causal pathway within which emotional experience was responsible for physiological effects (the Cannon-Bard theory). Cannon (1931) presented a neuroscience perspective of emotion, insisting that emotional states were dependent upon the neural programming of the brain. Cannon (1931) and Bard (1928) presented the three-level function system that differentiated emotional thought from reflexive and logical, placing each on a continuum based upon each type's level of autonomy (emotions were centralised between the highly autonomic *reflexive* thought and the largely conscious *logical* thought).

In very broad terms, theories of emotional experience can be separated into three categories: somatic theory (physiology rather than judgement is essential to emotion), cognitive theory (judgement is the crucial determinant of emotion) and perceptual theory (a hybridisation of the other two). Oatley, Keltner and Jenkins (2006) differentiate emotions from moods, personality and affect. Here affect is presented as a blanket term encompassing emotion, mood and personality as sub-classifications (and is used in this way throughout the thesis), each of which is distinguished by its intensity and temporal characteristics. Emotions have quick onset and dissipation times and typically last for a relatively short time, whereas moods have a lower intensity, more gradual fade in/out quality and can last for weeks, months or years. Personality is incorporated as it acts as a determiner of emotion and mood (e.g. introversion = anxiety = fear [within a social context]) however, it is itself determined by associated emotions and moods.

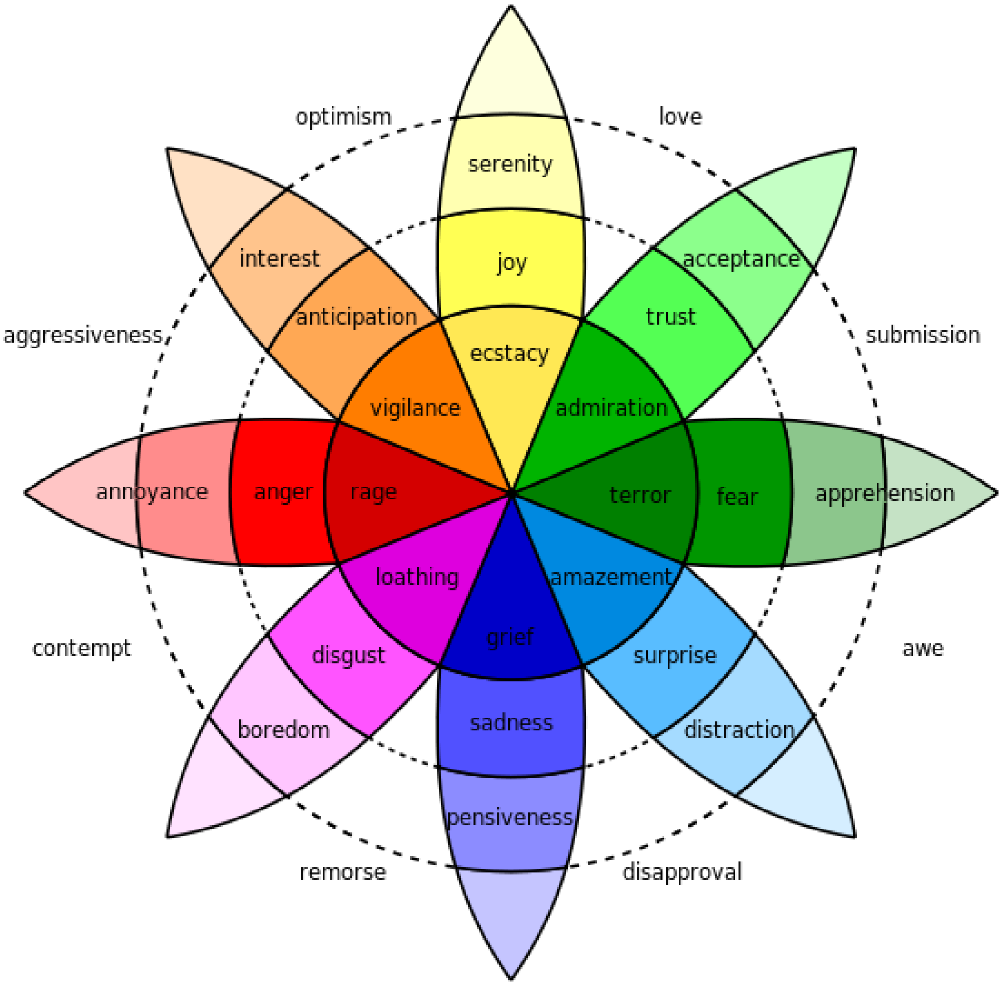
The Dramaturgical theory (Hochschild, 1979) positions emotions as enablers of socio-cultural roles (for example, love provides a general script for the role of protector within a relationship between parent and child). Isen (1987) highlighted the socio-cultural aspect of emotional function, positing that emotional experience within one situation can affect social judgements and behaviour within a subsequent situation; an ongoing looping mechanism that will be regularly referenced within the thesis. Oatley, Keltner and Jenkins (2006) provide additional insight into a culture-based understanding of emotion, presenting a complication in western cultures, reconciling the conflict between perceiving inappropriate behaviour as emotional, and the romanticist perspective that hypothesises emotional behaviour as the true expression of individuality and humanity.

Another distinction separates eastern and western perspectives into independent (based upon individualism, in which people are viewed as autonomous and unique) and interdependent (relating to collectivism; sense of shared goals and social cohesion) forms respectively. Within these perspectives different emotions, usually contextually bound, are treated differently. Oatley, Keltner and Jenkins (2006) present anger as an example, stating that an interdependent culture may look upon anger as unacceptable between relations but an independent culture is more likely to accept this emotion as an assertion of authority or independence, a phenomenon that has been observed in relevant research (Miyake et al., 1986). Benedict (1946) connects the notion of values to emotion, stating that in western society a value such as sincerity relates to behaviour that genuinely reflects emotional state; whilst eastern society perceives sincerity more as behaviour that satisfies a social duty without emotional conflict. Just as different cultural perspectives can alter the way in which emotions are experienced within a social environment, certain emotions have been shown to not exist within certain cultures due to the social value structure of that society. Other cultures claim ownership of an emotional state that is unique to them, such as the German term *Schadenfraude* (shameful joy: pleasure derived from the suffering of others) or the Bengali term *Obhiman* (sorrow caused by the insensitivity of a loved one [Russell, 1991]). Hyper and hypo-cognition of emotions refers to a mechanism by which an emotion can be given increased or decreased priority via cultural developments and social discussion.

EMOTION CLASSIFICATION SYSTEMS

Classification of human emotion is another ongoing area of study that can be separated into two primary approaches - discrete and dimensional. The six emotional states model of Descartian theory exemplifies early discrete classification and has since been presented in many distinct incarnations. Plutchik (2002) proposed a *wheel of emotions* (figure 2), a circular arrangement of eight primary bipolar emotional states, each of which is further broken into sub-components as determined by the intensity of the emotional experience.

Figure 2: The Wheel of Emotions, by Robert Plutchik (2002)



Differentiation between emotions has drawn upon alternative origin perspectives; *basic* (determined by biology and evolution, universal to all humans) and *complex* (idiosyncratic, socio-cultural) emotions relate to the theories documented earlier within this chapter. The alternate means by which emotions are believed to be triggered has also been utilised to differentiate emotions into discrete categories. States evoked by external stimuli within the environment have been identified as separate from those caused by internal physiological states (hunger, pain, fatigue, etc.), categorised respectively as *Classical* and *Homeostatic* (also referred to as *Primordial*) emotions (Craig, 2008; Denton, 2006). Prior to Descartian classification, the 1st Century BC Chinese encyclopaedist Li Chi (referenced by Russell, 1991: 426) identified joy, anger, sadness, fear, love, disliking and liking. A critic of Descartian dualism, Spinoza (1677) challenged Descartes' six emotions with a simplified paradigm that included only pleasure, pain and desire. In contrast to the relatively minimalist classical categorisations of human emotion, contemporary classification largely favours a more comprehensive list with many terms suggesting a leaning towards high-specificity, socio-culturally driven emotions that include: separation distress, aversive self-consciousness (Prinz, 2004) and pride in achievement (Ekman, 1999).

The distinct lack of cohesion between contemporary emotion classification systems may suggest that discrete classification of emotions is an inappropriate approach to emotion recognition and feedback systems as the significant inconsistencies between contemporary emotion class lists may restrict such recognition systems to being imprecise or potentially, completely arbitrary. Dimensional classification systems provide a practical alternative and typically plot emotional data along two or three-dimensional axis by way of related factors that are less difficult to ascertain by way of physiological measurements (including: heart rate, respiration rate, galvanic skin response, electromyography and electroencephalography) commonly interpreted as arousal and valence along a two dimensional plane. Dimensional classification arguably reflects the lateralisation (specialisation of function between the brain hemispheres) effects documented within emotion theory. Lateralisation theory has presented a number of assertions relevant to classification development that include: The right hemisphere is superior at recognition of emotional expression (Strauss and Moscovitch, 1981), emotions of positive valence correlate to greater left hemispherical activity whilst negative valence corresponds to greater right hemispherical activity (Davidson et al., 2003). The exact nature of lateralisation effects and emotions are yet to be fully uncovered, and it has been suggested that emotion processing itself is largely dominant within the right hemisphere (Tucker, 1992), which if true, limits the practical application of the above theories.

Dimensional classification can itself be sub-categorised into several commonly utilised forms: the circumplex model (see Russell, 1980), the 'consensual' positive activation / negative activation model (PANA, see Watson & Tellegen, 1985) and the vector model (Bradley et al., 1992). Both the vector and circumplex models integrate valence (centralised at zero, with the potential for positive and negative measures) and arousal (typically commencing at '1' and increasing in integers). The difference is a disagreement with regards to the possibility of neutral valence / high intensity emotional states. Within the circumplex model, such an entity is possible (creating a characteristic circular 'O' shape); whereas within the vector model it is not (creating a '<' shape).

Ruben and Talarico (2009) describe the PANA model as ‘a 45 degree rotation of the circumplex model’, in which positive and negative activations are ‘anchored’ at opposite ends of the model. Li et al. (2010: p.146) argue that although the PANA model is an improvement, all incarnations of the circumplex model lack ‘acceptable theoretical and psychometric integrity’, as the positioning of discrete emotion labels along the dimensional plane reflects how lay people visualise emotion structure in their minds rather than an informed, evidenced framework. Continuing to explore this problem, Li et al. discuss the *bifurcation model*, a relatively modern approach born from complexity theory (as opposed to the reductionist approaches that are more commonly employed as scaffolds of emotion theory) that asserts a dynamic nature of discrete emotions and a fluid, self-organising system in which ‘emotions aggregate (or disaggregate) depending on different environmental circumstances’ and ultimately strive to reach and maintain equilibrium (Li et al., 2010: p.148). The potential for practical application of these contrasting approaches is arguably dependent upon the specific aims and characteristics of the project being undertaken. Classification within emotion research is an area of continuing development and is not exhaustively documented within this chapter. Later chapters further explore and evaluate classification in greater detail, within the context of computer video game-based emotion feedback loop systems.

The debate between *basic* and *constructionist* accounts of emotion is of particular relevance to this thesis as it concerns our potential to recognise/interpret emotions by way of machine code. The basic account of emotion asserts that the function, meaning and, therefore, expression is quantifiably different between each emotion. As such, recognition systems would not require contextual knowledge as a unique neural and physiological pattern would elucidate distinction between the various emotional states (Ekman, 1992). Constructionist theory, however, integrates semantic meaning and conceptual knowledge and argues that such factors would blur the distinctions between emotional states if only brain activity and physiology were observed (Barrett, 2006). In development of a software-based emotion recognition system, it must be decided whether contextual information is necessary to enable successful categorisation and, if so, by what means such information will be acquired. This particular question is explored in more detail later within the thesis.

THE NEUROSCIENCE OF EMOTION

“[I]t is becoming increasingly accepted that emotions comprise a significant component of rational thinking and human behaviour” (DeGroot & Broekens, 2003)

It is the term ‘rational’ in the above quote that points to the lines between emotion and cognition, instinct and logic, and feeling and reason becoming increasingly blurred, and suggests that a comprehensive understanding of human thought processes must include emotion as an integral component; as Perron (2004) states: ‘cognition and emotions work together’. The previous section approached emotion theory from a range of perspectives but with the focus being on theoretical models and philosophical notions. Within this section, the biological and chemical processes that constitute affective neuroscience and embody emotional experience are discussed. Our perception of emotions within contemporary society continues to connect emotions to human biology, for example, the symbolic association between emotion and the heart still permeates recent music and art. VanScoy (2006) asserts that emotions and human biology share a steadfast connection: ‘emotions are […] whole-body states that activate hormonal responses, the cardiovascular system and other systemic reactions’. Winkle (2000) insists upon a significant connection between emotions and body chemistry, positing that an enduring suppression of anger inexorably leads to anxiety and depression by way of toxicosis. Particular chemical secretions have been associated with specific emotional states, including: cholecystokinin with fear/panic attacks (Bradwejn, 1993), dopamine with desire/motivation (Rolls, 2000) and serotonin with aggression (Crockett et al., 2008). Research has questioned this association however, and relevant research has documented several occurrences of individuals receiving damage to emotion-related physiology yet maintaining an accurate mental understanding of emotion (see Oatley, Keltner & Jenkins, 2006). Popular beliefs allude to the potential for controlling our emotional state by way of conscious physiology control (closing the eyes, slowing breathing, changing stance, etc.), however some of these assumptions have been contested (Conrad et al., 2007).

Whilst there may be a consensus that the primary organ responsible for emotion processing is the brain; debate remains as to which particular structures within the brain support emotions, how they interrelate and the role of the nervous system within the overall process. The collection of brain structures known as the limbic system is commonly believed to house the central processes of emotional experience (MacLean, 1952; Panksepp, 2005) although developing research increasingly advocates the involvement of high-level cortical structures in emotion processing (Bechara, Damasio & Damasio, 2000; Cardinal et al., 2002; Maddock, 1999). Rolls (2000) postulates that connections between the pre-frontal cortex and the amygdala reveal a cortical association with emotional valence and motivation. One explanation for this association, which supports a more fragmented perspective between reason and emotion, is that the higher cortical functions observed during emotional experience are acting primarily as suppressors (Levesque et al., 2003).

LeDoux (1995) advocates the amygdala as the primary neural structure involved with emotion processing, and this particular structure has also been described as playing ‘a crucial role in the development and expression of conditioned fear’ (Davis et al., 1992: p.255). Anderson (2002) contests the amygdala’s prioritisation; presenting evidence that damage to the structure did not impact upon patients’ expression of emotion, nor their ability to experience varying emotional valence. The notions that specific neural structures are of elevated importance in emotion processing do not suggest that emotional experience is contained within individual structures, and the ongoing debate regarding the prioritisation of emotion-related structures suggests that emotional experience is a hugely complex system; potentially incorporating every element of the human body, from the largest organ systems to the smallest chemical components and the billions of individual interactions that occur between them.

Figure 3: Neural structures commonly associated with emotion processing (see Dalgliesh, 2004)

Structure	*Role*	*Relevant Research*
Amygdala	Detection of emotional significance	LeDoux, 1995
Anterior Cingulate	Associated with motivational behaviour / Supports subjective awareness of emotions	Jackson et al., 2006
Cerebellum	Emotion regulation	Sell et al., 1999
Hippocampus	Inhibition, memory and space / associated with anxiety	Grey & McNaughton, 2000
Hypothalamus	Translates electrical impulses of the nervous system and hormonal secretions of the endocrine system	Papez, 1937
Insula Cortex	Embodies emotional experience in physiological changes via connection to various structures that regulate autonomic bodily functions	Marley, 2008
Prefrontal Cortex	Apply executive function (analysis, introspection) / connection to ventromedial prefrontal cortex	Price, 1999
Ventral Striatum	Associated with several limbic structures / association to emotion derived from reward	Gregorious-Pippas, Tobler & Schultz, 2009

Dalgleish (2004) presents an in-depth account of the neural structures involved in emotion processing, a summary of which (incorporating references to relevant literature) is presented below (figure 3). Whilst traditional cognitive neuroscience has characteristically omitted emotion from models of thought processing (Cacioppo & Gardner, 1999), distinguishing affective neuroscience (the study of emotion’s neural routines) as a separate field; contemporary research has revealed overlap between these areas of study (Davidson, 2000), suggesting that emotion and cognition are best observed as interrelating elements of an inclusive framework. LeDoux et al. (2004) supports this notion in an account of developing lists of neural structures believed to be associated with emotion. These lists reveal an initial separation of limbic and cortical structures (governing emotional and rational thought respectively), and the inclusion of various cortical structures into emotion-function lists reveals a gradual blurring of the initial distinctions.

One of the most significant debates surrounding affective neuroscience is that of autonomic specificity. To provide a brief informative background to elucidate this issue, the nervous system can be separated into two classifications: the central nervous system (CNS) and the peripheral nervous system (PNS). The former refers to the bone-housed structures within the brain, retina and spinal column; whilst the latter denotes neural networks that exist outside of the central structure and which connect the CNS to the various organs of the human body. The PNS houses two further sub-categorisations: the somatic nervous system (SoNS) and the autonomic nervous system (ANS). Whilst the SoNS characteristically represents voluntary movements, the ANS refers to the neural pathways between the brain (thought) and body (action) that typically reflect subconscious behaviours. The final (for the purposes of this outline) sub-categorisation distinguishes the sympathetic nervous system (SNS) from the parasympathetic nervous system (PSNS); the former referring to excitatory processes (increased heart-rate, deeper respiration, etc.), whereas the latter represents inhibitory processes that suppress the effects of the SNS in order to maintain an internal equilibrium, or homeostasis (Cannon, 1926). The SNS has been associated with fight or flight response and has been described as critical to social behaviours (facial expression, vocalisation) via the ventral vagal complex (Porges, 1998). For a comprehensive study of the nervous system, see Peretto (1992).

The significant interrelating connections that exist between the brain, nervous system and bodily organs have generated opportunity for a great flurry of continuing empirical and theoretical research that attempts to identify and quantify causal associations between the many elements of this complex system. The autonomic specificity debate exists as a primary interest within this field. Levenson (2003: p.212) refers to autonomic specificity as 'the notion that emotions can be distinguished in terms of their associated patterns of autonomic nervous system activity', a perspective that relates to the *basic* account of emotion detailed earlier within this section. There is significant support from relatively recent research that emotional specificity exists (Levenson, 1992; Witvliet & Vrana, 1995). However, more recent literature has suggested that although the observable autonomic effects reveal differences between emotions, there is little to no discernable pattern that might support an emotion recognition system (Christie & Friedman, 2004). Levenson (2003) appears to support this assertion, describing the major criticisms of autonomic specificity as *a priori*, primarily in that they critique opposing data but do not present their own. However, Levenson does agree that patterns of autonomic specificity may not enable emotion recognition, as differences are 'likely to be "prototypical" in nature, with particular occurrences of a given emotion showing variation around […] central tendencies'.

EMOTIONS & COMPUTER VIDEO GAMEPLAY

The focus of the thesis is upon emotional experience with relevance to CVG sound. Whilst later chapters will address this context in greater detail, this section provides an outline of emotional processes that exist within a computer video game playing experience. The ability of computer video games to evoke emotions in players is well documented, particularly in research connecting gameplay to aggression (Winkel, Novak & Hopson, 1987). The interactive nature of a computer video game distinguishes it from passive recreational media and therefore dictates unique emotion characteristics. Games require player-action to progress and the emotional state of the player can be described as a facilitator of that action (DeGroot & Broekens, 2003). Certain research has consequently argued that game development should centre around the player, not the game (Ermi, 2005). Several terms relevant to both positive and negative emotional experience have been closely associated with gaming, including interest, enjoyment/fun, anger and frustration (Perron, 2004).

Perron (2004) presents several emotion concepts that are most unique to a CVG medium, though they do share characteristics and are based upon film theory. Perron refers to Tan (1996) in describing the *F-emotion* (fiction emotion: empathetic states also referred to as *witness emotions* because they arise from the individual's observation of the fictional environment/scenario) and the *A-emotion* (artefact emotion: derived from appreciation of the artistry/craft that built the observed fiction, felt during brief realisations that the film/game is not real). In a later paper, Tan (2000) also proposes the *R-emotion* (representative emotion: denoting states evoked from action/interaction within a fictional world). Perron shifts the focus exclusively onto CVG, disclosing the *G-emotion* (gameplay emotion), emotions that arise from a hybridisation of fiction (narrative) and representative (action) emotion. For example, when undertaking the role of Gordon Freeman in *Half-life 2* (Valve, 2004), we may witness the dystopia within which we are placed as we read a newspaper headline entitled: 'Earth surrenders'. We may also simultaneously reflect on the fact that this environment is a direct consequence of our own prior actions and that it is our responsibility to produce further action to set things right.

Arguably, action and narrative are intrinsically tied within story-driven computer video games and the *G-emotion* acknowledges this to present an emotion-system unique to computer gameplay. In addition, Perron (2004) also differentiates between *circumstance-caused* (events caused outside of a player's and NPC's control), *other-caused* (direct responses to NPC action) and *self-caused* events (direct responses to player action), arguing that the same circumstance could produce a different discrete emotional state depending on the event type. For example, in *Left for Dead* (Valve, 2008), receiving a first-aid pack from a fellow survivor may evoke liking (other-caused) whilst presenting the first-aid to that survivor may evoke pride (self-caused) and finding additional aid during the level when you are close to death may evoke joy (circumstance-caused).

One of the key characteristics of a computer video game is the lack of a predetermined sequence of events and the very essence of the word 'game' necessitates that it must be possible to both win and lose. Therefore it is highly unlikely that a player would successfully overcome every obstacle within a game on the first attempt and instead, would likely replay several sections of gameplay repeatedly before progression. Consequently, developers cannot contemplate player emotional states solely upon initial exposure to the stimuli they have embedded, but instead must consider how a varied number of repetitions may impact upon player emotions over time. The integral nature of this characteristic relates to the positioning of *challenge* as a game-relevant emotional state. Ermi and Mäyrä (2005) describe challenge as consisting of cognitive load and pacing, arguing that 'quality of gameplay is good when these challenges are in balance with each other […] and the abilities of the player'. Klimmt (2003) argues that the connection between challenge and emotion is the shifting between positive and negative states, in which challenge difficulty will result in frustration (and possibly anger and aggression) that, in turn, will enable success to evoke intense euphoria and pride (as a result of overcoming an obstacle that the prior negative emotional state caused to be perceived as significantly difficult) in tandem with a feeling of relief as the stimuli that once caused intense negative emotional states are relinquished. Perron (2004) reflects this notion with the concept of motive-consistency and motive-inconsistency, within which Perron asserts that the two opposites are connected and that negative emotions, derived from challenge (frustration, anger, contempt, sadness), facilitate future-based positive emotions when the obstacles are overcome.

Within a survival horror game context in particular, challenge is often a frustration for developers, as a core element of fear is the unknown and repeated experience of the same event quickly suppresses the fear-content. Challenge also encourages high quantities of action, dictating larger numbers of enemies which also leads to repeated exposure even if the player does not repeat gameplay sections. The Dead Space (Visceral Games, 2008) series exemplifies the pacing problem of challenge; arguably presenting a genuinely frightening opening but (despite outstanding atmosphere and artistic quality) the intensity diminishes quickly as the repeated exposure to enemies quickly enables the player to memorise the characteristics of the enemy (reducing shock and improving coping ability), create effective strategies to defeat them and even predict when they will ambush. The contextual dependency of emotions means that the same action/activity/stimulus can have significantly different emotional effects if the situation is varied (Blythe & Hassenzahl, 2003). In this scenario, designers are essentially damned however they approach the problem as slow pacing and low challenge may facilitate a more consistent and intense fearful experience, yet a linear and unrewarding gameplay experience will be the inevitable side-effect.

Alongside challenge, *immersion* stands as a crucial and well-documented gameplay experience that has been directly associated with emotion (Brown & Cairns, 2004; Ermi, 2005; Nacke & Lindley, 2008). Whilst not a precise definition; immersion has been referred to as the ‘essence of games’ (Radord, 2000). Brown and Cairns (2004) provide a comprehensive review of immersion research, citing depth, realism and atmosphere as key components. Their three-level theory of immersion provides a logical characterisation of immersion; separating engagement (interaction with an accessible entity that the user has an interest in), engrossment (‘when game features combine in such a way that the gamers’ emotions are directly affected by the game’ [Brown & Cairns, 2004: p.1299]) and total immersion. Winograd and Flores (1986) refer to Heidegger’s ‘being ready to hand’, asserting that the invisibility (a system that is easy to use *off-line* without conscious thought) of the control interface enables immersion by allowing the user to focus their attention entirely upon the action taking place on the screen, an argument that may have been ignored in the development of modern gesture-based control systems such as the Kinect (Microsoft, 2010). Ermi and Mäyrä (2005) separated immersion into three discrete categories: sensory (relating to realism and technical quality [graphics, sounds etc.]), challenge-based (attention is focussed upon the objective cognitive faculties that are directed towards completing that objective) and imaginative immersion. Although few games would focus entirely upon a single form, the primary mode of immersion featured within a game is likely to depend upon its genre and audience; for example, Tetris (Pajitnov, 1984) focuses upon challenge-based immersion, relying on the addictiveness of the gameplay and desire to achieve ever-higher scores whereas Myst (Cyan, 1993) targets sensory immersion with a focus upon highly detailed first person 3D game worlds that encourage exploration and sensory stimulation.

Total immersion, as described by Brown and Cairns (2004) relates to presence (in their description an experience that gives the player a sense of detachment from reality), which is in itself an affective gameplay state that relates to emotionality. Nacke and Lindley (2008) describe presence as a combination of sensory and challenge-based immersion, coupled with 'feelings of empathy and atmosphere'. Lombard and Ditton (1997) support this definition, describing presence as 'a psychological experience of non-mediation, i.e. the sense of being in a world generated by the computer instead of just using a computer'. In a study conducted by Ermi and Mäyrä (2005) parental opinion regarding their child's gameplay experience revealed a possible connection between immersion and emotion when parents displayed concern that their children were too immersed within their games. The parents' primary reason for this concern was that they perceived their children to be more engaged emotionally with activities within the game-world as opposed to reality.

Another emotion-relevant gameplay experience is *flow*, a theory posited by Csikszentmihalyi (1990) that assimilates both challenge and immersion, stating that a successful balance of challenge and skill causes a player to become engrossed within the activity. Here, flow is essentially a temporal measurement of enjoyment (as determined by immersion and challenge) that can be broken if gameplay is too difficult or if there is a game event that disrupts immersion (such as a jarring diegetic shift within Fallout 3 [Bethesda, 2008] in which your player statistics, which so far had been set using diegetic systems, can be reset from an extra-diegetic interface window). This definition is not uncontested and a significant number of contrary theories of flow have been presented within recent literature (Novak et al., 2000). Nevertheless, flow has been acknowledged as a lay-term that many game players have a fluent concept of (Nacke & Lindley, 2008). McMahan (2003) implicitly connects the concept of flow to immersion when stating that one of the three conditions required to generate immersion within gameplay is a consistent game world (alongside matching if player expectations and meaningful activities provided for the player), suggesting that a break in flow will interrupt immersion. Elis et al. (1994) presented a four-channel model of flow that is frequently used within the context of computer gameplay experience (Nacke & Lindley, 2008), in which flow is a trade-off of boredom and anxiety that requires a high but balanced level of challenge and skill. According to the model, a balanced but low level output of these measures results in an apathetic response. Kivikangas (2006) revealed the lack of significant correlation between flow and psychophysiological measures of basic emotions, suggesting that flow could be better perceived as an emotion in its own right.

Marsella and Gratch (2002) distinguish two modes of emotion modelling associated with computer gameplay: communication-driven modelling refers to developing character believability by way of improved non-player character (NPC) emotional expression; whilst appraisal-driven modelling shares characteristics with emotion recognition, describing the development of systems that generate an NPC emotion state based upon their pre-set beliefs/desires and their current circumstances. Academic research has repeatedly attempted to elucidate computer game-playing experience by way of a dimensional model. Pine and Gilmore (1999) presented a two-factor model placing participation (the level of interactivity, ranging from passive to active) and connection (relating to immersion, ranging from absorbing to immersive) along respective dimensional axis. From this model, four broad classifications of game playing experience are revealed: entertainment (absorption and passive participation), educational (absorption and active participation), aesthetic (immersion and passive participation) and escapist (immersion and active participation). Frome (2007) presents eight classes of gameplay emotions based upon the source of the emotion and the role of the player. Ecological sources refer to 'when a player responds to a videogame in the same way [they] respond to the real world' (e.g. actually ducking your head whilst moving your avatar through an enclosed space), whilst narrative, game and artefact emotions relate to terms documented earlier within this chapter. Observer-participant and actor-participant relates to the witness-action distinctions documented earlier and combine with the source types to generate the eight classes.

Figure 4: Frome's (2007) eight classes of gameplay emotion

	Audience Roles	
Source of Emotion	**Observer-participant**	**Actor-participant**
Ecological	Sensory environment	Proprioception
Narrative	Narrative situations	Roleplay
Game	Game events	Gameplay
Artefact	Design	Artistry

Frome's (2007) classification system is arguably comprehensive and rational, but the presence of so many conflicting concepts regarding gameplay emotions confirms that our understanding suffers from the same lack of precision and clarity that plagues emotion theory as a whole. There is nonetheless a significant value in these concepts with relevance to development of emotion-recognition systems within games, specifically in terms of establishing context to enable vague dimensional physiological data to be processed through game event/situational filters to reveal accurate discrete emotional states.

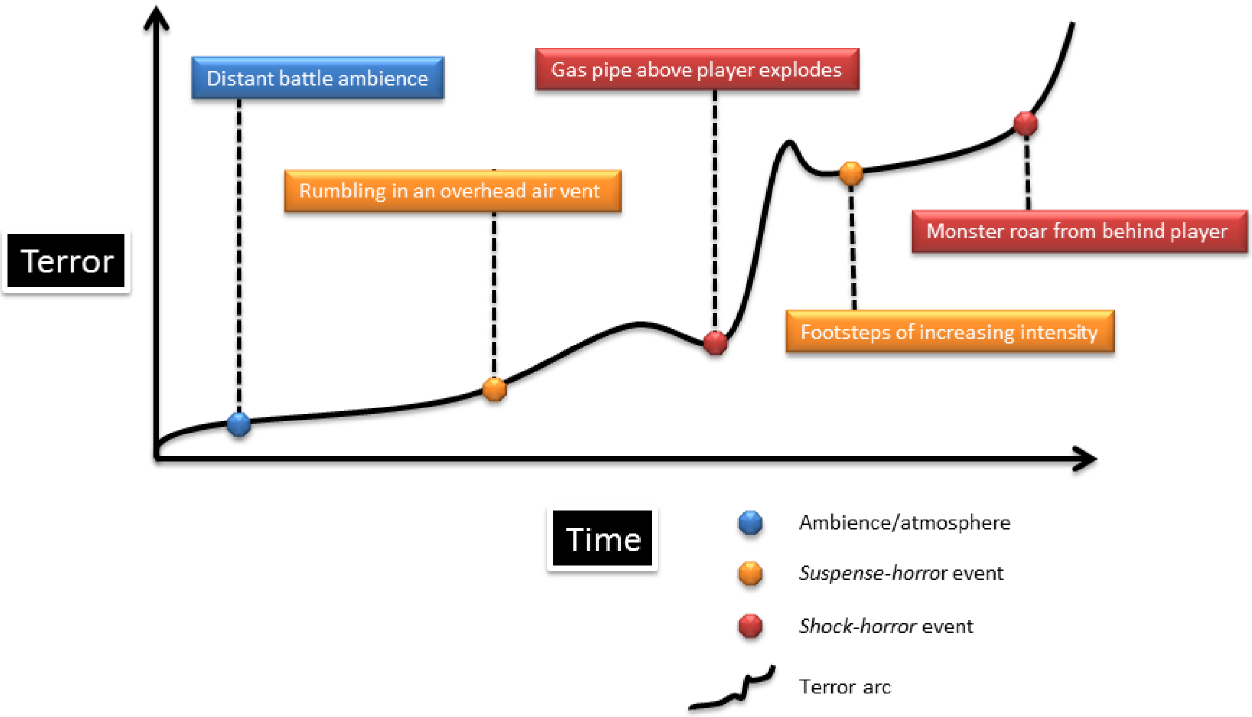
AN OUTLINE OF FEAR DEFINITIONS AND TERMINOLOGY

Within the realm of fictional media, the experience of fear can be sub-categorised by the terms: horror, terror, suspense and shock. Horror, by definition, is reactive and describes disgust or recoil from an object or scenario that grossly offends the senses; it is commonly related to revelation, shock and surprise and often relates to the cinematic term *gore*. Shock and surprise differ from horror, however, in that they do not necessitate a disgusting stimulus, but rather an intense surprise that the receiver did not anticipate. Terror precedes horror and is related to suspense, apprehension and anxiety. A feeling of terror is typically the result of suggestive stimuli resulting in a perceived sense of conviction that something horrific is about to occur. Suspense differs from terror in that it is not necessarily an anticipation of something horrific. Suspense can be used to describe both a precursor to terror and a more generic feeling of anticipation in the presence of the unknown. Varma (1966) supports the distinction between terror and horror; defining terror as the 'awful apprehension' and horror as the 'sickening realisation'.

This paper posits the notion of *threat* as an absolute necessity for experiencing fear and, in the context of a computer video game, argues that the only way to create a fear response is to present the player with a threat. In a virtual environment, irrespective of whether the threat is real (fear of failing, witnessing the grotesque, being startled) or virtual (fear of death, suffering, personal loss), it is vital that they be perceived as significant by the player if a fear response is to be generated. For the purpose of this paper, Varma's (1966) definition is altered to fit this specific context. Although a threat is not necessarily required to induce horror, this definition of a horrific experience is not one that will induce fear, but more likely sadness or disgust. Witnessing a grotesque scene or act may be described as a horrific experience yet without an attached threat to the witness, fear will not be experienced.

For the purposes of the thesis, horror is defined as the individual events (a fallen branch snaps nearby, a heavy panting can be heard behind you, etc.) within a complete experience that presents, or implies, threat. The more penetrating events can be described as *shock-horror*, referring to explicit individual revelations that cause intense pre-cognitive reactions (exclamation, screams, jaw/fist clenching involuntary jump, etc.) and is characteristically short and intense with heavy attack. Conversely, *suspense-horror* describes an implicit event that manufactures the perception of a threat without causing a shock response and instead contributes to a more sustained, developing and gradually intensifying experience. Terror is defined as the overall fearful experience, the complete scenario. Assuming that a significant threat is a necessity of fear, terror begins at the point a threat is perceived and ends when only the threat is resolved. The feeling of terror is not constant however, and can vary in intensity depending on horrific stimuli and the player's unique emotional processing. These definitions are strictly created for the purpose of classifying experiences of fear as induced by sound in a computer video game and do not intend to replace or modify existing definitions outside of this context. Figure 5 visualises these concepts to elucidate the interactions between horror and terror within an exemplary survival horror game sound context.

Figure 5: Terror over time – a theoretical example of the relationship between horror and terror



THE VALUE OF FEAR

One of the primary concerns of this thesis is enhancement of the experience of fear within the context of survival horror computer gameplay through manipulation of game sound. In relation to this objective, this section briefly outlines the contextually relevant definitions and terminology surrounding fear and also discusses the notion of positive fear associations, addressing why we would consciously wish to experience fear.

The intrinsic presence of hope and fear within a suspenseful narrative increases the potential for user-character investment and emotional experience (Alwitt, 2002). In a non-interactive context, Zillman (1996: p.200) identifies fear as the crucial component of suspense; arguing that concern for the well-being of the narrative characters and anticipation of negative plot resolutions generates the suspense that hooks the viewer. For video games, the habitual association with scenarios containing a variety of severely negative potential outcomes suggests that fear and suspense are already acknowledged and, within game genres such as survival-horror, fear is a necessity (Tinwell et al., 2010). In *A Philosophy of Fear,* Svendsen (2008) argues that there exist a number of reasons why fictional fear can manufacture a positive emotional experience (p.75). Svendsen begins by suggesting that fictional fear is a physically safe means of experiencing danger and is therefore more likely to induce positive feelings such as excitement (p.76). Svendsen elaborates upon this paradoxical notion, asserting that any emotional experience results in a measure of positive feedback derived from the resultant ‘feeling of being alive’, and that experiencing high intensity emotions increases the likelihood of this positive sensation, regardless of the valence of the initial emotion (Svendsen 2008: p.75). Svendsen also identifies relief as a further positive consequence to the ceasing of a negative emotion. Relating closely to gameplay experience, Perron (2004) contributes by suggesting an instinctive feeling of success results from facing your fears, standing tall against a terrifying force or creature, and succeeding. Perron’s argument can be compared to that of Kant (1964). Kant describes the procedure of positive experience drawn from fear-inducing stimuli: ‘The first shock of the sublime is turned around, in such a way that we gain an awareness of the elevated in ourselves, namely reason, and that judgement therefore finally experiences a feeling of delight’ (p.80). These concepts can be comfortably applied to the experience of a survival horror game and it would be logical to assert that a possible attraction to this gaming genre is the opportunity to face a fearful object/scenario and to overcome it. The feeling of delight is consequential of the feelings of success (the enemy has been vanquished), relief (you have survived) and excitement (resulting from conscious appreciation that you are experiencing rare and intense emotions).

The literature in this field does not conclude that a positive response to a negative affect is manifested purely by the desisting of the initial negative emotion. Kant’s (1964) concept of the sublime suggests that there is an intrinsic aesthetic quality to objects and acts traditionally perceived as horrific and macabre. According to Kant, a sublime experience results from the appreciation of an object’s unfathomable size (mathematically sublime) or an object’s incomprehensible power (dynamically sublime). The survival horror genre itself testifies to the value of dark artistry, in creating both horrific creatures and scenes of gruesome death and destruction as gameplay selling points. Furthermore, Kant’s (1964) definition of the mathematically and dynamically sublime can be seen manifested in many survival horror antagonists, particularly final boss characters (antagonist characters typically battled during level or game finales). Svendsen (2008) continues to explore these ideas via interpretation of an Aristotlelian concept, *catharsis*. Catharsis suggests ‘there is a favourable effect on the observer because he or she witnesses fearful impressions from a scene’ (p.87). Aristotle himself does not detail a procedure for these effects, however Svendsen interprets an ‘emotional discharge in which the observer gets rid of inner tensions that it would otherwise be difficult to find expression for in society’, and also a proposes a potential contribution to personal moral development – ‘catharsis would teach us to fear the right things in the right way at the right time’.

In addition to gameplay and physical design applications, the concept of the sublime could also be related to character and narrative designs. In both fictional worlds and in reality it is the serial murderers who commit their acts for no other reason than the act itself - to create art through terrible crime – thus becoming, under de Quincey’s (2006) categorization, sublime artists. Analysis of several popular culture mediums reveals that it is the ‘sublime murderer’ who is the most captivating and terrifying, such as: John Doe from the film Seven (Fincher, 1995), Alexander Cohen from the game Bioshock (2K, 2007) and Francis Dolarhyde from the novel Red Dragon (Harris, 1981). Such characters arouse a far greater fear because the lack of a traditional motive removes conventional logic, decreases predictability and suggests a far more monstrous persona. Captivation could be explained via the same processes that attract an audience to fear - the inherent excitement in exploring the unknown, the different and the dangerous (Svendsen, 2008).

The survival horror genre provides many examples that reflect all of the ideas detailed above. Final boss characters are predominantly colossal and powerful, inspiring Kant’s sense of the mathematically and dynamically sublime. Games with a focus on narrative often include De Quincey’s sublime characters who perceive morality as subordinate to aesthetics, including: Alexander Cohen and Doctor Steadman from Bioshock (2K, 2007) or Serial Killer X from Condemned: Criminal Origins (Monolith, 2005). The creatures of many survival horror titles match Svendsen’s concept of dark attraction, with many adversaries, horribly disfigured human or animal creations dripping blood and bile, seen acting out graphic acts of extreme violence. Finally, no survival horror game is complete without scenes that build suspense, elements that shock, and narratives that assign the player the role of victim or prey.

The ultimate goal of research into computer video games (CVG) is to enhance the experience of playing them. This thesis is concerned with enhancing the experience of fear within the genre of survival horror through manipulation of game sound. Two immediate questions are hereby raised – will enhancing the experience of fear improve the player’s positive experience of game-play, and would someone consciously wish to feel fear? Consider this scenario: You experience a fictional stimulus (horror film or computer video game). The experience not only causes you to jump in your seat, but also induces a lingering sense of dread during which your mind generates personalised scenarios based upon your experience. You feel anxious and unnerved, and even lie awake at night unable to shake the sensation of fear. These feelings pass yet the experience remains significant, and you find yourself recommending the stimulus to others. Anyone who has experienced such a phenomenon could be inclined to agree in retrospective appraisal of the experience, that they felt some sense of positive affect towards it. A second question is presented: *Why would someone consciously wish to experience fear?*

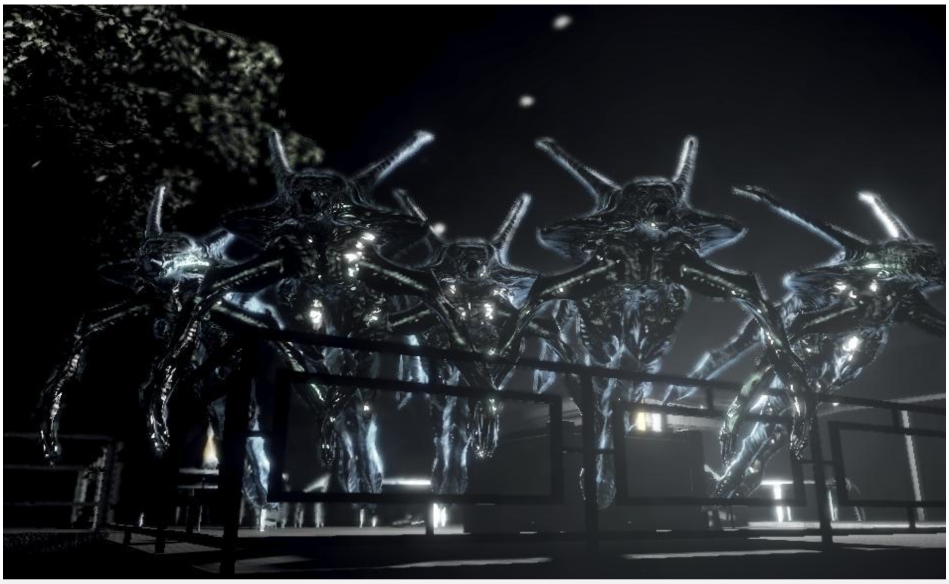
Developing Kant's (1995) concepts regarding the sublime has sired a controversial theory; that if morality were presupposed for aesthetics, then positive appreciations such as beauty, symmetry and artistry could be applied to acts of extreme violence, torture and murder (De Quincey, 2006). Svendesen (2008) asserts that under certain conditions, human perception can place aesthetics above morality, consequently freeing the individual to experience enjoyment from witnessing (and even participating in) acts of extreme violence, torture and murder. In reality, such a hierarchical shift would most likely be the result of extreme circumstances (Oppenhiemer and Frohlich, 1996). In a virtual world however, this can be achieved through detachment (aspects of gameplay that restrict the opportunity to connect emotionally with a non-player character) and through the construction of a framework of virtual rules. These methods allow the player freedom from moral responsibility and even to delight in acts ranging from the morally questionable, such as killing enemy soldiers or alien monsters in Half-life 2 (Valve, 2004) to deplorable acts, such as attacking and killing innocent civilians in Grand Theft Auto 3 (Rockstar, 2001) or Call of Duty: Modern Warfare 2 (Infinity Ward, 2009).

Exploring the above argument, it has been theorised that to fully appreciate the sublime of terrible acts, we must do more than separate ourselves from morality. Svendsen argues that 'an aesthetics of transgression always presupposes morality, since it is morality that makes the transgression possible […] The fact that a given act exceeds a moral or legal norm is an important precondition of its aesthetic quality' (Svendsen, 2008: p.86). This assertion could be interpreted to suggest that CVG players may seek opportunities to commit acts they understand to be morally or legally wrong provided that there is a guarantee of no real-world consequences. The reason for this is the aforementioned attraction to new experiences, exploration of virtual worlds vastly differing from our everyday reality and a freedom from responsibility. Pearce's (2008) survey corroborated this argument, suggesting that exploration and new experiences were a top requirement for players. Consulting the game summaries on the backs of many CVG cases strongly suggests that games industry marketing also believes in this concept. A convenience sample of survival horror games (Fear 2, Condemned, Dead Space, Left 4 Dead and Bioshock) all described their offering of new experiences; actions the player could perform, weapons and special powers to be wielded, enemies to be confronted and exciting new worlds and scenarios to explore.

CONCLUSIONS & CHAPTER SUMMARY

The information presented within this chapter advocates emotion theory as a worthy field of contemporary study, with distinct potential value for cognition theory, human-computer interaction developments and computer video games. Beyond this, better understanding of emotion and affective processes has inherent merit in a more general sense, providing greater insight into our everyday experiences and behaviours. Comprehensive frameworks, which can be applied to the development of any product or service, would enable CVG businesses to progress through better understanding of their clientele and may have notable worth for all mediums of communication.

When assessing the value of fear, different forms of value are revealed; the most notable being cathartic release (coupled with intense excitatory responses) that enables individuals to experience fear within a physically safe environment and phobia therapy (repeated exposure to fear-object, again within a safe environment, to facilitate coping practice). This chapter also addressed the relevant concepts of the sublime (aesthetic appreciation of horror and violence) both in the form of events and characterisation. The outline of fear definitions and terminology provides an introduction to fear concepts and these initial ideas are expanded upon within the next chapter, in which fear and its associated details are analysed in greater detail, alongside a discussion examining the modern concepts of fear processing both within a general and a CVG contextualisation.



Chapter 3

Understanding Fear and Game Sound – Definitions, Processes and Variables

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2012

Chapter 3: Understanding Fear and Game Sound - Definitions, Processes and Variables

"The oldest and strongest emotion in mankind is fear and the oldest and strongest kind of fear is fear of the unknown." Bleiler E.F, Foreword written in - Lovecraft H.P, (1973) *Supernatural Horror in literature*

INTRODUCTION

This chapter documents core theoretical research and associated experimentation relevant to the study of fear. Commencing with a brief examination of connected areas of study (Human-computer interaction and cognition); this chapter investigates the definitions and sub-categorisations of fear, alongside an analysis of the emotional potential of sound and individual acoustic/psychoacoustic parameters that could modulate an affective experience during computer video gameplay. These discussions provide a theoretical foundation upon which a new framework for the fear experience, both in a general and computer game-specific context, is constructed (chapter 9). Such a model is intended to expose a core procedure of human fear response that may transcend interpersonal differences, ultimately with the intention to better inform creative decisions relevant to computer video game development and sound design.

FEAR: PERSPECTIVES AND ASSOCIATED THEORY

The intrinsic presence of hope and fear within a suspenseful narrative increases the potential for user-character investment and emotional experience (Alwitt, 2002). In a non-interactive context, Zillman (1996, p.200) identifies fear as the crucial component of suspense, arguing that concern for the well-being of the narrative characters and anticipation of negative plot resolutions generates the suspense that hooks the viewer. For video games, the habitual association with scenarios containing a variety of severely negative potential outcomes suggests that fear and suspense are already acknowledged and within game genres such as survival-horror, fear is a necessity (Tinwell et al., 2010). Whilst the fundamental approach to fear manipulation is drawn from the creative instinct of the developer, a theoretical framework for understanding the macro and micro processes that exist within a fearful experience would serve to increase the intensity and reliability of fear-induction design in survival horror video games, films and beyond.

The potential for a video game to evoke emotional responses beyond those intrinsically drawn from gameplay (such as frustration, anger, joy, competitiveness) supports the increasing sophistication of game design that is allowing virtual worlds to more closely reflect reality. Whilst several game genres would arguably benefit from emotion-related developments, it is the fundamental first-person shooter (FPS) approach of positioning of the player within a simulated environment with a first-person perspective that supports the notion of ecological relationships paralleling those of the real world. For the purposes of this chapter, ecology refers to the relationship between a living organism and their surroundings. A computer video game places the player in a virtual environment which in itself exists within reality, revealing three interrelating entities (the player, the game and the environment) that give a virtual ecology a character dissimilar to the traditional, *natural* ecology.

For the purposes of this discussion, reality refers to the everyday world in which we operate; whilst virtuality refers to the artificial environment contained within a computer video game. Players relate to the environment of reality through visual, acoustic, kinaesthetic, haptic, olfactory and gustatory interactions that can be mapped onto ecological profiles. A more detailed discussion regarding virtuality (and an attempt to untangle the array of associated terminology) is presented in the next chapter. Initial contemplation regarding the nature of reality and virtuality posits the terms as related opposites, the two sides of our existence. As discussed in greater below, the distinction between these terms is notably unclear, with a range of variables potentially determining the real or unreal nature of an entity. In response to this a *reality-virtuality* continuum, connecting the real with the virtual and positioning them on polar extremes of the spectrum, is a concept that acknowledges the difference between real and virtual but also the explicit association that exists between them. The inherent problem with a continuum is the assumption that it requires polar extremes which would dictate that reality and virtuality existed in some forms as an absolute. Calleja (2012) reconciles the terms, placing virtuality as an aspect of reality, acknowledging the distinction whilst emphasising the connection between the two. With regards to this chapter, it is the association, rather than difference, between reality and virtuality that supports the argument that in order to achieve an inclusive understanding of an ecological system within a virtual model, we must first comprehend the ecology as it exists within reality.

This chapter primarily utilises a cognitive perspective of psychological processes to construct the fear framework. Evolutionary and behavioural concepts are incorporated; however, they are presented as components of a bespoke cognitive design. The cognitive perspective has long been associated with computer functionality to the degree that the processes of a computer provide a metaphorical scaffolding to support the cognition concept and traditional cognitive theory disassociates emotion from cognition, describing each as individual processes that interact (Zajonc, 1984). Cognition theory has recently been challenged however, and emotions argued to be not only an integral component of the cognitive process, but also influencing factors of attention, thought and behaviour (Carroll, 1999; Grimshaw, Lindley & Nacke, 2008; Norman, 2004; Shinkle, 2005). Niedenthal et al. (1999) argue that the intense nature of an emotional experience supports the preservation of past events, stored as salient recollections within long-term memory (LTM), and that these memories have the capacity to influence present comprehension and decision making.

Human-computer interaction (HCI) is a popular topic for research and is arguably one of the key components of an emotion-based framework that details interactions between player and game. HCI has been argued to be largely social, and an understanding and appreciation of emotional function is as crucial to human-computer interfacing as it is to exchanges between two people (Reeves & Nass, 1996). The concept of *Emotional Intelligence* has been applied to computer software in efforts to reduce user frustration and increase productivity (Picard, 2000), although this does not explore beyond the functional, nor venture into the potential for developments in a recreational and/or social HCI context, such as a computer video game. The nature of computer video games makes them ideal for exploring human-computer relations (Keeker et al., 2004). Within certain games, further relations can also be observed. Virtual worlds can depict representations of any corporeal form (of both real and fictitious origin) and, furthermore, such worlds utilise semantics and metaphor to project abstract concepts. Graphics technology is propelling us closer towards photo-realistic computer generated characters, and artificial intelligence (driven by HCI research), with the capacity to evoke player emotions through believable affective displays and model accurate emotional responses to player input, has the potential to dramatically improve the intensity and diversity of our emotional experience whilst playing computer video games. Such diversity will arguably facilitate improved potential for evoking discrete emotions, such as fear.

The subsequent sections within this chapter explore the concept of fear; first by defining key components and relevant terminology, then utilising existing research to explore the inner processes, individual variables and relationships that characterise fear. Differences between reality and virtuality-based experience are documented, and game sound research is reviewed to assess the roles of acoustic parameters, psychoacoustic listening modes and cognitive appraisals of audio, within a virtual ecology of fear.

UNDERSTANDING FEAR

For the purposes of this chapter, fear is positioned as a master-term, to which all associated words (horror, terror, anxiety, suspense, etc.) branch from. Freud (1956) asserts that fears are subconscious efforts to avoid disturbing experiences; generating aversive behavioural responses to stimuli perceived as threatening to an individual's physical and/or psychological well-being. A more recent perspective defines fear similarly as 'an activated, aversive emotional state that serves to […] cope with events that provide threats to the survival or well-being of organisms' (Öhman, 2000). The fear response is commonly associated with aversive behaviour (Brown et al., 1951; Öhman, 2000; Schneider, 2004) neatly characterised by Gray (1971) as fight, flight and freeze actions. This concept positions object (stimulus), perception (of threat) and response (aversive action) as organised components of an interactive process. Although such an understanding may appear over-simplified, the notion of object, threat and response is rarely questioned but rather built upon and expanded around this foundation.

A step towards a more reductionist view positions the awful apprehension of *terror* and the sickening realisation of *horror* (Varma, 1966) as crucial elements of the fear sensation. Rockett's (1988) understanding of these terms strongly reflects that of Varma's; describing horror as a revelatory event, incurring deep upset manifest as overt human behaviour, and terror as the anticipatory trepidation. Terror is evasive, action-orientated and situational whilst horror encourages fixation and is object-focused (Schneider, 2004; Perron, 2004). The two components are very possibly co-dependent (each requiring the other to exist) and the causality between them appears to be unidirectional; meaning that an existing appreciation of a horrific stimulus is required to rouse the relevant sensation of terror, as can be observed in phenomena such as phobias (Poag, 2008 p.232) and post-traumatic stress disorder (Yehunda, 2002). The computer video games industry shows an awareness of the various cogs spinning within the fear machine; with different titles employing varied tactics based upon these elements. A classic example of this distinction is notable upon comparison of the original *Resident Evil* (Capcom, 1996) and *Silent Hill* (Konami, 1999) games; the former relying heavily upon horrific gore and startle, and the latter employing steady pacing and terrifying slow-building tension. This is not to say that these titles were opposites in their approach. Both utilise gore, violence, horrific monstrous antagonists, tense uncertainties, and striking revelations. Baird's (2000) fear process of 'a character presence, an implied off-screen threat and a disturbing intrusion' arguably applies to both games, whereas the difference lies in the subtle variations in pacing and direction of attention.

One of the core elements of a horrific experience is startle (also referred to as *shock* or *surprise*). Bradley et al. (2002: p.463) state that 'abruptness is the key to startle elicitation: Ideally, the rise-time of the startle stimulus should be instantaneous'. The two components of startle are documented in Reisenzein (2000) as 'evaluation of the stimulus as unanticipated' and 'reaction time'; supporting the notion that a startle must be both unexpected and sudden (allowing little or no time to appraise the situation cognitively or produce a rational reaction). Perceiving the startle effect as a variable in the horror-terror interaction helps us to neatly distinguish the two gaming approaches to evoking fear during play. Whereas the horror approach utilises immediate startle probes that encourage autonomic response behaviour, the terror approach employs forewarning and paced revelations that support cognitive appraisals and generation of unnerving hypotheses from our expectations of the macabre. For the purposes of understanding startle in a CVG context, it is the temporal element that establishes the difference between horror and terror-based approaches to fear elicitation.

Terror, anxiety and suspense cannot be viewed simply as indicators of intensity. Whilst it is logical to assume that the relative values of the quantitative variables associated with fear (probability, temporal immediacy, potential damage, coping ability and spatial proximity of the negative event) can distinguish between these three types, they do not merely exist on a basic linear construct. Whereas certain definitions of anxiety bear resemblance to terror (Rachman, 2004: p.3; Attwell, 2006: p.2), anxiety can refer to a relatively long-term state of distress incited by more general, implicit cues (Brown et al., 1951). Stevenson (2008: p.11) identifies anxiety as an internal experience, greatly associated with physiological responses of the Sympathetic Nervous System (SNS); a view reciprocated with Bourke (2005: p.189), who described anxiety as fear from within, and to distinguish between fear and anxiety quotes Freud: '[A]nxiety relates to the condition and ignores the object, whereas in the word fear attention is focussed on the object'. Freud's theory does not suggest that the framework of anxiety is devoid of an object, instead that the connection between object and individual is indirect and distant.

The concept of object is analogous to that of threat which is at the heart of an anticipatory fear response (Lazarus, 1964). Other synonymous terms within this context include *danger* and *peril* (Bleiler, 1973). Ultimately, such terms could be defined as loss of that which is perceived valuable and gain of that which is painful. If threat is defined as the true underlying source of a fear response, it could be suggested that the threat is neither the invading entity nor the action; but instead the loss that may result. For example, the true source of our fear is not necessarily the psychotic killer advancing, or the act of a vicious attack, but the permanent damage or death that their assault signifies. The notion of loss has been applied to our understanding of CVG emotional experiences with research suggesting that loss of progress and flow is a key contributor to stress and tension during gameplay (Perron, 2005; Shinkle, 2005). Although both fear and anxiety can be reduced to well-being defence procedures, the absence of an immediate and objective threat distinguishes between the two. Here anxiety is described as an undesirable internalisation of the *horror-terror* process and it is consequently associated with the purely negative response to fear stimuli. After experiencing a terrifying stimulus, such an internalisation would lead to continued production of unnerving hypotheses for a prolonged period; even after the object has been removed (the film is over, the game console switched off). The fearful sensation would continue outside the boundaries of the stimulus and potentially attach itself to perceptually related entities - all of this outside the control of the individual. Within a CVG context, all cognitive, autonomic and behavioural responses to fear can be viewed as positive provided they occur only within the temporal boundaries of gameplay and the user-defined intensity margins. The players have willingly subjected themselves to these stimuli, understanding the consequences but reserving the right to cease all frightening sensation at their command and expectant that removal of the fear object will do so. In this circumstance, a continued sensation without object denotes loss of emotional control and there is the potential that such anxiety may harm emotional and physical wellness; in extreme cases insomnia, paranoia, panic attacks, paraesthesia etc. are possible (Marks and Mataix-Cols, 2004: p.6).

Acting in this framework as a counterpart to anxiety, *suspense* is defined as a desirable emotional sensation and identified as a critical component of fiction media, and also a driver a CVG enjoyment (Klimmt et al., 2009). Zillman defines suspense as 'an experience of uncertainty whose hedonic properties can vary from noxious to pleasant' (Zillman, 1996: p.200), suggesting that the value of uncertainty is the causal variable that defines the experience and that high levels of uncertainty are likely to be distinctly unpleasant. Within the boundaries of fictional media, however, this unpleasantness would arguably be a lack of coherence in the plot or a difficulty for the audience to relate to the events rather than a response of genuine upset. The notion of uncertainty is arguably a requirement of both fear and suspense (Carroll, 1996: p.73; Massumi, 2005; Perron 2004). Furthermore, it can be attributed to both the concepts of terror and horror; the former because, as Bleiler (1973) states 'uncertainty and danger are always closely allied; thus making any kind of an unknown world a world of peril and evil possibilities', the latter because shock is an intrinsic part of a horrific event (distinguishing horror from pain, sadness and disgust). Massumi argues that fear is derived from threat, and that a genuine threat cannot take a substantial and immediate form; instead the nature of a threat is an indeterminate futurity, '[i]ts future looming casts a present shadow, and that shadow is fear' (Massumi, 2005). Perron (2004) argues that without uncertainty, suspense cannot occur; a view supported by Comisky and Bryant (1982) who noted participant rated suspense was minimal when either success or failure appeared absolutely certain. Carroll (1996) posits that audiences are even capable of experiencing suspense during repetitions of fiction because the investment in the protagonist is sustainable over several repeat experiences, and recidivist behaviour creates a sense of denial where the outcome is displaced and the focus is on the present chronology within the fiction.

PROCESSES AND VARIABLES WITHIN FEAR

The previous section differentiated between the terms associated with the human fear response; identifying them as individual components within a larger paradigm. This section builds upon these foundations by exploring the dynamic interactions that exist between these components and the internal and external variables that potentiate the various response behaviours, in an effort to understand the process of fear from beginning to end.

Existing theory asserts that fear responses originate from both a central evolutionary circuit and conditioned behavioural responses (Staats & Eifert, 1990). Evolutionary based emotional responses (arguably including fear) are hard-wired processes that can be observed in both humans and animals (Panksepp, 1991), suggesting that a fear response is likely to be instinctive and display comparable response behaviours between individuals and even species in certain circumstances.

In *Fear (The Spectrum Said)*, Brian Massumi (2005) argues that, if exposed to the same fear stimulus, each individual will experience the sensation differently; a notion supported by Cacioppo et al. (1993) who observed varying emotional experiences between individuals in response to identical physiological and somatic states. Massumi does, however, outline a process which exists along a temporal plane that can be interpreted as a universal framework of the fear experience. Threat is the origin of a fear sensation yet ironically is a futurity that can only be manifest in the present if a fearful response is generated. Massumi refers to the chronological order of events as the *line of fright*, and argues that, during the initial stages of fear the emotional sensation and physical actions of the body are indistinguishable, moving in parallel along the line of fright. At this stage emotional and physical responses are both governed by the conditioned autonomic processing of the threat. Overt physical action (characterised as fight or flight within a fear scenario), although typically determined consciously by the SNS, appears automated.

Literature suggests that certain involuntary motor movements (covering face, shutting eyelids, evasive running, etc.) can result when the action impulse is transmitted directly to the spinal cord, not reaching the central nervous system; a procedure known as a *reflex arc* (Ganong, 2001: p.123). Massumi (2005) argues that beyond this stage the subconscious and cognitive loops begin to diverge as the former continues to be influenced primarily by the origin stimulus and begins to desist over time. For example, when confronted by a predator the subconscious response to run is activated and, as the threat reduces due to increased distance, speed decreases and the autonomic action tendency concludes. Massumi describes the cognitive loop as cumulative; taking continuing influence from the changing environment, the response actions and internal representations. Cognitive processing continues beyond the cessation of the subconscious loop and it is at this stage that initial shock and automated response subsides, allowing emotional evaluation and reflective thought to occur. The above describes a process similar to the stimulus-behaviour-emotion-interpretation (motor feedback) pathway of Ellsworth (1991), whose research also documented two alternative pathways and suggested that the nature of the stimulus would determine which was employed.

The interior of human emotion processing consists of the subcortical system and cognitive appraisal; two interrelated, continuous feedback loops connecting the physical environment to the human mind (Lang et al., 2000). Located in structures such as the thalamus (Öhman, 2000), the sub-cortical routine is concerned with the immediate environment and information is only partially processed, allowing for more instantaneous communication with the autonomic nervous system (ANS); which commands several physiological responses known to be affected by fearful stimuli such as heart rate, respiration, pupil dilation, and blood flow (Funkenstein, 1958: p.223). In contrast, cognitive appraisal (located in the prefrontal cortex) introduces numerous conceptual notions such as logic, comprehension, and semantics; it also involves the identification and communication of our emotional states (Mériau et al., 2006). One perspective argues that high level construals originate from low-level received sensory input in a bottom-up model (Clarke, 1997). For example, a creaking floorboard heard downstairs under cognitive analysis could return increasingly high level construals such as *there is an intruder downstairs*, leading to *their intention may be to hurt me* and finally *I am in danger*.

Cognition is capable of regulating the sub-cortical output, the somatic response and (to an extent) autonomic reactions for various task-orientated goals; including suppression, accentuation and false response (Ekman & Freisen, 1975; Gross & Levenson, 1993; Ochs et al., 2005). Sotres-Bayon et al. (2006) state that the high level thought processes originating from the medial prefrontal cortex (mPFC) play a vital role in emotion regulation. Within a healthy human model, mPFC regulation uses rational thought to identify when the emotional consequences of a stimulus changes from threatening to secure suggesting that one potential cause for unwanted anxieties is failure of the mPFC to regulate autonomic reactions. Incorporating cognitive reasoning demands we acknowledge the differences that exist between individuals such as gender, culture and personality and their potential influence on affectivity and emotional response (Mériau et al., 2006; Hamann & Canli, 2004). In addition, the theoretically vast and continually expanding nature of long-term memory (LTM) generates the notion that present cognitive processes could potentially be influenced by innumerable LTM information gathered throughout an individual's life.

Lang et al. (2000) argue that the reactions of the human body to negative stimuli 'depend on the activation of an evolutionarily primitive subcortical circuit, including the amygdala and the neural structures to which it projects'. They suggest that fear appraisal and response originates from human ancestry and the evolutionary principle of survival; a procedure that reveals matching response patterns 'as [we] process objective, memorial, and media stimuli'. Further research expands upon this notion, positioning cognitive reasoning as an integrated development (much like an upgrade). Research (Lakoff & Johnson, 1999: p.4; Wilson, 2002) identifies reason as evolutionary; arguing that all information processing (including rational, higher level cognition) and behavioural response are developments of animal processes; a notion called *rational Darwinism*, that places humans on a continuum with animals and ultimately suggests that the nature of our thought processes will continue to evolve as time passes. A review of relevant literature reveals notable support for the concept of such an integrated autonomic-cognitive system. Much as elements of the respiratory system can be controlled via automated and conscious commands for adaptive efficiency, effective response to fearful stimuli demands that the system be responsive to time constraints and threats developing at a socio-cultural rather than evolutionary rate. For example, in the event of an ambush mugging attack, the subcortical responses of fight, flight and freeze may have detrimental consequences (the victim is outnumbered and likely to be outrun) and a cognitive compliance response requiring override of the subcortical impulse and a rationalisation argument (that losing possessions is a fair price for life and health) is most likely to ensure survival.

The above argument identifies the physical and abstract components that make up the fear response yet the question remains as to how these systems work together to mobilise the most appropriate behaviour in response to the vast array of fear-related scenarios. To understand this, we must attempt to chronologically examine the individual sub-processes and related variables. Within this framework, the fear process must arguably commence with an input threat assessment to establish which routine to activate, *horror* or *terror*. The characteristics of threat-associated stimuli under initial scrutiny are physical and temporal distance (Blanchard & Blanchard, 1989; Fanselow, 1994). Immediacy of the threat as defined via these variables activates the horror-pathway leading to defensive action, and nociceptive reflexes should damage be sustained (Lang, 1995). Increased distance instead stimulates the terror-pathway, characteristically resulting in immobility, bradycardia and hyper-attentiveness (Smith, 1991); a response notably referred to as the behavioural inhibition system (Gray, 1982).

Within a genuinely fearful situation, several cues may be observed and terror may not always precede horror. A horrific experience is partially characterised by a startle response and consequently, any cue perceived to be sudden has the potential to initiate the horror-pathway. However, the intensity of the stimulus dictates the subcortical activation and the degree to which the cognitive feedback loop can attenuate behaviour. Gameplay during a particularly frightening scene may include several sudden audio stimuli that stimulate a low-intensity response (creaking floorboard, object knocked over) accentuating the terror in anticipation of the final revelation. Fanselow (1994) describes three stages of fear behaviour that can be readily applied to a survival horror scenario: *pre-encounter defence* refers to initial anxiety experienced when entering an environment where predators are expected to appear (a dark tunnel, old mansion, or dilapidated factory); *post-encounter defence* describes heightened fear in response to cues that signify the presence of a predator (approaching footsteps, nearby items knocked over, etc.); and *circa-strike* defence refers to an intense fight or flight response when in region of physical contact and imminent threat (revelation of monster and attack). The descriptions of the latter two stages reveal striking similarity to our established definitions of terror and horror respectively. The concept of pre-encounter defence, however, is one that has not yet been addressed within our fear framework and for the purposes of this chapter is referred to as the *caution* stage.

Fearful stimuli can be understood as emotional prompts and cognitive cues for problem solving (Perron, 2004). Understanding of the relationship that exists between cognitive and subcortical processing requires identification of the variables that determine the degree of control each opposing force will exert. Yurgelun-Todd and Killgore (2006) identify a positive correlation between increasing age during adolescence and prefrontal cortex activity measured during a fear-related activity. Hale et al. (1995) revealed that increasing the level of fear arousal in a message would result in a shift from systematic (comprehensive analysis / high cognitive load) to heuristic (partial analysis / economic cognitive load) process and concluded that there is a positive correlation between fear sensation and economisation of processing routine. Whilst the immediacy of the threat determines the type of behavioural and autonomic response, it is the intensity of the fear sensation that defines the dynamic between cognitive and subcortical control. Reber, Schwarz and Winkielman (2004) identify ease of perceptual processing as a causal variable of emotional experience. Causes of disassociation between input cues such as semantics, modality (visual, auditory, etc.) and attributes have been shown to decrease temporal processing speeds and evoke negative emotional valence (Spence et al., 2001). In accordance with the routines described earlier, an increased negative emotional experience is expected to further increase activation of the subcortical response (and, correspondingly, attenuate cognitive processing); the mind essentially perceiving the complexity of the threat cues as a rise in danger level. However, ease of processing should not be confused with ease of identification. Within the context of audio processing, Alho and Sinervo (1997) argue that sub-cortical (referred to as pre-attentive) processing can be observed in subjects when appraising complex patterns of sound; this suggests that the sub-cortical routine is capable of processing more than very basic stimuli. Although this autonomic process is capable of identifying a deviant object within a complex and dynamic environment, the task of identification is still arguably a base-level thought process in accordance with Bloom’s taxonomy of thought (Krathwohl & Anderson, 2001).

The purpose of the terror routine is to alter the physiological state in a way that maximises opportunity for aversive response should an immediate threat be presented. Utilising positron emission topography (PET) to measure cerebral blood flow, Kimbrell et al. (1995) noted that fearful stimuli induced greater blood flow in the inferior frontal gyrus (associated with the go/no go principle) and the left temporal pole (associated with the ability to make lexical and semantic links between different words, making it possible to understand a story [Dupont, 2002]). Conversely, fearful stimuli revealed decreased activity in the right medial cortex (high-level executive functions and decision-related processes [Talati & Hirsch, 2005]), the right superior frontal cortex (self-awareness [Goldberg et al., 2006]) and the parietal lobe (integrates sensory information from different modalities, particularly determining spatial sense and navigation). Here, neurobiology supports behaviour, as the inferior frontal and right medial cortex initiates an urgent and direct response routine and the left temporal pole and parietal lobe can be attributed to context (the participants were recollecting past experiences of anxiety, not experiencing physical fearful stimuli). The contextualization of the Kimbrell et al. experiment suggests that overall activity is unlikely to fit the above profile in a direct-interactive fearful scenario and ethical considerations limit researchers' ability to expose participants to immediate physical threats. Fortuitously, the nature of a CVG environment allows for a simulation that may well reveal the exact neurophysiology of an individual's fear response.

Bradley et al. (2005) compared the effects of pleasant/unpleasant stimuli and threat/safe associations on the startle reflex. Experiment results revealed that unpleasant stimuli potentiated startle regardless of subtext and that stimuli connoting threat potentiated startle regardless of inherent meaning. This supports the notion that the fear response process is sensitive to both objective and subjective fear-object attributes. Orgs et al. (2007) and Van Van Petten and Rheinfelder (1995) collected evidence that conceptual priming via two related inputs produced faster reaction times when compared to unrelated inputs. In response to a fearful scenario we are primed by the initial stimulus, allowing us to respond to associated subsequent stimuli immediately; as Smith (1999) states: 'A fearful mood puts us on emotional alert, and we patrol our environment searching for frightening objects', allowing us to react with more immediacy and increasing the probability of successfully evading the threat. The above findings support the notion that subconscious appraisal (dependent on biological variation and behavioural conditioning) of a terror stimulus stimulates a pattern of physiology that primes the individual for action in response to a horror stimulus (immediate threat). In the context of a horror film, prior knowledge of upcoming events generated increased sensations of fright and upset (Cantor et al., 1984). However, the nature of the forewarning arguably contained little information that could be utilised to aid survival (supporting uncertainty); with cues consisting of shadowy figures and sounds of masked position as opposed to cues that could reveal the location, identity or weaknesses of the threat. This suggests that forewarning cues that insinuate threat rather than describe it have greater potential to evoke a terror response.

As mentioned earlier, the startle component of a horrifying experience has the potential to significantly alter the intensity of the overall sensation. It has been proposed that the startle mechanism is continuous and that the human individual is unlikely to ever be in a complete state of non-alert (Hoffman & Searle, 1965). Brown et al. (1951) suggest conversely, that a startle response can be potentiated by a preceding cue that connotes danger and threat via a conditioned association. The response is sensitive to the individual's current emotional state and, consequently, such affect-toned material preceding a startle probe has the potential to significantly potentiate or attenuate the intensity of the response (Lang et al., 1993; Roy et al., 2008). Relevant experimentation reveals that this effect remains consistent despite cross-modality between stimuli (for example, visual affect stimuli followed by auditory startle probe) and that positive affect preceding a startle probe invariably reduces the behavioural response whereas a negative emotional state has a magnification effect (Frijda, 1994; Vrana et al., 1988; Yartz & Hawk, 2000). One particular emotional state, capable of dramatically potentiating the startle effect is anxiety (Cuthbert et al., 2003; Kumari, 2001); an effect further increased if the nature of the anxious state relates semantically or perceptually to the startle probe. The threat of pain and the induction of disgust have also been associated with potentiating of the startle reflex (Bradley et al., 2005). Yartz and Hawk (2002) found that fearful stimuli caused a greater startle response when compared to disgusting stimuli, but only in male participants. This suggests that we cannot predict the startle potential (and consequently horror potential) of a terror stimulus without knowledge of individual character and psychophysiological features.

This relationship between fear types is arguably not unidirectional, and a horrific experience has the potential to influence future terror appraisals. Barlow and Durand (2009: p.123) provide a review of anxiety causes; proposing an integrated model of anxiety induction entitled *triple vulnerability theory.* This theory identifies *generalised biological vulnerability* (diathesis: genetic causes of fear/anxiety susceptibility), *generalised psychological vulnerability* (associated with a lack of self-confidence and an overarching belief that the world is a dangerous place) and *specific psychological vulnerability* (a belief pertaining towards a discrete object or situation) as causes of anxiety. The latter can be associated with horrifying experience in that specific, intensely emotional events such as these are strong candidates for future anxiety developments. A horrific experience can potentially connect a substantial number of seemingly disparate items via conceptual networking links (Medin et al., 2000), creating an intricate mesh of associations and, as a result, massively increasing the number of memory items that could potentially impact upon the perception of future objects or events as fear-related and terror-inducing. Upon examination of the above literature, the bi-directional relationship appears to exist within a two-stage framework of fear (terror primes horror). If we are to accept Fanselow's (1994) three-tier construct, then there is the relationship between pre-encounter (environment orientated caution) and post-encounter defence (object orientated terror) to consider. Understanding of the exact nature of these relationships remains, at present, theoretical. However, an initial hypothesis; that the same priming relationship that exists between terror and horror also incorporates caution and that the three stages are interrelated, is worthy of consideration.

Conscious cortical brain activity occurring during a terror state may arguably be working against the survival instinct; shifting focus away from the immediate environment to contemplate higher level construals and, consequently, reducing ability to react to a sudden threat. The imperfect nature of the human response system means that we are susceptible to both false-positive (believing there is a genuine danger when there is not) and false-negative (believing there is no danger when there actually is) error. Differences between individual coping styles are exemplified by the monitor-blunter spectrum. With regards to the extreme poles of this continuum, *monitors* are individuals highly sensitive to fearful stimuli; revealing strong semantic associations between the context of threat and numerous memory items. In contrast, a *blunter* is comparatively insensitive to fearful stimuli and significantly less likely to associate memory items or current stimuli to their concept of threat (Folkman & Lazarus, 1990; Miller, 1998). Sparks (1989) revealed that individuals identified as *monitors* generated positive emotional responses in the presence of forewarning cues and negative response in their absence; individuals identified as blunters revealed opposite results. Emotional response was identified via debrief questionnaire and galvanic skin response (GSR) data designed to assess the overall experience as opposed to phasic examination of the startle response. This suggests that although forewarning invariably amplifies startle, an absence of warning may create a more frightening overall experience (providing the individual is a monitor). A logical conclusion could be that, in order to maximise the potential intensity of both a terrifying (preceding) and horrifying (startle) experience, the environment preceding a startle probe is required to contain stimuli that connote negative affect but that (in the case of monitors) reveal little to no information that could assist in coping (size, position, movement, speed, etc.).

In summary, the subcortical processes and autonomic physiology in response to terror stimuli are designed to prepare the body for a horrific confrontation. The function of higher level thought is primarily homeostatic; attenuating the subcortical routine to mitigate the physiological changes in response to absence of threat. It is the cognitive appraisal routine that is most susceptible to fault however. The nature of the cortical system means that thoughts transcend the here and now and, as a result, past experiences and future conjecture can bias an otherwise objective evaluation of the current situation. These biases appear as *type 1* and *type 2* statistical hypothesis errors (*false positive* and *false negative*) that either risk an individual under-preparing in the face of a threat or cause needless anxiety through the conjuring of an unreal threat that is unsubstantiated by objective evidence. The chronological period within which both errors can occur is after the physiological priming of terror and before the possibility of horrific revelation. A suitable period of time between these events allows the cognitive functions to analyse the situation. It is here that a blunter may underestimate the threat by semantically associating the stimulus to non-threatening concepts whilst the monitor overestimates, relating the stimulus to inappropriately dangerous theories. At this time, such a structure remains theoretical and would require real-time observation of neural activation during a genuine fear experience. It is also acknowledged that these dynamics are focussed upon the short term and do not account for effects such as prolonged horrific experiences on the perception of terror and anxiety.

FEAR AND COMPUTER VIDEO GAMES

Within the context of a computer video game, the sensation of fear cannot directly stem from an actual threat to physical wellbeing, if that were the case the respective industries would have been required to take a rather relaxed view on ethical concerns. Instead, such media attempts to displace actual physical damage via representation; creating a virtuality in which the audience can be hunted, attacked injured and killed without actual sustained damage (within reality). Fictional media can utilise the notion of self-perpetuating fear, wherein audience members are afraid that the media may make them terrified or cause them to jump in their seats (Massumi, 2005). However, if identification and acceptance of a threat is central to a genuine fear response, phobophobia alone may not comprehensively clarify a fearful experience during gameplay. Instead, an alternative may exist in which an artificial environment is (at least partially) accepted as reality; causing a player to experience a fear that is comparable to a *natural* fear sensation.

Although a distinction between virtuality and reality at first appears clear, such boundaries rapidly deteriorate upon close inspection. The previous paragraph suggests that acceptance of a virtual environment as real has a substantial potential for inducing more intense affect, and perceptions of a genuine fear experience. The line separating man from machine and reality from virtuality is becoming increasingly blurred (Sorgatz, 2007). This may serve to facilitate both a computer video game player's perception of a virtual threat as real and manifest an experience of genuine fear in the absence of physical danger. In *Discrimination and Perceptual Theories* (1976), Alvin Goldman suggests that a representative entity (described as façade) can generate a false perception of reality. Within a real-world scenario a proposal fulfilling an individual's requirement for acceptance (as real) may not necessarily be the truth. Goldman elucidates, describing a papier-mâché facsimile of a barn that on visual appraisal is undeniably a barn, however deeper investigation (additional sensory data, attempts to exploit expected function from object) unveils the deception and upon discovery alters the perceiver's reality, simultaneously disproving the knowledge of the prior proposal. The subjective perception of reality is distinguished from the acquisition of objective knowledge; however Goldman's theory suggests that knowledge is itself, a belief. Within a CVG context, virtual worlds have potential to represent reality and exploit causal assumptions to facilitate immersion and manufacture belief in the façade. The facsimile barn within reality may generate a perceptual certainty for the viewer via no more than distant visual data; by comparison the virtual barn may provide a wealth of additional inputs (additional visuals, audio, interactive physics) to consolidate its appraisal as *real*.

The information detailed above is focussed primarily on the core processes of fear and arguably describes the phenomena as a negative experience necessary for coping with threat. Irrespective of this, research has suggested that not only is fear capable of producing positive emotional experiences (Andrade & Cohen, 2006; Svendsen, 2008: p.75) but that it is a sensation that many will actively seek out as a way of emotional exploration (Pearce, 2008). Poole (2000) argues that within the context of a supposedly pleasurable overall experience such as a computer video game, consumers wish to experience emotional variety and intensity within user-defined boundaries. Perron (2005) describes the pleasurable experience of fear as *recreational terror*, likening the experience to that of a rollercoaster; a sensation that lies between security and uncertainty. Placing the player experience between these polar opposites is possible via manipulation of boundaries (Perron, 2005; Pinedo, 2004). A gamer who may wish to experience the visceral nature of war, nevertheless is highly unlikely to desire the experience of being shot. Consequently, very few fictional horror media genuinely terrify their audience (Schneider, 2004: p.135). Boundaries between desirable and detrimental emotional experiences arguably follow the same principle and, by definition, real terror is an emotional experience no individual is likely to long for, but paradoxically the terms *terror* and *terrifying* remain two of the most prevalent descriptors used to market computer video games within the survival horror genre.

Andrade and Cohen (2006) argue that the disparity between individuals is a variable likely to impact upon whether a fearful scenario is regarded entirely as a negative experience or as a co-activation of positive and negative. For example, a survival horror game that is perceived to be deeply upsetting and disturbing to one individual may be experienced as partly disturbing and partly exhilarating to another. Andrade and Cohen put forward the notion of displacement as the potential cause of this variation between individuals; a concept echoed by Perron (2005). Displacement in this context refers to the psychological distance the individual has placed between themselves and the stimulus. Such an effect may even cause players to misread a horrific emotional cue and respond with laughter (Giles, 1984). Displacement theory resonates with that of ‘a bounded experience of fear (Pinedo, 2004: p.106). In a CVG context, displacement appears to be the antonym of presence and immersion; if a player had a deep sense of presence within a virtual scenario, a fear stimulus would have greater potential to create an exhilarating and intense adrenaline response, but also increases the risk of genuinely disturbing and upsetting the player to the point of withdrawal from the game. Alternatively, if a player was too far displaced from the scene, the apprehension that the stimuli do not constitute an actual threat to well-being would reduce the danger of genuine upset but would simultaneously risk nullified impact, boredom and misreading of the stimuli. Experiencing horror and terror sensations does not require the objects of fear to exist within reality, as individuals can be moved by the imaginary (Carroll, 1990 p.88); a notion referred to by Tan (1996) as fiction emotions. Survival horror games project a real threat of physical danger creating a partial experience ‘bounded by the tension between proximity and distance, reality and illusion’ (Pinedo, 2004: p.107). These games (like all fictional horror media) seek to strike a balance, raising the realism and immersion to a level that enraptures the audience; evoking autonomic behavioural responses to create a genuine sensation of fear, whilst providing time (periods of absence from threat) and *reality cues* (events and/or entities that remind the player that they are playing a game) for subsequent relief.

Effective manipulation of the fear-boundary concept requires a full appreciation of the factors that make CVG a unique medium. The interactivity of a computer video game immediately differentiates it from a film, providing genuine player consequences (loss of progress, threat of repetition) alongside an increased association between fictional protagonist and player self (Shinkle, 2005) and the opportunity for “*testing the limits of the game, playing with the game* *instead of playing the game*" (Perron, 2004). The fluctuating temporal nature of a CVG experience (as a result of save, load and checkpoint replay functions) means that already experienced horror moments (a difficult boss fight where the avatar was killed and the player must return to the last checkpoint) can induce terror during a repeat play; the horror event re-characterised as a terror stimulus (Perron, 2004). Fear induced action tendencies that cannot be realised when watching a film are a central aspect of the dynamic between the player and the game, and these interactions generate virtuality-based feedback emotions, described by Perron (2004) as *gameplay experiences*. Examples of gameplay experiences include challenge (Nacke & Lindley, 2008), game immersion (Brown & Cairns, 2004), flow (Csíkszentmihályi, 1990) and frustration (Perron, 2005) and must be considered before a comprehensive ecology of CVG fear can be constructed.

The discussion documented above suggests that evolutionary developments are crucial to the characteristics of the fear process as the ultimate purpose of fear is arguably to facilitate homeostasis by enabling the body to evade dangers that may cause injury, dysfunction or death. The exact nature of the fear process however is much less straightforward; integrating preconscious autonomic (both evolutionary/biological and behavioural) circuits with cognitive internalisation, reflective with reflexive thought and integrating memory, personality, physiology and environment into a complete scenario. The following sections of this chapter will progress these notions further by exploring the affective qualities of audio and laying the theoretical groundwork that will inform an integrated conceptual design that assimilates the ecological fear framework with game sound theory in an effort to construct a virtual acoustic ecology of fear.

THE POTENTIAL OF ACOUSTIC AND PSYCHO-ACOUSTIC SOUND PARAMETERS TO CREATE AND INTENSIFY FEAR

The preceding section addressed the substantial terminology associated with fear, elucidating the individual processes that exist within a fearful experience and demonstrating how they interact along a chronological path. Here, both the acoustic and psychoacoustic parameters of sound that can potentiate fear are discussed. Existing empirical and conceptual work is addressed and then expanded upon; integrating acoustic parameters, audio classes and modes of listening, into a structure of fear that is then re-contextualised into a gameplay-relevant acoustic ecology. These sections commence with an outline of various acoustic parameters that have been associated with human emotional response; followed by an exploration into the emotionality of sound in an attempt to elucidate ways in which sound can not only propagate emotional meaning, but also evoke a listener's emotional reactions across a wide variety of discrete emotions that includes, but is not limited to, fear.

EMOTIONAL PROPERTIES OF SOUND

Sound is a critical component to consider when developing emotionality, as it is directly associated with the user's experience of emotions (Shilling et al. 2002; Alves & Roque, 2009). Parker and Heerema (2007) suggest that sound carries more emotional content than any other part of a computer game. Grimshaw et al. (2008) discovered that players felt significant decreases in immersion and gameplay comfort when audio was removed from gameplay; an assertion also made by Jørgensen (2006) who, via observations and conversations with players, revealed that an absence of sound caused a reduction in engagement such that ‘the fictional world seems to disappear and that the game is reduced to rules and game mechanics’. Foley sound design supports the emotionality of sound effects in creating both fantastic and everyday worlds. Ekman (2008) describes how ‘often non-realistic sounds are purposefully used to make the action sound better’. She exemplifies this process as ‘walking on cornstarch sounds much 'more real' on film than the actual sounds of walking on snow’. Shilling et al. (2002) quote industry professionals: ‘A game or a simulation without an enriched sound environment is emotionally dead and lifeless’, implying that sound effects must be analysed in terms of their emotional qualities so that they may be implemented in a way that will maximise the audience’s sensory experience.

If we accept that sounds can be manipulated to maximise emotionality, it is reasonable to assume that specific game genres require specific audio ‘emotioneering’ (Freeman, 2003). Therefore the survival horror genre, most commonly associated with the emotion of fear, would require emotion-based sound design that strived to evoke fearful responses (Kromand, 2008). As will be discussed later within this section, there are many acoustic and psychoacoustic properties of sound that could be investigated as to their fear-inducing potential. Some are quantitative, in that they can be objectively measured and applied to synthesis and audio processing. Others are more qualitative, based upon perception of a sound’s (or collection of sounds’) meaning(s) and are influenced by factors such as culture, experience, context and expectation. Later sections within this chapter survey relevant academic literature concerning the affective properties of sound in both quantitative and qualitative classes, particularly with reference to discomforting properties within the context of computer video games. Slaney (2002) concedes that the dynamic characteristics of sound make it difficult to analyse using objective acoustical measurements. Nevertheless, several approaches have been documented that identify quantifiable sonic parameters that can be associated to a sound’s emotionality. Cho et al. (2001) provided evidence that pressure level, loudness and sharpness of a sound can directly affect emotional valence and intensity. Loudness and sharpness are admittedly perceptual, psychoacoustic properties; however, using a model outlined by Zwicker and Fastl (1999), such properties can still be measured to provide objective values.

Moncrieff et al. (2001) reference attack-decay-sustain-release (ADSR) as a quantifiable sound energy parameter showing a significant association between ADSR and specific emotional responses. Bach et al. (2009) document the concept of increasing intensity as a measurable audio property that is psychoacoustic in nature via its intrinsic nature as a warning cue, while signal to noise ratio (Ekman, 2008) can also affect a sound’s emotional impact because of ease of cognitive processing. Periodicity, tempo and rhythm have the potential to elicit substantial affect through audio-physiological effects such as entrainment wherein, according to Alves and Roque (2009), a rhythmic simulation of a heartbeat, steadily increasing in tempo, has the potential to induce an increase in the heart rate of the listener. Parker and Heerema (2007) suggest that an evolutionary survival instinct exists today that encourages humans to associate low-pitched sounds (growls and rumbles) with predators and consequentially experience fear in response to such a stimulus.

Reverberation is one regularly implemented effect that can affect a player's perception of the game environment (Grimshaw, 2007). Alongside reverberation, an important function of the audio effect *delay* is to provide architectural and material information regarding the listener's environment: long reverberations and delays suggest reflective spaces that are large in comparison to the listener who can be made to feel quite small and lonely through this technique. Winer (1979) documents how the application of frequency manipulation or equalisation (EQ) affects a sound's emotionality and aesthetic. Localization of a virtual object, although currently limited in terms of game implementation, has significant emotion-related potential (Winer, 1979; Sonnadaraa et al., 2006; Steele & Chon, 2007). The doppler-effect can also be measured objectively and manipulated to further create a more realistic illusion of position, direction and speed. Compression and normalisation techniques are used regularly across a multitude of audio applications; whilst their primary function is to limit erroneous sound pressure levels and create a more uniform audio stream, manipulation of such parameters creates noticeable differences to a sound's psychoacoustic properties and therefore begs investigation as an emotioneering parameter.

Earlier sections within this chapter detailed the characteristics of the sub-categories of fear: horror (associated with shock/surprise) and terror (suspense, anxiety and threat). Established literature describes implementation of this knowledge via a number of audio design techniques. Breinbjerg (2005) posits that intentional ambiguity of a sound's source and location is critical to building suspense and terror, arguing that '[k]nowing that something is happening around the corner, without knowing precisely what it is, is most frightening'. Breinbjerg also suggests that a *lo-fi* audio soundscape consisting of many interfering sounds can increase disorientation and decrease the player's perceived coping ability. Kromand (2008) exemplifies this by describing the implementation of sensory fillers (sounds irrelevant to gameplay) that nevertheless resemble sounds relevant to gameplay. This practice dissolves the barrier between diegetic and non-diegetic sound, consequently encouraging the player to cautiously treat every sound as a threat harbinger; suspense is characterized (in this context) as a more prolonged, less intense feeling of terror. Kromand (2008) suggests that this can be achieved via a system of audio 'warning' cues that steadily reveal localization and movement information. He argues that the consequentially slow rising of intensity, plus no clear indication of when the inevitable shock will occur, manifests as suspense for the player. Parker and Heerema (2007) propose that acousmatic sounds perceived as threatening increase the sensation of terror: 'A prey animal that can only hear the predator is in an unknown amount of trouble, and it pays to believe the worst'. Reber, Schwarz and Winkielman (2004) argue that positive value judgements of audio strongly correlate with the ease with which they can be processed. Inverting this argument supports the notion that a sound that is difficult to identify, localize, and/or apply semantic meaning to, will evoke negative judgements.

Shock-horror requires a different approach. Despite Alfred Hitchcock's famous objection to shock (often referred to as cheap and simplistic) it remains a hallmark of the survival horror game genre. The most frightening part of the original *Resident Evil* (Capcom, 1996) is arguably the shocking moment when two mutant dogs jump through a window to attack the player's avatar. Xu et al. (2005) state that an audio shock is most effective when it is preceded by silence; a technique utilized in the aforementioned example. Cho et al. (2001) insist that acoustical properties of audio (specifically intense loudness and sharpness) can produce quantitative increases in negative emotional valence. These sonic characteristics are typically descriptive of audio designed to shock. Kromand (2008) details a deceptive technique that can be arguably associated to shock. This technique first establishes a sonic convention that aids player survival (Kromand uses the radio from *Silent Hill 2* [Konami, 2001] as an example) then intentionally defies this convention and morphs the semantic meaning of the sound from supportive to antagonistic.

Cox (2007) tested various sounds assumed to be *disgusting* and *horrible* in nature suggesting that (mainly as a result of cultural factors) individual sounds can have distinctly different levels of perceived disgust. There appears to be a fine line between the disgusting and the horrific and, although Cox suggests that a sound can be exclusively either, it seems reasonable to assume that perceived disgust will impact upon an overall sensation of horror when combined with a perceived threat. Parker and Heerema (2007) describe third-person audio cues as distinctly horrific in nature. They use a human scream as an example, asserting that '[a]s humans we tend to react with emotional similarity when we hear such sound, not in sympathy so much as in fear of whatever is inflicting pain or fear on the other'. In this example the sound is not only shocking due to its sudden, sharp and intense acoustic quality, but also horrific in that it implies the presence of a horrific creature and/or act.

POTENTIALLY FEAR EVOKING ACOUSTIC PARAMETERS

Relatively little literature exists concerning the effects of quantitative acoustic properties upon a listener's emotional state (with specific reference to fear). However, relevant research indirectly referencing this area of study or presenting relative theories is detailed throughout this section. Several concepts regarding the potential of specific sound parameters to manipulate emotional affect are concisely accumulated by Grimshaw (2009). Identified notions include: rapid onset/offset (attack/release) of an audio signal relates to a perception of urgency, slower attack relative to faster release increases perceived intensity by way of connoting an approaching source, and both loudness and frequency equalisation have the capacity to attenuate and amplify negative emotional activation.

Attack (a component of ADSR) refers to the distance (time) between the onset of a sound and the intensity/volume peak. Research relating to this parameter suggests that short attack periods (sudden, immediately intense) potentiate greater startle responses that are likely to be interpreted as frightening events; a response similar to the primitive Moro reflex, often referred to as the Strauss reflex in adults (Mulhall, 2011). In contrast, long attack periods slowly introduce a sound to the listener thereby greatly reducing startle potential. Long attack may however be employed when presenting a sound that establishes setting and builds tension (Parker & Heerema, 2007). An attack of considerable length may have further connotations of threat, suggesting that the source is moving towards the listener (Bach et al., 2009). Grimshaw (2009) addresses audio de-localisation (manipulating the sound to mask the position of the source), suggesting that in the context of a predator sound, occlusion of the source's position may augment the fear sensation, but that this de-localisation effect cannot be generalised to all sounds. Localisation refers to the positioning of the originating audio source in relation to the player and is determined by the interrelations between the source, the listener and the surrounding environment. Various assertions associated with localisation exist. Increased localisation difficulty may cause increased fear sensation due to uncertainty of source location reducing coping ability and consequently amplifying the severity of the threat (Ekman & Kajastila, 2009; Grimshaw, 2009). *Point-like* sounds that are easily localised within the environment are perceived to be more frightening if localised behind the player than in front (Ekman & Kajastila, 2009).

Acousmatic audio (sounds that have no visible source on screen) causes similar emotional effects if connoting a threat by limiting information that may support a coping strategy (Chion, 1994). Grimshaw (2009) also documents several additional psychoacoustic sonic properties associated with negative emotion experience; highlighting the unexpected nature and occurrence of an audio entity and the concept of defamiliarisation (the processing/distortion of a familiar sound to create the strange/uncanny). Sounds identified as approaching evoke a greater fear response than sound identified as receding (Bach et al., 2009). Signal to noise ratio (Ekman, 2008; Grimshaw, 2009) expresses a similar theorem, that decreased clarity (low-fidelity) resulting from a low signal to noise ratio may increase a fear sensation by way of increasing the difficulty in identifying and localising the signal source. Low quality or distorted audio may also lead to an uncanny sensation resulting from exposure to sound that connotes a familiar entity, but is presented in a deformed manner that generates an unsettling psychological disturbance (Kirkland, 2009).

Tempo derives from the musical definition, specifically referring to the frequency of repeated sounds (or repetitions of significant components of a soundscape). Research regarding entrainment (synchronisation between resonant systems) has asserted that alternative tempo properties have the potential to change the rate of brainwaves, heartbeat, respiration, etc. (Alves & Roque, 2009). This theory can be applied to a gameplay horror scenario by suggesting that increased tempo of threat-relevant audio may augment a fear sensation both cognitively (quick tempo of enemy footsteps connotes fast moving opponent and increased threat) and physiologically (by way of entrainment, the quick tempo of repeating audio encourages increased heart-rate, which is then interpreted as increased stress and perception of fear). Grimshaw (2009) suggests that 'frequency might have an effect on the unpleasantness of sound and this may lead to negative affect'. This notion has been explored further, addressing the perceptual acoustic property of sharpness (Cho et al., 2001). The sharpness concept refers to the frequency and purity of a sound and suggests that increased sharpness (higher frequency and purer tone) produces increased discomfort and negative affect for the listener. Parker and Heerema (2007) suggest that evolutionary development instils instinctive fear responses to certain audio properties. Specifically, slowly evolving, low frequency audio encourages a fear response by way of association with predator growling, whilst comparatively, high-frequency sounds evoke the same response via instinctive connotations of human screams.

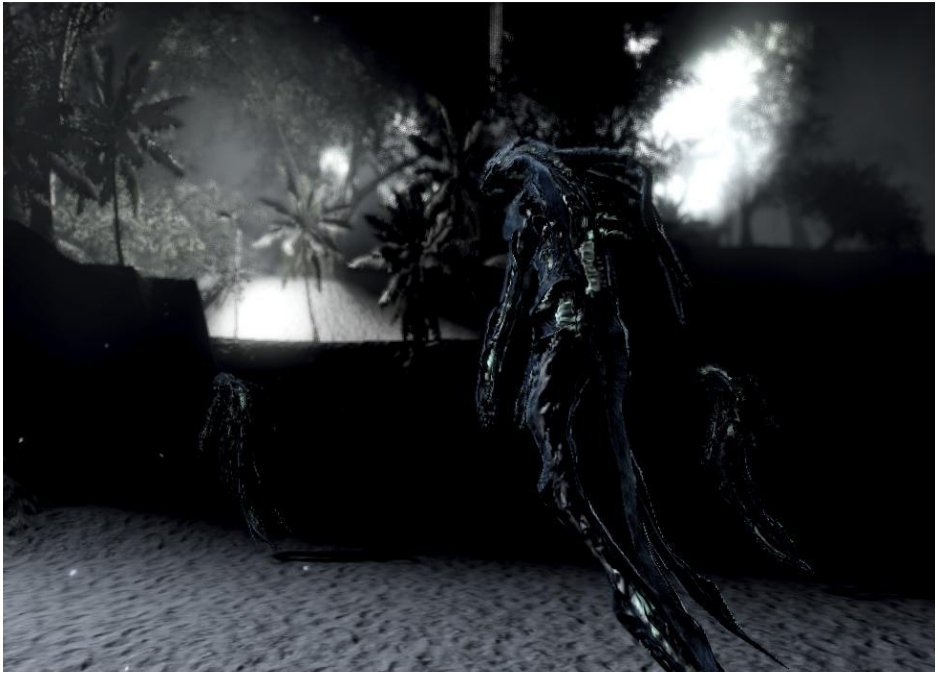
CONCLUSIONS AND CHAPTER SUMMARY

This chapter has presented a review of relevant literature, to support two hypothetical frameworks. The first accounting the processes of a fearful experience within a computer video game context and the second detailing the interaction between real and virtual acoustic ecologies within a game sound context. From this discussion, several opportunities for further study are revealed. Adjustments in quantitative acoustic parameters such as reverberation, tempo, rhythm, loudness and spectral frequency could be compared in both situation-integrated and disassociated classes during survival-horror gameplay to establish the potential of individual acoustic qualities in modulating the intensity of player fear. Use of proprioceptive audio remains inconsistent within mainstream horror game titles and the opportunity exists to compare presence, contextualisation and acoustic characteristics of this sound type. Event logging systems support the collection of player action during play, providing an opportunity to confirm the classification of a sound as an attractor or retainer. Electroencephalogram hardware supplies a means of testing listening function by way of measuring cortical activity to suggest the way in which the player is auditioning the sounds presented. Ultimately, this information has the potential to allow game sound developers to direct the perceived intensity of the player-fear experience by effectively preparing the player in the initial stage, then utilising biometrics and avatar action logging to identify (in real-time) heightened anxiety and emotional arousal, activating both terror and horror sounds that capitalise upon prior preparation. Such a system has the potential to both extend the replay value of a horror game and present a genuinely frightening recreational experience, testing the nerves of even the most hardened survival horror computer game enthusiasts. This chapter nominates ADSR, pitch, sharpness, periodicity, reverberation, loudness, equalisation, and localisation parameters as strong candidates for potential fear elicitation, based upon the scenarios they can signify.

The next chapter provides additional background information before an amalgamation of theoretical concepts is undertaken. The notion of virtuality is explored in an attempt to elucidate the nature of virtual environments with relevance to game sound and the first-person shooter (FPS) genre. Embodied cognition theory is discussed in detail and forms a core foundation from which the meaning of virtuality is explored. In addition, the subsequent chapter will also document audio functionality and the modes of listening; stressing the importance of contextualisation upon audio perception and investigating the continuum of sonic virtuality in an attempt to comprehend the relationship between audio properties and perception of a sound as real (‘genuine’) or virtual (‘false’).

Chapter 4

Embodied Cognition and Sonic Virtuality



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Chapter 4: Embodied Cognition and Sonic Virtuality

INTRODUCTION

This chapter explores acoustic ecology (AE) theory within the domain of computer video games and examines the variables and measurements of sonic virtuality. Also discussed are the various concepts connected with embodied cognition (EC) and knowledge theory, and also the associative notion that reality is an illusion and that all existence is inherently virtual. As stated within the thesis introduction, the term *computer video games* (CVG), refers chiefly to modern games, more specifically, the first-person shooter (FPS) genre that places the user within a three dimensional virtuality. This chapter explores concepts of virtuality, primarily to better elucidate the nature of its technological associate, virtual reality. First, discussing the possibilities of virtuality and its distinction from reality and artificial reality, this chapter subsequently addresses the virtuality of sound, deliberating on what determines a sound to be real or virtual and presents a graded continuum of virtuality. Previously referenced within the thesis, embodied cognition theory is explored in greater detail and applied to virtuality and acoustic ecology concepts, incorporating modes of listening, attention and cross-modal effects, construal level theory and psychological distance in an effort to better elucidate the nature of sound within a virtual environment.

DEFINING VIRTUALITY

A precise understanding of virtuality is notably hindered by disagreements concerning its exact definition. From a perspective of popular usage, the word virtual is synonymous with *near* and *almost*, which - when applied to our understanding of virtual reality (VR) - describes a near-perfect recreation of reality, placing virtuality a single notch below reality at the top of a continuum, with unreal at the base. The term *virtual* is also echoed in words such as *essential* and *fundamental* - a reflection that could describe VR as an approximation of actuality that achieves the most significant aspects of the reality it imitates whilst being distinguishable in the minor details. We differentiate between virtuality and virtual reality, identifying the former as a more general term for describing an entity as less than real. In contrast, virtual reality can refer to both a technological development implementing computer generated sensory information, and an individual’s subjective perception of reality. As the definition of virtuality will be developed throughout the chapter, the opposing term *real* will also be addressed. To clarify later statements, *real* will primarily (unless otherwise specified) refer to entities (events, objects, processes, etc.) that exist outside of VR and are observable within the natural world (as opposed to an emulated one).

John Leslie King (2007: p.13) identifies the inherent meaning of virtuality as the opposing counterpart to what is real, suggesting that without the virtual, reality could not exist. Logical deduction develops this notion to posit that virtuality has existed for as long as we have been able to comprehend reality. The difficulty with this definition lies in our limited and abstract understanding of *real*. King (p.14) cites research identifying cognitive perception of the unreal as real (referencing actual improved sound quality affecting perceived visual quality of a multimodal stimulus). What we perceive is unequal to what *is*. This notion could be extended to suggest that each individual possesses their own unique reality, containing various *perceived truths* that are accepted within that reality with a conviction comparable to that felt towards objective truths. This calls into question the existence of so-called objective truths and asks: is all existence inherently virtual? Does the very nature of our thought processing distil all knowledge and certainties to beliefs and opinions? Could the oxymoronic signifier *virtual reality*, in fact, be the single concrete truth?

Accepting virtuality as simply the antithesis of reality would classify the term as anything unreal (unnatural, inauthentic, false, etc.). From a philosophical perspective, such a definition is valid at a theoretical level, but ultimately limits our opportunity for development, both in terms of conceptual understanding and technological advancement. A more detailed understanding of virtuality would support creative design choices within various industries, developing the immersive qualities of various media to ultimately generate a better user experience for innumerable products.

The associations between virtuality as a concept and virtual reality as a technology advocate computer video games as a prime medium for virtuality research. Whilst visual information from a game exists on a two dimensional plane, game sound exists within the same 3D environment as the listener (Grimshaw, 2008), revealing greater complexity and blurring the lines that separate reality from virtuality; consequently promoting sound as the preferred sensory modality for this research.

CONCEPTS OF VIRTUALITY

'There has never been a totally secure view of reality, certainly not in the industrial era of history. People say that the world is not as real [as] it used to be.' (Woolley, 1993: p.6)

From a highly theoretical perspective, it is appropriate to suggest that, should a computer video game successfully generate a virtual world indistinguishable from that of reality, then potentially any dream from within the imagination could be fully experienced in both body and mind; with a further opportunity for such dreams to be shared, exchanged and experienced alongside other people. Such possibilities reveal a substantial potential value for virtuality research, whereby a comprehensive understanding of human perception could facilitate technology capable of placing a user within a total immersion environment that is perceivable as reality but with the limitless freedoms that virtuality could afford.

Chalmers et al. (2009) argue that although human beings perceive the world with five senses, cross-modal effects can have substantial impact upon perception 'even to the extent that large amounts of detail of one sense may be ignored when in the presence of other more dominant sensory inputs'. This may go some distance to explaining the immersive capacity of a computer video game. Whilst information received during gameplay may typically be limited to visual, audible and haptic data, the way in which the information is presented generates an illusion of full sensory input (a concept that is more fully explored later in the EC discussion). Hughes and Stapleton (2005) support this notion, arguing that ‘the goal of VR is to dominate the senses, taking its users to a place totally disconnected from the real world’.

In her book *The Rational Imagination*, Ruth Byrne (2005: p.3) identifies counter-factual imagination as a component of creative thought in which an impossibility, related to reality, can be experienced within the mind’s eye. Reality is transformed through manipulation of facts into an alternate world of fiction, a world that could arguably be described as virtual. Imagining an alternate reality in this way is not a passive ‘dream-like’ experience but rather an (inter)active one, directed by the creator in real-time. This differentiates the alternative reality of counter-factual imagination from film, theatre and fiction novels. Computer video games, however, share with imagination the opportunity for real-time user interaction within an impossible environment. For Michael Heim (1998: p.4), virtual reality is technological - an ‘emerging field of applied science’. This focus differentiates between terms associated with *unreal*, separating virtuality from *Artificial Reality*, a phrase that Woolley (1993: p.5) defines as a circumstance in which a fiction has become fact through creation of a product that originally only existed within a fictional world. In utilising a technological perspective, it is best to avoid more abstract theoretical notions and a clear distinction between reality and virtuality, alongside a practical method for measuring virtuality, is required. Heim (1998) distinguishes between *hard* and *soft* virtual reality (VR). Soft VR is described as essentially a diluted form; that is anything based in computers or that can be argued as *other than real* (Heim illustrates by way of advertising techniques that state their product or sevice as *the real thing*, suggesting that their competitors are less than real and, in essence, virtual). Heim argues that such a definition is counterproductive to the progression of virtual reality development and presents the three standards of Virtual Reality (1998: p.7): immersion, interactivity and information intensity.

In the book *Architecture Depends* (2009: p.87), Jeremy Till asserts that an established statement by Laurie Anderson (that virtual reality will never be fully accepted as truth until developers ‘learn how to put in dirt’) is not to be literally translated and subsequently posits that *dirt* refers to temporality. The more obvious, literal definition appears valid nonetheless in that the technological restraints put upon virtual world construction (e.g. texture tiling, model duplication, sound repetition, etc.) dictates a flatness that differentiates VR from reality. Within even the most complex game engines, every pixel is accounted for and clearly stated within the program code whilst reality is encapsulated in (seemingly) infinite and uncontrollable variations. Modern VR systems do attempt emulation of temporality, particularly within the genre of role-playing and real-time strategy games. Weapons may deteriorate, buildings may fall into disrepair, plants and animals may starve, and relationships may lose closeness; these are but a few examples of gameplay mechanics simulating the temporal *dirt* of reality, with consequences and interrelations that relate directly to the player. However, the association between virtual reality and time documented by Till asserts that such efforts remain distinctly unreal because such temporal elements are autonomous and most commonly relate to an internal clock as opposed to the globally shared system of time.

Hughes and Stapleton (2005) consolidate relevant literature to elucidate various conceptual positions on the reality/virtuality continuum. In this framework reality and virtual reality (VR) exist on polar extremes with mixed reality (MR - a relatively even distribution of real and virtual elements within an environment) occupying the centre point, augmented reality (synthetic objects added into a real landscape) positioned between MR and reality, and augmented virtuality (real objects, situated within a virtual landscape) located between MR and VR. In addition, Hughes and Stapleton note that MR also refers to the entire spectrum of reality/virtuality and that the reality types are points on a continuum rather than discrete classes of reality.

THE VIRTUALITY OF SOUND

A player is situated in their living room, seated comfortably and initiating their game experience. As they commence by progressing through the game setup menus, a variety of feedback beeps confirm their actions within the interface. As the player enters the game, they hear a transcendent voice counting down to match-start followed by verbal orders from a non-player character (NPC) heard over a short-wave radio. The player hears the sound of their plasma rifle charging, their footsteps in the snow and the rattle of their equipment as they proceed. As an enemy is observed and engaged, the sound of plasma weapon firing dominates the soundscape, followed by a visceral impact expressed by the sound of screams and melting flesh. As the enemy lays sprawled across the battlefield, their voice (originating from a live player via voice-over internet protocol [VoIP]) is heard loud and clear; “Whatever! Lucky shot!” as a chorus of cheers confirms the player’s righteous kill.

The above scenario elucidates the complexities that arise when attempting to classify and measure sonic virtuality. Feedback sounds supporting menu/interface navigation have no physical relationship between action and sound, with the chosen sound sample retaining only a semantic association. Transcendent voice-overs are pre-recorded material with no identifiable (real or virtual) source whilst NPC radio messages originate from a clearly identifiable source but are not propagated via a natural physical source. The sound of a fictional entity such as a plasma rifle (a symbolic auditory icon [Grimshaw and Schott, 2008]) does not possess physical causality and can only be created by way of synthesis or sampling (recording) of an alternative sound (again, with only a semantic link between sound and source/action). Footsteps in the snow may utilise a sample taken from a genuine source yet often a recording of walking on corn starch is implemented (an oft-used technique in cinema). This represents a common example of hyper-real sound, in which designers have consistently utilised an alternative sound sample to the extent that a listener is more likely to recognise the false sample as more genuine than the physical sound.

All of these sounds originate from the game engine, but they still exist within reality - propagated by artificial (but nonetheless physical) equipment, travelling and reflecting through real spaces (Grimshaw, 2008). In a similar vein, Natkin (2000) documents a practical implementation of virtual soundscapes within real spaces, in which the sound waves are propagated via headphones and utilise postproduction processing to create an artificial representation of the physical space. In this circumstance it is not the actual sound that is virtual, but instead the method with which the sound is broadcast. For Natkin, this propagation of sound is virtual, though the sound samples themselves are high likely to be classified by many as real. Bronkhorst (1995) provides a correlating argument, identifying a differentiation of sound virtuality between sounds that originate from a natural and from an artificial propagation source.

This notion is complicated further when considering VoIP sound. Although VoIP transmitted sound originates from a live speaker, the information is digitised then re-encoded as sound wave data before it reaches the listener and commonly a delay exists between speaking into the headset and receiving the sound from the sound output. Whilst the sound input possesses a stronger temporal and semantic association to the received output, the propagation is nonetheless artificial. This can be expanded to question the *reality* of electronically amplified live sound and further complexity arises when considering the difference between analogue and digital signal processing (an issue that has garnered significant debate in recent years). If we were to define virtual sound as any sound propagated by an artificial projection medium, then a significant proportion of academic experimentation into sound deals exclusively with virtual sound. This highlights the following questions: is the nature of recording/playback/amplification of a sound originally emitted from the natural world enough to make that recording virtual? Is there a distinct separation between virtual and artificial?

At present, mainstream computer video games generate sensory data in visual, sound and tactile modalities. As a result, even game developers that strive to achieve realistic soundscapes must expand the purpose of sound to perpetuate a simulated sensation of olfactory, tactile and gustatory input via representational inference. A visually rendered corpse alone may not trigger an olfactory sensation of decay, but the sound of buzzing flies and wriggling maggots around it has a much greater potential to do so. This issue establishes a clear divide between reality and the virtuality of current computer video games. Sound designers are often required to compromise between playability (a sound design that supports player action via extra-diegetic sound feedback, representative of other sense data) and realism (a soundscape more akin to reality, focussed upon diegetic sounds). The notion of realism is questionable, however, when observing a game experience as a whole. Although a *realistic* virtual soundscape may (virtually) reflect its reality counterpart, the lack of sound input compensating for other sensory modalities creates an incomplete experience, lacking immersion and, ironically, appearing unrealistic. Extended exposure to fictitious *Hollywood-esque* foley sounds has determined that genuine source recordings of many dynamic sounds (shotgun blasts, footsteps in the snow, etc.) are often perceived to be unrealistic. As the lines separating the virtual and the real become increasingly blurred; the audience is becoming more likely to be immersed by the hyper-real than the real. Games are not simply simulations of real events; they are unique constructs that are better perceived as real-life activities (Shinkle, 2005).

Several questions concerning virtuality are hereby raised: how can we better understand sonic virtuality? Where does reality end and virtuality begin? Can virtuality in relation to sound be classified and measured and, if so, how? Subsequent sections address these questions and the chapter includes a conceptual framework to facilitate clearer classification of sounds and support future development of a workable measurement system for sonic virtuality. Here, the various concepts of virtuality (as they relate to sound) form a framework that distinguishes between real and virtual sound, whilst allowing space for incremental points between the polar extremes. Understanding the complex interrelations between human and environment (be it real or virtual) is fundamentally shaped by the psychological approach adhered to when theorising the processes of the human mind. This chapter advocates EC theory to explore the way in which we define, perceive and interact with sound. Virtual and real acoustic ecologies are also explored within the context of affective response to computer game play.

VIRTUAL ACOUSTIC ECOLOGY AND EMBODIED COGNITION

The following sections explore the relationships that exist between player, game and environment from a more distant but comprehensive perspective. Commencing with a detailed review of embodied cognition (EC) theory, the relevance of EC is explored, when considering the way in which we perceive and relate to game sound. Original acoustic ecology theory is presented and contrasted with the more recent notion of virtual acoustic ecologies and finally, EC theory is overlaid to support the production of an embodied virtual acoustic ecology (eVAE), presented in chapter 9.

Human-audio interactions have been demonstrated to be self-sustaining, autopoietic systems referred to by Grimshaw (2008) as *acoustic ecologies*. Within the domain of reality, the acoustic model has already been discussed, refined, and more recently has been adapted; integrating relevant game theory to establish a virtual acoustic ecology to elucidate the dynamic interaction between the player(s) and artificially generated audio landscapes. Understanding the complex interrelations between human and environment is fundamentally shaped by the psychological approach adhered to when theorising the processes of the human mind. This chapter cites *Embodied Cognition* (EC) as the preferable perspective template for our ecology model, with a detailed examination of EC concepts and their impact upon the understanding of fear processing during game play. Situational and temporal cognition are evaluated within a CVG context, alongside cognitive offloading mechanisms and bottom-up construction theory. Core concepts of embodied cognition, acoustic ecology, CVG experience and fear processing theory are brought together to inform construction of an acoustic ecology of fear within a virtuality framework. Beginning with an overview of fear conceptualisation and processing from various perspectives, these sections progress by examining the six main concepts of embodied cognition and integrate them to put forward an embodied perspective of fear processing which is then applied to construct a model of virtual ecology between player and game world with specific focus upon the audio landscape and the experience of fear.

CONCEPTS OF EMBODIED COGNITION

The *mind-body* problem associated with Cartesian Dualism (discussed in more detail later within this chapter) questions the notion that the mind exists as a separate entity from the body in favour of an integrated system. In searching for an approach to elucidate this conundrum, research can be referenced that supports the concept of such a unified system and identifies problems with a centralised framework. Stepper and Strack (1993) revealed that the posture of an individual had a notable effect on emotional response. Duckworth et al. (2002) produced an experiment that revealed faster reaction times to positive stimuli when responding by moving a lever towards the body, and matching results to negative stimuli when moving the lever away from the body; revealing an association between emotional valence and physical movement. Core cognitive tasks such as reading and comprehension have also been associated to bodily states. Havas et al. (2007) induced smile and frown states during emotion comprehension tests and discovered that smile induction facilitated understanding of positive events and inhibited the comprehension of negative events, whilst frown induction facilitated negative understanding and inhibited positive understanding. Existing research strongly supports the notion of integrated cognition, stating that '[t]he biological mind is, first and foremost, an organ for controlling the biological body' (Clarke, 2007: p.1).

Traditional artificial intelligence (AI) frameworks operate on a sense-model-plan-act (SMPA) system, a framework based on traditional cognitive theory that has yet to meet the immediate, dynamic requirements of a real environment. Anderson (2003) criticises the central SMPA system, suggesting that in attempting to react to real-world dynamics, a central system would need to store an individual response plan for every potential future outcome. The number of outcomes would be dependent on number of variables compounded by variance of each variable and accommodating every possible interaction between two or more variables; as such the likely number of stored action strategies would be unmanageable. Anderson (2003) suggests that an intelligence structure must relate abstract thought to primitive, evolutionary devices but does point out that, although this target has not been achieved and handling of such data is beyond current computing technology, progress is being observed and a central, representational model should not be altogether dismissed. The fundamental lack of immediate responsiveness is arguably the essential problem associated with the centralised cognition concept. As also documented earlier within this chapter, Clarke's (1997: p.21) concept of the representational bottleneck reveals the efficiency limitations of a central processing design and advocates the integrated model. Von Uexkull's (1957) concept of *Umwelt* may explain how the mind reduces incoming data to increase efficiency of processing, but further questions are raised; is perception defined by lifestyle and what factors dictate the nature of these desires and needs?

We cannot hope to truly understand the nature of our reality; a task described by Fox (1997) as 'like trying to carry water in our hands. It is not a thing to grasp or keep'. Fox references Heidegger's concept of *Befindlichkeit*, as 'the way our thrownness is disclosed to us' (1997), and suggests that how we interpret, attend to or *be with* our thrownness is our only real freedom. Although disagreement exists surrounding exact nature of this concept, Dreyfus (1991: p.173) concludes that it is our emotional state that defines our individual *Befindlichkeit*, proposing a parallel between affect, thrownness and embodied cognition in that an individual cannot be separated from their emotions; as Dreyfus states, 'we cannot get behind our moods; we cannot get clear about them, and we cannot get clear *of* them' (p.173). Rapid eye movement (REM) dream states provide a possible example of disembodied cognition, in which partial nullification of primary sensory cortices allow the mind to become disconnected from the environment; it is posited that the sensation of presence and experience is consequently internalised (Laureys & Tononi, 2009: p.100).

Dreams originate from the forebrain regions that also govern much of cognitive processing during conscious states (Bischof & Bassetti, 2004; Solms, 1997). During REM sleep, the limbic regions of the brain such as the amygdala have been shown to measure greater activity during a dream state than in wakefulness. Areas of the prefrontal cortex that receive input from limbic structures measure significant activation during REM sleep; including the areas of the forebrain that process mental imagery, spatial awareness and symbolic representation (Laureys & Tononi, 2009: p.94). Research posits that higher level thought processes can occur during dream states, including: conscious perceptual representation (LaBerge & Degracia, 1998); speech production (Salzarulo & Cipolli, 1974); and metacognition (Kahan & LaBerge, 1994). This suggests that cognitive interpretation of internally generated data is plausible when we consider our ability to make sense of our surroundings during a dream.

A lucid dream (in which the dreamer is aware that they are dreaming) has significant potential for facilitating higher-level internalised thought. LaBarge and Degracia (1999) review a number of texts that claim individuals are capable of situating themselves within a dream world, in which their simulated senses can influence their actions and react to temporal influence due to an awareness of precedents and antecedents within the dream. Sensory stimulation across all modalities, whilst acknowledged not to be real, is nonetheless felt by the dreamer as a vivid sensation that is close to that experienced in reality. LaBarge and Levitan (1998) conducted studies on lucid dreamers, evaluating the difference in subjective sensation of somatosensory experiences. The results indicated that the brain is capable of modelling particular *touch* sensations; specifically light touch and pressure were vividly experienced (however pain was not) during lucid dreaming. LaBarge and Degracia (1999: p.299) go on to posit that the experiences that occur during a lucid dream are likely to be to be remembered after waking and, ultimately, have the potential to transcend from the dream world to reality and alter the course of a dreamer's waking life.

Cognitive thought during wakefulness is arguably influenced by immediate sensory input to the degree that the environment must be integrated into all frameworks of human thought processing, thereby observing the mind within an ecological perspective. However, during unconscious states associated with dreaming, the mind appears capable of interpreting internally generated data, evoking emotional sensations via the limbic regions of the brain and also stimulating autonomic physiological activity and virtual motor responses. Furthermore, the research into lucid dreams supports the notion that the mind is able to reflect upon internalised scenarios and respond with voluntary virtual interactions. Internally generated stimuli during dream experience supports the notion of *sensory simulation* (a central aspect of embodied cognition theory); suggesting that this phenomenon can occur in both consciousness and dream states. This could suggest that during a dream state, information regarding sensory input (collected during wakefulness and stored in the long term memory) is recalled and reconstituted as a simulated experience, essentially creating a virtual environment within which the cognitive processes can remain embodied.

Embodied cognition can be understood as thought processing within the here and now. The fundamental idea behind time-pressured cognition (the *now*) is that all human thought can potentially be influenced by the concept of time as perceived by the individual, and relating to objects or events. Liberman and Trope (1998) illustrated how an individual's perception towards a future event could change in response to different relative temporal distances. Personal evaluation has also been described as susceptible to PD influence; as research by Freitas, Salovey and Liberman (2001) reveals, individuals were likely to employ a negative, diagnostic assessment when it was expected in the more distant future but more likely to prefer a positive, non-diagnostic assessment when it was perceived as imminent. Greater temporal distance encourages more generalized thought (one cannot see the trees for the forest) whereas immediacy evokes increased specificity (one cannot see the forest for the trees). Time therefore manipulates attention and becomes a significant factor in appraisal and decision-making (Liberman & Trope, 2008). Temporal distances are interrelated quantifiable values that, alongside hypotheticality, spatial and social distance, establish PD and influence higher-level cognitive processes such as evaluation and prediction (Bar-Anan et al., 2007; Liberman & Trope, 2008; Stroop, 1935).

The central notion of situated cognition (the *here*) is that all informational processing is susceptible to the continuous stream of incoming sensory data (Wilson, 2002). Furthermore, any sensory information that is stored in long-term memory (LTM: alongside any relationship between the sensory input and associated objects, events, physiology, behaviour, etc.) has the potential to influence future thoughts regardless of construal level or context. Wilson (2002) suggests that thought processing gradually builds a framework of automated subcortical routines. Regularities in comparable circumstances encourage an automated response generated by sensorimotor simulation; essentially a behavioural response, preceding cognitive appraisal and contextualised by conditioned representational links. This concept is supported by Garbarini and Adenzato (2004) who argue that cognitive representation relies on *virtual activation* of autonomic and somatic processes as opposed to a duplicate reality based in symbols. For example the sound of hissing is likely to have an acute physiological impact upon an individual with an anxiety towards snakes. Although establishing threat connotations (*there is a snake nearby, snakes are poisonous, snakes could bite me*) to the object requires cognitive signification, a history of ophidiophobia would support a conditioned subroutine, bypassing lengthier cognitive processing to connect the object (hiss sound) directly to the ANS. An embodied theory would not accept pure behavioural conditioning however and, instead, would suggest that the object would first stimulate virtual sensory data (a snake's image, movement, etc.) that characterise the actual stimulus and generate a threat interpretation. The entire process remains fundamentally cognitive but only a fraction of the input data needs fully appraising as the simulated data is already directly linked to the ANS through conditioning; supporting an efficiently responsive process achieved via reduced cognitive load.

Recollection of memories to deduce and arrange future plans is also embodied in attachments to sensory data. Existing research has argued that memory retrieval can cause a re-experiencing of the sensory-motor systems activated in the original experience, the physiological changes creating a partial re-enactment (Gallese, 2003; Niedenthal, 2007). The notion of implicit memory, relating to perceptual fluency and procedural skill (Johnston, Dark & Jacoby, 1985) supports the developmental nature of embodied cognition. Wilson (2002) argues that implicit memory is automated action; acquired through practice whereby repetition instils conditioned movements and reduces the need for full cognition. Returning to our snake example, declarative knowledge of how to effectively deal with a snake may reveal a coping strategy. However, a lack of practice requires increased cognitive processing (remembering instructions, talking internally through the action), reducing the immediacy and accuracy of the action. By contrast, implicit knowledge of the coping strategy forged through practice and repetition generates direct pathways between the stimulus and the somatic nervous system, allowing fast and controlled response action. Wilson (2002) argues that these processes of perception and action have the potential to become 'co-opted and run "off-line", decoupled from the physical inputs and outputs that were their original purpose, to assist in thinking and knowing.' A potential consequence of this theory is that any prior thought process that generated representations and relations between objects has the potential to impact upon any future thoughts regardless of construal level.

In consideration of the various perspectives and concepts detailed above, it is an hypothesis of this thesis, that the fear response exists on a two-level model of thought processing: cognitive associative functions that bypass conscious appraisal to directly connect sensory data to both the autonomic nervous system and motor responses; and full cognition where reflective thought and emotional state is defined and the entire situation is rationalised and comprehended. It is the behavioural-cognitive level that is central to the experience of fear, as the initiating process and the determiner of immediate response. Sensory simulation, as observed in dream states and everyday tasks, helps to explain the procedure in which the mind manifests a notion of threat from a single, disparate stimulus by generating a full context via virtual associated stimuli.

ACOUSTIC ECOLOGY

Sound has the capacity to convey more emotional content than any other component of a CVG experience (Parker & Heerema, 2007). Research suggests that human recognition of the fear emotion is peaked during exposure to audio stimuli, suggesting that audition has a greater association to the fear response than any other modality of sensory input (DeSilva et al., 1998). Sounds have the potential to not only influence an audience's perception of a visual scene (Tinwell, 2009) but also to generate immersion, depth and emotional colour via sensory simulation.

Research concerning environmental sound is no longer in its infancy and yet the exploration of emotion processes within CVG non-musical audio contexts is still a recent venture. Existing research suggests that audio conveys negative emotional data (specifically fear and sadness) more effectively than visuals (DeSilva et al., 1998) and controlled sounds associated to virtual characters have shown to increase the perceived *scariness* of that character (Tinwell, 2009). Quantitative psychophysiological research has recorded biometric (facial muscle, cardiac and electro-dermal) activity in response to various sounds and revealed significant variation in response between different sounds (Bradley & Lang, 2000). Ekman and Kajastila (2009) further suggest that specific characteristics of an audio signal may impact upon the listener's emotional response, revealing a difference in fear response in reaction to changes in sound position and spread. This information not only identifies an area of research in need of further development, but also nominates audio as a feasible approach to manipulating a player's fear response.

Preceding acoustic ecology construction, this section explores the functions and processes of listening. Breinbjerg (2005) describes the anthropocentric nature of the listening experience and indicates that, unlike vision, audio stimuli cannot be shut out. Breinbjerg suggests that sounds facilitate the perception of physical properties attributed to objects outside our visual perspective and can confirm or enhance perceived detail of physical properties that lie within our visual perspective. Breinbjerg also describes the function of listening as a way of realising the *design of the set* (immersion in the nature of the environment) and the *narrative* (objects and/or actions that the listener may need to react to) of a landscape. Kromand (2008) supports this notion, proposing that sound exists as a purveyor of information and immersion. Tuuri et al. (2007) posit that perceptual processing is intrinsically linked to the functionality of audio, stating: 'The procedural chain of events, actions and causalities in a situation can give an indicative meaning even to a meaningless beep'. Studies have argued that contextual scenarios can have a tremendous effect upon the way we listen and, consequently, research has identified several *modes* of listening that attempt to account for such effects. Gaver (1993) suggests that non-specific, or everyday listening refers to hearing events within the environment rather than the sounds themselves; a definition supported by Tuuri et al. (2007). Gaver elaborates, insisting that, during everyday listening, audio perception bypasses conscious semantic translation. The sound of a car's engine accelerating is not consciously perceived as such, instead simply as *a car*. Chion (1994) identifies this type of listening as *casual listening*, and defines the process as *ecological* and *event-orientated*. With regards to the study of CVG sound, Collins (2006) describes causal listening as the 'preparatory function of game sound, affording the player information relating to game objects' positions and dynamics'.

Psychophysiological experimentation has provided quantitative data to support the notion of automatic, instinct-based audio processes. Alho (1997) presents the concept of pre-attentive audio processing and identifies pre-conscious brain activity resulting from infrequent changes in repetitive musical patterns. Bach et al. (2009) discovered that, overall, reaction times for audio cues were slower than those for visual targets, a logical outcome when considering the nature of an audio signal exists along a temporal plane and consequently, time is required to project all information contained within the sound (as opposed to the immediate disclosure of data when viewing a static image). Cusack and Carlyon (2004) expand upon the above concepts in their exploration of attention processes on audio perception. They describe a "hierarchical decomposition of the soundscape" wherein attention is focussed on ever increasing levels of specificity. This concept reflects the notion of *reduced listening* (Chion, 1994), which describes conscious attention towards the sounds themselves. Ekman (2009) posits that attention 'will guide the traversal of the 'listening hierarchy' and so determine what detail the listener will and can attend to at each moment'.

Attention is one of four influences contributing to audio perception, as identified by Ekman (2009) alongside proprioceptive sounds, emotions, and multimodal processing. Proprioceptive sound refers to sound occurring inside or conducted through the human body (swallowing, heartbeat, sounds conducted through bones). Ekman (2009) suggests that extreme stress can also impact upon sonic perception. Using examples including soldiers and law enforcement officers, Ekman describes auditory acuity (an increased sense of clarity and specificity) and auditory blunting (the loss of sound detail or inability to hear very loud sounds) as involuntary perceptual filters, and observed from a survey that auditory blunting is a commonly occurring phenomenon in scenarios generating extreme stress. Referring back to Massumi (2005), increased acuity is a potential response to the apprehensive terror phase (senses are primed and attention focuses on data associated with the threat), whilst blunting neatly integrates with the horror phase (innate physical response behaviour is prioritised and present sensory data and cognitive appraisal is attenuated until the action reaches a stop). Emotional influence incorporates personal preferences, cultural and social factors and Ekman proposes that these factors "compose a frame of reference in evaluating heard sounds", a function that reveals similarity to the notion of *semantic listening* (Chion, 1994). Multimodal perception describes the impact of data acquired from other human senses upon auditory perception. Recent research has typically explored multimodal phenomena in terms of audio/visual effects (Adams et al., 2002; Ma & McKevitt 2005; Özcan & van Egmond 2009; Väljamäe & Soto-Faraco 2008) with several articles addressing the concept as part of the acoustic ecology of CVG experience (e.g. Ekman 2009; Grimshaw & Schott 2008).

Grimshaw and Schott (2008) support Chion’s (1994) three-part construct of *semantic*, *reduced* and *causal* listening but also incorporate a fourth. This mode, entitled *navigational listening*, is defined by Grimshaw and Schott as sound that guides the individual through the world via audio beacons. Grimshaw (2007) argues that a central aspect of human interaction with sound is the ability to: conceptualise the position of the object (as relative to the individual); identify movement speed and direction; and support kinaesthetic interaction with objects within the environment. Schafer (1994) suggests that sounds can facilitate the identification of spaces or territories without requiring visible boundaries. Breinbjerg (2005) extends the notion of space by categorising types. *Architectural space* describes areas with quantitative and measurable sizes/boundaries such as an indoor environment. *Relational Space* describes the space indicated by the distance and position of sound sources in relation to the listener. Breinbjerg also describes the notion of *space as place*; the phenomenon of semantic meaning attributed to the audio environment that identifies a place within a historical and geographical context. This concept can be compared to the notion of temporal functions of audio; as Grimshaw (2007) asserts, sound ‘also has the ability to indicate a point or period of time in the past, present or future’. *Space as place* and historical temporality bear relation to Parkes and Thrift's (1980) concepts of paraspace and paratime (particularly social time).

Tuuri et al. (2007) identify eight discrete modes of listening that can be positioned along the CLT continuum; from the low level construals associated with pre-cognitive listening to higher level source, context and quality orientation. In this framework a distinction is made between connotative (immediate, free associations labelled pre-cognitive) and semantic listening (cognitive evaluation of symbolic / conventional meaning); a separation supporting the assertion that higher level associative thought functions can transcend from the conscious to the pre-cognitive via conditioning. The specific modes of listening support the process of a fear experience; at the pre-conscious level, reflexive listening connects the sound object to the ANS and SNS for immediate physiological support (a sudden noise may cause a startle, increased respiration and perspiration), whilst connotative listening stimulates the perception of associated virtual stimuli (simulated multi-modal sensory input that supports the audio). Within a more generalised cognitive appraisal, causal listening utilises the information gained to identify a potential source whilst empathetic listening uses the same data to assess affective content and propose emotional motivation. Requiring more attuned focus upon the sound, functional listening describes an attempt to identify the function of the sound and consequently, the possible function of the source object. At the higher construal level of audio comprehension lies semantic, critical (an evaluation of the associative strength between audio and function) and reduced listening (an awareness of the individual properties of the audio signal). Although comprehension of acoustic properties via reduced listening requires conscious higher-level cognitive appraisal, variations in these parameters (position, movement, loudness, etc.) have been revealed to influence precognitive and emotional responses (Ekman & Kajastila, 2009; Garner et al., 2010). Several properties of a sound have well-established associations to environmental information that is perceived as significant during a fear experience. The relative loudness of an audio signal suggests object size and relative distance (Winer, 2005) whilst an increasing or decreasing volume indicates movement and direction (Bach et al., 2008). Low frequency sounds reflect the growling of a predator whilst high-pitched sounds reflect pain and screaming, both of which signify a threat (Parker & Heerema, 2007). Within a genuine fear evoking scenario it is unlikely that critical and reduced listening will be utilised; however within the context of a computer video game, it is probable (particularly as their coping increases) that a player will assess the effectiveness of the game sound in achieving the desirable effect and consequently utilise reduced listening to support their conclusions (for example – *the sound that accompanied the sudden monster attack was not frightening because the relative loudness was not great enough*).

Grimshaw (2007) posits that a comprehensive understanding of soundscape optimisation facilitates more than simply a replication of reality into virtuality; instead game sound design should seek to understand the relationship between the virtual audio landscape and the acoustic ecology of reality. Grimshaw also identifies the complexities that arise from synchresis of audio/visual relationships, the simultaneous presentation of acousmatic and ideodiegetic sounds and the kinaesthetic feedback loop resultant of player interaction. It is this loop that is of prominent importance when one considers that the essence of a game playing experience is arguably interaction. (Ekman, 2008) argues that: ‘Games ask players to become active and play. Hence, sounds must support action, respond to player control and often survive high repetitiveness’. Here, sound is identified primarily as a ‘facilitator and confirmatory of action’ and, therefore, the most effective sounds will have a transparent perceptual association to a gameplay element/event. Gärdenfors (2002) testifies to the importance of this association by documenting the use of sound specifically designed to enhance a gameplay action, which in reality has no association with that particular sound; a good example would be the sound of Mario jumping in *Super Mario Brothers* (Nintendo, 1985).

At present, mainstream computer video games generate sensory data in visual, audio and tactile modalities, and the latter is limited to interaction with the control interface. Feeling the sensation of physical action within the virtual world is typically limited to vibration feedback, providing a gross generalisation of tactile experience. To differentiate between various environment textures or to utilise olfaction to further characterise a scene are notable research endeavours (Hoffman et al., 1998; Richard, Tijou, Richard & Ferrier, 2006) but not mainstream or commercial ones. As a result, even games that strive to achieve realistic soundscapes must manipulate the limited resources to perpetuate a virtual sensation of olfactory, tactile and gustatory input via representational inference. A virtual corpse alone may not trigger an olfactory sensation of decay, but the sound of buzzing flies and wriggling maggots around it arguably has a much greater potential to do so. This issue establishes a clear divide between reality and the virtuality of current CVG; audio designers are often required to compromise between playability (a sound design that supports player action via extra-diegetic sounds, representative of other sense data) and realism (a soundscape more akin to reality, focussed upon diegetic sounds). The notion of realism is questionable, however, when observing a CVG experience as a whole. Although a *realistic* virtual soundscape may accurately reflect its reality counterpart, the lack of audio input compensating for other sensory modalities creates an incomplete experience, lacking immersion and consequently appearing unrealistic. Extended exposure to fictitious *Hollywood* foley sounds has determined that genuine source recordings of many dynamic sounds (shotgun blasts, footsteps in the snow, etc.) are often perceived to be unrealistic (Parker & Heerema, 2007). Within the realms of fiction media, the lines separating the virtual and the real have become blurred, creating scenarios where an audience is more likely to be immersed by the hyper-real than the actual. Computer video games are not simply simulations of real activities and, particularly within the fictional constructs of a survival horror game, are better perceived as real-life activities themselves (Shinkle, 2005). Grimshaw and Schott (2008) point out that a developing understanding of sound design (within a specific context/domain) resulting from experience in playing several similar computer video games or learning a single game system can alter sonic perception via the learning of conventions. Sounds that initially signified an unknown enemy now identify the physical characteristics, motivation and damage potential, allowing a player to make an informed threat assessment. Within a survival horror game, such a system could be intentionally exploited to support the player (see *Left 4 Dead*, Valve 2008) but also has the potential to undermine the effectiveness of a terror stimulus.

A sound without context is effectively a shell that can have little significance for the listener. The contextualisation of sound is arguably a process central to acoustic ecology, where assumption and expectation originating from the individual's perception of their current environment establishes a context frame that supports associations made between the sound and information regarding the source (Özcan & van Egmond, 2009). Situational knowledge provides a filter of associations perceived as irrelevant (Bar, 2004), allowing the mind to more efficiently reach appropriate conclusions (such as, knowledge of dog ownership is likely to filter associations between light impact sounds heard during the night and the concept of intruder as source). Bar and Ullman (1996) argue that contextualisation occurs in two stages: firstly the sound stimulates generation of associated sensory simulations, then the collective information is correlated to more salient representations stored in the long-term memory. Contextualisation has the capacity to alter completely a listener's perception of audio source and preceding audio signals are also capable of manipulating the perceived source of a subsequent sound (Ballas & Mullins, 1991).

In *An Introduction to Acoustic Ecology* (2000), Wrightson states that sound cannot be disconnected from the natural environment. The acoustic environment is determined by culmination of all processes and physical properties of the world, and consequently cannot be sustained without change to its nature during environmental changes. The audio landscape is connected to both the individual and the environment by a bi-directional influence potential (Truax, 1984) that incorporates both external and internal sound. Internal sound is referred to by Schafer (1977) in the form of internalised dialogue; suggesting that such a phenomenon can modulate attention and attenuate sounds originating from the environment, and that individuals may consciously restrict environmental sounds to support internal dialogue and may also amplify incoming environment sound to attenuate internal dialogue. Sound reflects the ecology, establishing equilibrium across the sonic spectrum (incorporating frequency, tempo, rhythm and volume), allowing individual sounds to be distinguishable in even dense audio environments (Krause, 1993). Listening becomes an embodied experience, dependent on not only the past memories of the listener, but also on their present state and the countless interactions that occur between the listener and the ever-changing environment. Wrightson (2000) presents an example to elucidate this point, referring to the impact of industrialisation on both the functions of audio within human society and the gradual deterioration of audition accuracy, whereby man hearing, once capable of determining a range of audio subtleties, can now only describe sound in (comparably) polar extremes. Industrialisation has also been charged with damaging the acoustic ecology in a way that ultimately is threatening to life. Barot (1999) argues that the generation of certain artificial sounds can be acoustically matched to that of bird mating calls, thereby creating a sonic barrier between animals in a way that limits their capacity to reproduce. The above argument supports the fusion of sound with ecology, suggesting an interrelationship whereby life has the capacity to influence sound and sound has the capacity to influence life; a concept succinctly outlined by Truax (1984).

The concept of a virtual sonic ecosystem within a first-person shooter (FPS) resonates with the notions of embodied cognition and acoustic ecology in that it embraces an amalgamation approach; classifying listener, soundscape and environment as inseparable components in an integrated system. Virtual acoustic ecology asserts that CVG sound exists as part of an intricate relationship between the player, the audio engine (virtual soundscape) and the resonating space (real acoustic environment). Grimshaw and Schott (2008) describe FPS audio engines as *sonification systems*, in which both individual sounds and collections of sounds have both intended meaning (as established by the designer) and received meaning (player interpretation). In *The Acoustic Ecology of the First-Person Shooter* (Grimshaw, 2008) the nature of this system is elucidated via identification of: the various functions of a FPS audio; the individual relationships that exist between components of the system; the perceptual factors that influence interpretation; and the unique circumstances that contextualise the ecology within a CVG framework.

The foundational belief underpinning and embodied ecology construct of listening is that our biology, the enveloping sensory input of the present and the LTM data representing our history, are all crucial factors in thought processing and behaviour determination; essentially an intricate matrix of causality with emotional affect residing at the helm. Emotion directs attention towards specific current stimuli and filters out sensory data that possesses a low emotional relevance. LTM retrieval and memory transfer function between short-term memory (STM) and LTM depend upon the emotional value of the content and, therefore, govern how an individual’s history will impact upon their current cognition and behaviour. During an audio-induced fear sensation, the intensity of the emotional experience will influence the listening modes, determining the nature of the sonification data that will be encoded from the audio. That information may in turn determine the reappraisal and characterisation of the audio, subsequent auditory data perception, attention focus, emotional state changes, etc. Without the capacity to evoke emotion, an audio input could only be interpreted in an objective and detached manner via reduced listening. The emotional content of the audio instigates recollection of emotion-related LTM data, facilitating subjective analysis and representational association.

The principle views of embodied cognition theory provide opportunity for an intriguing framework within which a more comprehensive theory of game sound can be exhibited. Whilst it is not presumed that complete understanding such a complex system is quite within our grasp, it does reveal the various theories surrounding this study appear to be, in part, components working in cooperation with each other to create a dynamic and constantly changing system. The nature of our environment, coupled with our memories and current physiology, determines our perception of sound, including: the mode of listening we employ, whether a sound evokes an emotional response and the exact profile (including intensity) of the experienced affect.

EMBODIED COGNITION AND VIRTUALITY

The following is a hypothetical thought process designed to elucidate a central concept of embodied cognition: A contemplative fellow briefly imagines an act of defying gravity and leaping upwards into space – a notion that, with hindsight, is revealed to have originated from a brief glance at the sky. As the thought formulates, a visual representation of James Bond on a jetpack, the physical sensation of leaping ever higher and John Williams’ iconic superman theme all manifested themselves. In this example, a single conceptual construct has been characterised by both virtual sensory stimuli and simulated motor actions. A concept that many may experience is personalised by the immediate environment and our unique memory, formed by the inimitable experience of personal history. The concept that cognition is a biological process grounded by bodily experience and the environment has garnered increasing support in recent years (Garbarini & Adenzato, 2004). Shinkle (2005) argues that, although sensory input and physical response is characteristic of a computer video game, many game studies methodologies overlook the impact that embodied cognition and physiological response have on game experience. Shinkle also posits that memories of past events are not limited to stored knowledge of external proceedings; emotional responses (characterised by physiological states and discrete response behaviours) play a crucial role in defining these perceptions and experiences. This notion concurs with the argument described so far in this chapter; a system that processes objective and affective data initially at an autonomic level, producing physiological changes that are *felt* by the individual and fed back into the system for cognitive processing. Questioning the exact nature of this system refers to a considerable philosophical quandary; the *mind-body* problem, which asks whether such a system is a) centralised within the brain and capable of detached processing (Cartesian Dualism), or b) an integrated system that incorporates all somatic and autonomic actions and the ecology of the surrounding environment.

Andy Clarke’s 1997 book *Being There: Putting Brain, Body and World Together Again* advocates the concept of integrated cognition, stating that ‘[m]inds are *not* disembodied logical reasoning devices’ (Clarke, 2007: p.1) and that rejection of the centralised processor concept in favour of an embodied perspective is an increasingly popular attitude in the fields of robotics and artificial intelligence. The concept of integrated cognition bears some similarity to the notion of *autopoiesis,* especially in the autopoietic concept of a *consensual domain*. This domain is brought about by the structural coupling (the interplay) between mind, body and environment (see Winograd & Flores, 1986: p.46,49). Clarke (p.21) further questions classical cognitive theory by means of the *representational bottleneck* concept which states that, for a central processing unit to function, all sensory data must be converted into a single symbolic code for comprehension then translated into various data formats to carry out the different motor responses. Such a process is theorised to be time consuming and expensive, leading to the conclusion that a centralised system could not possibly respond adequately to real-time pressures of everyday life. Sensory filters, such as attention, reduce the processing load by 'sensitizing the system to particular aspects of the world – aspects that have special significance because of the environmental niche the system inhabits' (Clark, 2007: p.24), a system that Clark relates to Jakob Von Uexkull's (1957) concept, *Umwelt* (a reduced perception of the *real* environment as defined by the individual's needs, desire and lifestyle).

Construal level theory (CLT) argues that increasing psychological distance (space-time-relevance) promotes more abstract thought (Liberman & Trope, 2008), however psychological distance (PD) can only be measured in relation to the here and now and is consequently dependent on the current environment. The *here and now* notion that constitutes part of the EC theory is detailed in Margaret Wilson's *Six Views of Embodied Cognition* (2002). This text argues that a cognitive model must: be established in a real-world environment context (*situated cognition* – the *here*); recognise temporal and real-time effects (*time-pressured cognition* – the *now*); acknowledge the environment as an integral part of the model (an ecological framework); and accept that the function of all cognitive thought is ultimately to guide action whether in the immediate circumstance or in planning for a future event. A futurity can be related to virtuality in that it cannot be directly interacted with and exists as an insubstantial entity. If we accept that contextualisation determines a significant proportion of a sound's perceptual make-up, then any attachment of PD may severely affect the perceived reality of a sound (for example, the sound of a distant car alarm may be less *real* than an individual's home fire alarm as the latter is more firmly rooted within their personal reality).

The concept of EC posits that thought cannot exist outside the here and now and that conscious appraisal of an object or situation cannot be detached from sensory input, a notion not dissimilar to that of *thrownness*. First established by Martin Heidegger in the 1927 publication *Sein und Zeit* (Being and Time), the concept of thrownness is succinctly communicated within the contexts of computer science and cognition by Winograd and Flores (1986: pp.33-35). Within this text, thrownness supports the principles of EC, in that it refers to existence within the world as fundamentally inseparable from the environment in which we exist. Winograd and Flores document that to *not* impact upon the environment is essentially impossible, as even *to do nothing* has consequences. They also state that an individual cannot separate themselves from a situation to reflect upon it, as the situation is not a static entity but rather a continuous movement and accurate prediction of outcomes (outside of a laboratory) is consequently, unachievable. This constant fluctuation and evolution of existence makes a stable representation of the environment (or a situation within it) unattainable, arguing that ‘every representation is an interpretation’ (p.35) and post-event analysis remains fraught with subjective bias.

If we are to agree that all thought is under the continuous and forceful influence of the surrounding environment, current personal physiology and long-term memory, and also that such circumstances dictate that no perception can reflect reality entirely, then we could further posit that all experience is virtual. We are the sole population of our own virtual realities. Our universe supports countless parallel worlds, each with many consistencies, but many with striking differences. In developing a continuum of sonic virtuality, the above theory argues that *real sound* is impossible, and the polar extremes cannot be absolute real and absolute virtual.

Garbarini and Adenzato (2004) argue that cognitive representation relies on *virtual activation* of autonomic and somatic processes as opposed to a duplicate reality based in symbols. For example the sound of hissing is likely to have an acute physiological impact upon an individual with an anxiety towards snakes. Although establishing threat connotations (*there is a snake nearby, snakes are poisonous, snakes could bite me*) to the object requires cognitive signification, a history of ophidiophobia would support a conditioned subroutine, bypassing lengthier cognitive processing to connect the object (hiss sound) directly to the autonomic nervous system. An embodied theory would not accept pure behavioural conditioning however and, instead, would suggest that the object would first stimulate virtual sensory data (a snake’s image, movement, etc.) that characterise the actual stimulus and generate a threat interpretation. The entire process remains fundamentally cognitive, yet only a fraction of the input data needs fully appraising as the simulated data is already directly linked to the human autonomic nervous system (ANS – a primarily subconscious system, chiefly controlling involuntary physical actions) through conditioning; supporting an efficiently responsive process achieved via reduced cognitive load.

This suggests that the embodied cognitive processing of a sound can be significantly affected by the presence (or absence) of cognitive shortcuts. Özcan and Van Egmond (2009) discuss the way in which ambivalent sound can have dramatically different meanings depending upon associated visual stimuli. Without such contextualisation support, the listener’s perception of the sound would be greatly dependent upon long-term memory (established conventions, passed experiences, etc.), current environment (temperature, space, etc.) and physiology (including established neuro-pathways such as cognitive bypass routines). Essentially, the listener is immersed within their own exclusive virtual reality, where the perception is embodied and the received sound is as unique as the individual.

Recollection of memories to deduce and arrange future plans is also embodied in sensory data. Existing research has argued that memory retrieval can cause a re-experiencing of the sensory-motor systems activated in the original experience, the physiological changes creating a partial re-enactment (Niedenthal, 2007). This notion strongly relates to the auditory concept, *phonomnesis* (an imagined sound that can be unintentionally perceived as real [Augoyard & Torgue, 2005]). In this scenario, the mind (in response to an initial stimulus) generates a re-experiencing of a sound that can be classified as virtual.

Augoyard and Torgue provide an invaluable reference guide to various acoustic and psychoacoustic events in their work, *Sonic Landscapes* (2005), within which various phenomena are documented that relate (in varying ways) to both EC and virtuality. As an individual experiences numerous and complex soundscapes throughout their lives, such phenomena are potentially commonplace. Sound may bring forth a past memory by way of anamnesis; it may force their attention upon a specified place through hyper-localisation, or even provoke a sensation that the space within which the listener is positioned is shrinking (narrowing [Augoyard & Torgue, 2005]). As a listener, we have the perceptual capacity to focus our attention upon an individual speaker within a room of thousands by disregarding all irrelevant sound information (known as the *cocktail party effect*). Psychoacoustic entities can manipulate listener behaviour and dictate future action via incursion (alarm, phone ringing, etc.), dictate the listener's level of vigilance (*the Lombard effect*) and even incite a euphoric state (phonotonie). With regards to virtuality, three perceptual phenomena of particular interest are *phonomnesis, remenance* (a perceptual continuation of a sound that is no longer being propagated) and the *Tartini effect* (a sound that is physiologically audible but that has no physical existence); here a combination of tones will provoke the sensation of an additional frequency that is not physically present (an occurrence that has been implemented in military and crowd-control applications [Augoyard & Torgue, 2005]). Such auditory phenomena arguably relate heavily to EC theory; if the listener were capable of detached and objective sound perception, then such sonic illusions and auditory holograms would not exist.

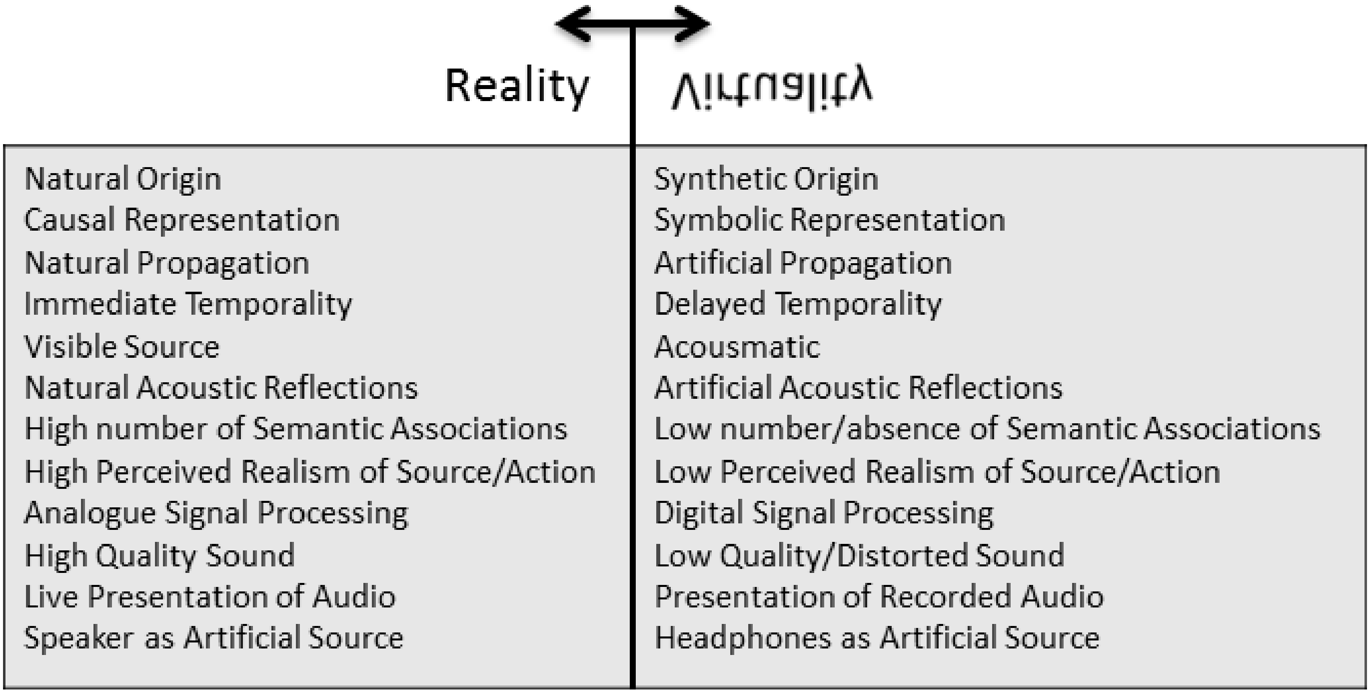
RECONCILING ACOUSTIC ECOLOGY WITH SONIC VIRTUALITY

Originating in the 1960's within R. Murray Schafer's seminal works, *acoustic ecology* refers to 'how organisms interpret and are affected by natural and artificial sounds' (Esbjörn-Hargens & Zimmerman, 2009: p. 491). This ecology incorporates the auditioning organism as an integral component of the soundscape, in which separate individuals may receive widely different sound information from the same acoustic space. This clarifies the connection between AE and EC, in that the embodied nature of listening creates a personalised virtual auditory experience; because the individual is part of the foundation of ecology theory, AE is therefore, virtual. Within this chapter, general conceptual notions relating to virtuality have been explored and consequently, this thesis asserts that there exist several ways in which EC theory may determine all sound (indeed all existence) to be inherently virtual. Progressing from these ideas, this section details human hearing (incorporating modes of listening, psychoacoustic theory and contextual conventions), alongside virtual AE models.

The concept of a virtual sonic ecosystem within a first-person shooter (FPS) resonates with the notions of EC and AE in that it embraces an amalgamation approach, as outlined by Grimshaw and Schott (2008); classifying listener, soundscape and environment as inseparable components in an integrated system. Their *virtual* acoustic ecology (VAE) asserts that game sound exists as part of an intricate relationship between the player, the sound engine (virtual soundscape) and the resonating space (real acoustic environment). First-person perspective game sound utilises a substantial number of sounds with the explicit purpose of representing a virtual environment that the player will find immersive, irrespective of the fact that they are not physically situated within that world. Such sound is intrinsically associated with virtual actions and entities, but the sound waves physically exist purely within the domain of reality; each sound resonating within actual spaces and interacting with real surfaces before reaching the listener's ear.

The foundational belief underpinning this construct is that our biology, the enveloping sensory input of the present and the long-term memory data representing our history are all crucial factors in thought processing and behaviour determination; essentially an intricate matrix of causality. Emotion directs attention towards specific current stimuli and filters out sensory data that possess a low emotional relevance. Long term memory (LTM) retrieval and memory transfer function between short term memory and LTM can depend upon the emotional value of the content (Friestad & Thorson, 1986) and, therefore, could manipulate how an individual's history impacts upon their current cognition and behaviour. During audition, the intensity of the emotional experience and the conscious desire of the listener will influence the listening modes; determining the nature of the sonified data that will be extracted from the sound. That information may in turn determine the reappraisal and characterisation of the sound, subsequent auditory data perception, attention focus or emotional state changes, formulating a circulatory loop.

Figure 1: The Sonic Virtuality Framework of Variables



Reality	Virtuality
Natural Origin	Synthetic Origin
Causal Representation	Symbolic Representation
Natural Propagation	Artificial Propagation
Immediate Temporality	Delayed Temporality
Visible Source	Acousmatic
Natural Acoustic Reflections	Artificial Acoustic Reflections
High number of Semantic Associations	Low number/absence of Semantic Associations
High Perceived Realism of Source/Action	Low Perceived Realism of Source/Action
Analogue Signal Processing	Digital Signal Processing
High Quality Sound	Low Quality/Distorted Sound
Live Presentation of Audio	Presentation of Recorded Audio
Speaker as Artificial Source	Headphones as Artificial Source

The above diagram consolidates the associated theoretical concepts of VAE, EC and virtuality to establish a framework of variables relative to sonic virtuality (Figure 1). Creating a sound from component waveforms by way of synthesis is a more virtual sound class when compared to a sound with a natural origin. Although the framework also classifies recorded and artificially propagated sound as virtual, unless the sound is synthesised, the ultimate origin is arguably more real. Propagation differentiates between natural resonance and electronic amplification, classifying the latter as more virtual. Several variables connected to semantic association are presented; the rationale stating that a sound with several, relevant semantic attachments to entities perceived as genuine will support the *reality* of the sound (for example, a voice with semantic attachments to a NPC will resonate with more truth than a transcendent *voice of god*).

SOUND FUNCTIONALITY AND MODES OF LISTENING

The previous section outlined a set of (relatively) objective acoustic variables that determine the virtuality of a sound. Here, we explore contextualisation and listening function, asserting that such effects further enable the personal virtual realities documented earlier.

A sound without context can have little significance for the listener, and may potentially be classified as virtual because the listener cannot attach the sound to an entity that exists within their reality. The contextualisation of sound is a process central to AE, where assumption and expectation originating from the individual's perception of their current environment establishes a context frame that supports associations made between the sound and information regarding the source (Özcan & Van Egmond, 2009). Contextualisation has the capacity to alter completely a listener's perception of sound information and, consequently, research has identified several modes of listening that attempt to account for such effects.

Gaver (1993) states that non-specific, or everyday listening refers to hearing events within the environment rather than the sounds themselves. Gaver elaborates, asserting that during everyday listening, sound perception bypasses conscious semantic translation. The sound of a car's engine accelerating is not consciously perceived as such, instead simply as *a car*. Cusack and Carlyon (2004) expand upon the above concepts in their exploration of attention processes on sound perception. They describe a 'hierarchical decomposition of the soundscape' wherein attention is focussed on ever increasing levels of specificity. This concept reflects the notion of *reduced listening* (Chion, 1994), which describes conscious attention towards the sounds themselves. In their conceptual framework of listening modes Tuuri et al. (2007) indirectly support EC theory, stating that listeners 'do not perceive sounds as abstract qualities, rather, we denote sound sources and events taking place in a particular environment'. Their work identifies eight discrete modes of listening that can be positioned along the construal level theory continuum. The act of separating an individual sound from a composite (hi-hats from a drum loop for example) is that of clearly distinguishing the received sound information from the actual soundscape. In this circumstance, our mode of listening is generating a virtual representation of the real sound environment.

Tuuri et al. (2007) also argue that 'some sounds encourage the use of certain modes more strongly than others'. In *A Climate of Fear* (Garner & Grimshaw, 2011) we argue that the modes of listening are largely determined by the perceived intensity of the sound; as determined by psychological distance, physiological reflex and immediate affective response. Consider a fire alarm as an example. When listening to such a significantly intense sound, a high-level listening mode (e.g. reduced listening – evaluating the frequency and temporal difference between the component tones) is highly improbable and the listener is effectively forced to respond by way of reflexive (break current behaviour, immediate new action) and connotative (imminent danger, must evacuate!) listening. The sound itself was intentionally designed to evoke such a response, supporting the acceptance of this theory within general product design industries. A continuous, unchanging sound may fluctuate in terms of the listening mode it encourages due to the complexities of the sound ecology. Returning to our fire alarm, whilst the immediate listening mode demands a reflexive function, prolonged exposure to the sound affords the listener time to appraise the sound with higher level cognition. At this point a listener may begin to evaluate the causality (*Where is that alarm coming from?*) or the functionality (*Is that actually the fire alarm, or is it the burglar alarm?*) of the sound. Such changes in perceptual listening modes are primarily instinctive and although conscious control is possible the notion of choice is essentially an illusion, as the embodied nature of the listener's personal virtuality manipulates the outcomes of the choice.

Within a complex soundscape we are capable of attenuating sonic input to focus on increasing levels of specificity. A city soundscape may be reduced to the compound sounds of a motorbike, which can then be concentrated to the individual sound of tyres treading asphalt. We may reflexively recoil from these sounds to avert the vehicle, or evaluate the qualities of the sound to cross the street without visually confirming the location of the bike. In such a circumstance, individuals placed within the same acoustic space may provide dramatically different descriptions of the sonic environment even if they were required to provide an objective account of their experience. Through hearing alone, we may even mistake the vehicle for a taxi or van through misinterpretation of semantic associations. John Greco (2010) argues that 'our causal explanations typically cite only one part of a broader causal condition'. This may explain how such a sound misinterpretation may occur, as the listener perceives an engine sound; establishes a causal syllogism (motorbikes have engines, I hear an engine, therefore a motorbike is present) and makes a false assumption that is accepted as reality unless conflicting information is provided. The well-established *Gettier Problem* (Gettier, 1963) highlights issues with justified true belief theory, proposing various scenarios (similar to that above) that argue an individual may (justifiably) accept a truth as knowledge from a misinterpretation of information. Here truth is accepted as reality despite the fact that the justification is virtual and it could further be asserted that (in many scenarios) an individual is capable of accepting a fallacy as knowledge (and feeling justified in doing so) due to the nature of the virtuality of the causal explanation.

CONCLUSIONS AND CHAPTER SUMMARY

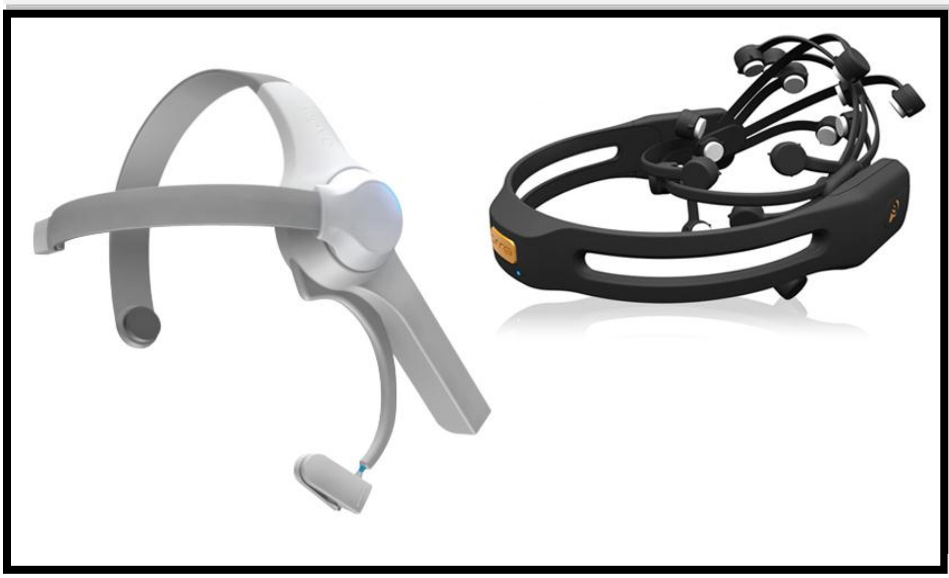
This chapter has utilised concepts of EC theory to help explain why both reality and virtuality remain deeply subjective and personal concepts. This, in turn, can be applied to our understanding of listening to suggest that all sound may be subjective in terms of the way it is appraised by the human mind, and whilst modern equipment may be capable of quantitative analysis, their lack of an embodied existence (interconnecting emotions, memories and physiology) enables their objectivity whilst we remain subjectively bias, unable to detach from our embodied reality.

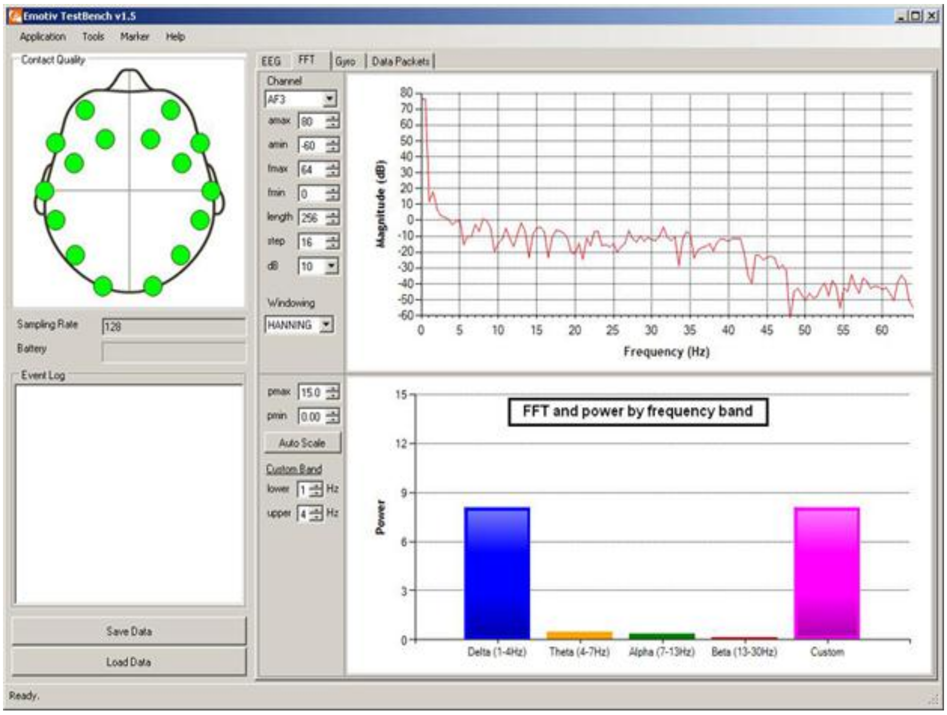
A review of relevant literature and logical deduction has provided a theoretical differentiation between real and virtual computer video game sound which could precipitate a great deal of future empirical research. At this stage it would be inappropriate to describe these variables as concrete determiners of virtuality. Instead, the intention is to highlight the potential factors that could have an impact upon perceived virtuality. It is also suggested that virtuality can only be perceptual and is always sensitive to the nature of the individual's personal reality. That such individual virtual existences are truth is a bold but compelling statement; the notion that a higher level of being may have control over our lives in the same way that we control our representative game avatars is one best left for another day.

In preparation for the experiment methodologies documented in chapter 6, the next chapter hosts a detailed analysis of psychophysiological approaches to data acquisition with regards to a range of general and specific, thesis-relevant applications. The concept of biometrics is addressed in greater detail and electrodermal activity (EDA: skin conductance), electroencephalography (EEG: brainwaves) and electromyography (EMG: muscle activity) measures are scrutinised in terms of their advantages and limitations in comparison to alternative psychophysiological methods. Alternative approaches to hardware configuration, participant preparation and data processing are also comparatively analysed. These discussions will then lead to three initial experiments, within which EMG and EDA biometric data alongside qualitative debrief player responses reveal the effects of digital signal processing (DSP) treatments upon objective and subjective measures of fear elicitation.

Chapter 5

Psychophysiology and Biometric Feedback Systems in Computer Video Gameplay





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2012

Chapter 5: Psychophysiology and Biometric Feedback Systems in Computer Video Gameplay

INTRODUCTION

A review of psychophysiological methods and approaches is presented within this chapter; commencing with a general overview of the field and concluding with a more detailed discussion regarding the potential application of specific psychophysiological measurements within the contextualisation of emotion recognition, biofeedback and computer video gameplay. The intention is to provide the necessary theoretical background required to expand upon the more qualitative audio analysis discussions documented in previous chapters and will support the last of the three subsequent preliminary trials, obtaining quantitative electrodermal and electromyographic data in response to audio cues within a horror-themed first-person shooter (FPS) game level. This chapter also investigates the electroencephalography (EEG) biometric measure with relevance to sounds and emotions. This includes a comparative analysis of alternative approaches to EEG data collection, from hardware configuration/montage setup, to participant preparation and signal processing technique.

PSYCHOPHYSIOLOGY: DEFINITIONS AND APPLICATIONS

'The field of psychophysiology is concerned with the measurement of physiological responses as they relate to behaviour' (John L. Andreassi, 2006: p.1)

In the broadest sense, psychophysiology refers to study of the relationships that exist between physiological and psychological processes. Despite being a relatively young research field, that Cacioppo et al. (2007) describes as 'an old idea but a new science', psychophysiology has branched into a wide range of applications and integrated with various other disciplines including dermatology (Panconesi & Hautmann, 1996) and psychopathology (Fowles et al., 1988). Modern psychophysiology was envisioned in response to the physiology/psychology divide problem (that between the two they provide a comprehensive explanation of human behaviour yet remain distinctly separate fields of study) that also led to the creation of physiological psychology (see Wundt, 1904).

The distinction between physiological psychology and psychophysiology has itself been a point of contention between researchers. Andreassi (2006) provides a detailed overview of the dissimilarities, initially focussing upon differences in methodological approach despite a shared goal in understanding the physiology of behaviour. Andreassi cites Stern (1964), who suggests that psychophysiology studies psychological independent variables (IV) and physiological dependent variables (DV) whilst in physiological psychology the opposite is true (physiological DV and psychological IV). Andreassi notes that some researchers have presented particular methodologies that are exceptions to the above rule, and states that this has led to differentiations between the two fields in terms of subject matter (see Furedy, 1984). To summarise Andreassi (2006), psychophysiology is a primarily non-invasive approach to physiological data collection in response to psychological manipulations, obtained from living human beings. Drachen et al. (2010), citing Cacioppo et al., (2007) present a similar description, defining psychophysiology as '[investigating] the relationships between psychological manipulations and resulting physiological activity (measured in living organisms to understand mental and bodily processes and their relation to each other)'.

For the purposes of the thesis, the term *biometrics* refers to a definition that deviates slightly from traditional understanding. IBM (2012) presents biometrics as 'the science of identifying, or verifying the identity of a person based on physiological or behavioural characteristics', a definition that is relatively constant throughout academic literature and typically concerns identity, security and product development (Ashbourn, 2000; Nanavati et al., 2002; Woodward, 2003). Within this contextualisation, biometrics identifies affective states from physiological input. The term is thereby used throughout this thesis to refer to psychophysiological data collection methods and processes (such as electromyography, skin conductance response, heart rate).

The collection and analysis of psychophysiological data to interpret an individual's emotional state is a firmly established methodological approach. Our understanding of the exact role of physiological changes within a framework of human behaviour and thought processing is, however, not comprehensive and there remains uncertainty regarding the exact nature of the emotional experience (as discussed in chapter 2). Russell (2003) asserts that physiology is a component within a larger process, whereby cognitive appraisals of physiological state changes determine emotion; a theory not dissimilar to the *two-factor* theory of emotion as described by Schachter and Singer (1962) with its derivation dating back to the James-Lange (physiology determines emotion) and Cannon-Bard (emotion determines physiology) debate. It could be viewed that psychophysiological methods of experimental data collection circumvent the origin of emotion debate, instead functioning on the assumption that irrespective of chronological order, emotions and physiology are intrinsically linked to the degree that a comprehensive account of physical (biometric) state changes can reveal subjective emotional information. Psychophysiology is therefore not as persistently concerned with chronologically ranking the chicken and the egg as it is intent on proving their correlation to each other.

Biometric data collection addresses several problems experienced when evaluating emotions via self-report, such as affect insensitivity and emotion regulation (Ohman & Soares, 1994). Research has documented circumstances in which the agendas of the individual facilitate regulation (suppression, enhancement, false presentation) of outward emotional expression, providing severe reliability concerns if relying entirely upon visual analysis and self-report to interpret emotional state (Jackson et al., 2000; Russell et al., 2003). Biometric data collection has the potential to circumvent this problem via measurement of emotional responses characteristically associated with the autonomic nervous system (ANS) and is significantly less susceptible to conscious manipulation (Cacioppo et al., 1992). Recent research concerning emotion suggests that comprehensive information from the participant and the environment is required alongside biometric data before any accurate emotional interpretations can be generated. A great deal of research exists whereby physiological readings are cross-examined this way in the search for reliable associations and causal patterns (Cuthbert et al., 2003; Ekman & Friesen, 1975).

Nacke and Mandryk (2010) provide a positive testimony for eye-tracking as a cost-effective solution capable of giving further insight into human behaviour, particularly in a visual media context such as computer video games (they assert that modern software can perform this operation using only a standard webcam as acquisition hardware). Eye-tracking solutions have appeared within a notable number of varied research studies that include: exploring how users interact with web-mediated search engines (Granka, Joachims & Gay, 2004), studying the effectiveness of animation-based learning materials (Bouchiex & Lowe, 2010) and examining abnormal perceptual strategies in patients with autistic spectrum disorder (Sasson & Elinson, 2012). For the purposes of research into affective states during gameplay, eye-tracking information would primarily support the contextualisation of data from additional biometrics, while the ability to pinpoint where on-screen a player is focusing, at any given moment, could allow associations between in-game events/entities and significant biometric readings to be better informed and more accurate.

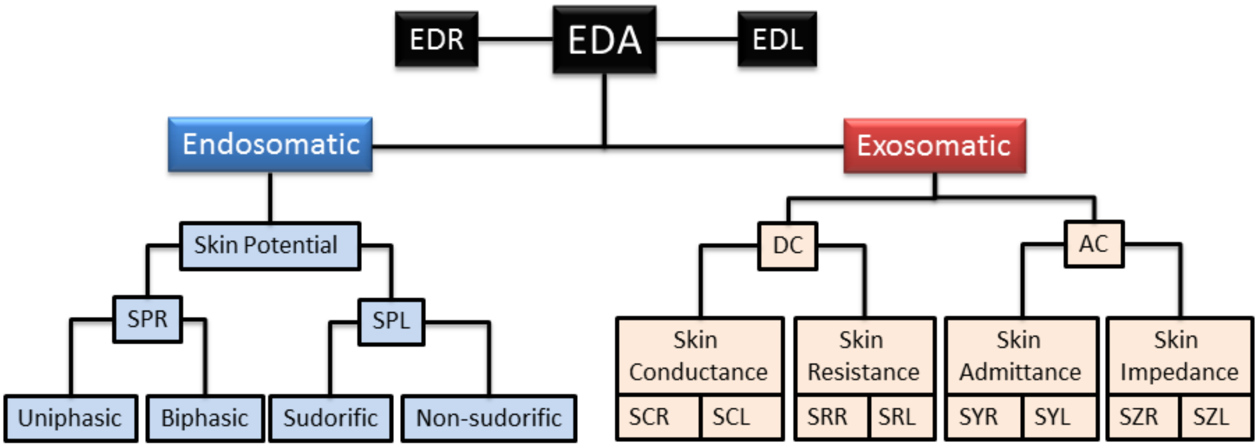
Electrocardiography (the standard instrument for measuring heart rate) and respiration measurements are also acknowledged as worthy biometrics across many research studies. However, they characteristically appear as supportive physiological measures alongside additional biometrics (e.g. Cuthbert et al., 2003; Vrana, 1993; Weber et al., 2009). Kivikangas et al. (2010) suggesting that, although cardiac activity is widely used throughout academic literature, the heart is associated with a variety of bodily processes and therefore inferring a psychological state solely from changes in cardiac activity is likely to be unreliable. As such, it would be appropriate to suggest that such biometrics performs a supportive role in this context, strengthening the correlations between psychological events and physiological responses.

ELECTRODERMAL ACTIVITY

Both within and outside of computer video games research, the term *electrodermal activity* (EDA) can refer to a variety of physiological response measures and has associations with several other closely related terms. Kivikangas et al. (2010) assert that EDA and galvanic skin response (GSR) are too often confused and that a clear and agreed upon set of definitions is necessary to avoid methodological error. In her review of electrodermal developments up to the 1980s, Christie (1981) cites several research articles calling for GSR to be retired, asserting that its use has led to unnecessary complications (Edelberg, 1972; Venebles & Christie, 1973). Christie (1981) does address this issue, placing EDA as the central, overarching term under which all associated terminology is a sub-classification (figure 1).

Within this framework, electrodermal activity is divided into endosomatic (the invasive application of electrodes under the skin to measure impulses directly from the sympathetic neurons) and exosomatic (surface-placed electrodes). Further distinction is determined by finer variations in the methodology, primarily the type of current under analysis, the characteristic of the electrical signal being studied. Temporal characteristics of the methodology provide the final distinction, separating long-term tonic measurements (EDL – electrodermal levels) from short-term, phasic activity (EDR – electrodermal response).

Figure 1: Framework of EDA terminology (Christie, 1981)



The invasive nature of endosomatic acquisition is naturally unsuitable for application in most psychophysiological studies and consequentially is highly unlikely to appear within methodologies relevant to this thesis. It has been suggested that the difference between the direct current (DC) and alternating current (AC) variations of exosomatic electro-dermal activity measurement is limited (in terms of obtained data [Fowles et al., 1981] as the receptor measurement is always compared to a baseline [uniphasic]). DC measurements are nonetheless the most commonly employed method within relevant studies, and the term *skin conductance* features regularly as the biometric descriptor (e.g. Cuthbert et al., 2003; Kivikangas et al., 2010; Koelsch et al., 2008; Vrana, 1993). From the information presented above it is rational to assert that, for the purposes of experimentation relevant to this thesis, phasic skin conductance response (SCR) is the most appropriate EDA sub-type due to the low-invasiveness of application, relevance to short-term activity variation and commonality alongside comparable research. Despite this framework being established many years ago, GSR still appears in modern research although it most typically refers to skin conductance (e.g. Mirza-Babaei, 2011).

Lang et al. (1993) relate the conductance level of the skin to sweat production from the eccrine glands, which are resistors of electrical current. Sato et al. (1989) provide a detailed account regarding the physiology of sweat secretion, positing that activation of the SNS increases sweat secretion in preparation for bodily action. Sato et al. continue, stating that the chemical composition of sweat possesses a significantly lower electrical resistance than the dermal layers which, during increased secretion, results in an increase of electrical conductivity between neurons and the skin surface that enables a meaningful EDA signal to be recorded.

EDA is associated with the peripheral nervous system (Nacke et al., 2009) and more specifically, is connected to the sympathetic nervous system (SNS) which, as discussed in chapter 2, associates EDA exclusively with autonomic and excitatory processes (Poh et al., 2010). Recent physiological studies have presented evidence in support of this association through electrically stimulating autonomic regions of the brain to reveal reliable EDA increase responses (Lanteaume et al., 2007; Mangina & Beuzeron-Mangina, 1996). Brain structures within the limbic system (specifically the hypothalamus and amygdala) have been associated with EDA, suggesting a connection between EDA and emotion-related activity (Yokota et al., 1962). Critchley et al. (2000) observed SCR levels in tandem with functional magnetic resonance imaging (fMRI) data in an effort to correlate increased SCR to particular brain regions. Their study revealed a strong association between SCR and preconscious structures (that include the prefrontal cortex, anterior cingulate, parietal lobe, and cerebellum) directly relating skin conductance to emotional and instinctive processes.

Research has testified to the autonomic-excitatory function of EDA via observations of distinct correlations between increased levels of electro dermal activity and excitatory behavioural disorders such as Attention Deficit Hyperactivity Disorder (Rosenthal & Allen, 1978). Stress has also been connected to increased EDA levels, the rationale being that stress disrupts balance within the ANS by eliciting significant excitatory activity impacting upon heart rate, respiration and sweat secretion. Research concerning psychopathology has revealed notable correlation between attenuated EDA in response to stress and pathologic behaviour (Fung et al., 2005); a response that was also observed in patients who suffered injury to particular brain structures (Critchley et al., 2000). Vaez-Mousavi et al. (2007) assert that stimuli demanding immediate or significant attention also generate notable EDA increases. The nature of EDA and its connections to an array of physiological and behavioural processes can be broadly simplified to stating that electrodermal activity characteristically measures human arousal (Gilroy et al., 2012; Hedman et al., 2009; Nacke & Mandryk, 2010) and is currently the most commonly employed biometric when attempting to quantify this psychological trait (Ravaja, 2004).

ELECTROMYOGRAPHY

Electrical impulses, generated during muscle contractions, are the foundation of electromyography (EMG). Chemical induction and electrical stimulation generate a voltage difference that cause muscles (specifically, striated muscle) to contract, and it is the same voltage difference that is recorded during an EMG assessment (Gilroy et al., 2012). Gielen (2010) provides a detailed account of the physiology surrounding electromyographic study, describing the biological sub-structures within muscle tissue and elucidating the neural pathways that connect the brain to individual muscles via the central and peripheral nervous systems. Electrical impulses travel across this intricate array of pathways towards muscle fibres and fibrils as action potentials (AP), stimulating the secretion of neurotransmitters and causing depolarisation (opening a gate within cell membranes that exchanges the position of sodium and potassium ions) which, in turn, generates new APs that travel across the length of the muscle, causing further depolarisation and releasing calcium ions that facilitate the activation of a complex interaction between muscle substructures that finally leads to movement.

As with EDA, electromyographic data can be collected by way of internal (intramuscular) and external (surface) methods that likewise have advantages and limitations. For the purposes of psychophysiology, surface electromyography (sEMG) is most appropriate (as opposed to primarily medical diagnostic applications that more often employ intramuscular assessments) due to the non-invasive and painless application of the surface sensors that facilitate freedom of movement (Gielen, 2010). Gielen also notes that sEMG supports more accurate test reproducibility as sensor arrangements can be accurately marked. Such advantages do come at the cost of weaker signal strength (primarily due to electrical resistance from the skin) limiting the effectiveness of sEMG to muscles close to the skin surface (Franssen, 1995).

EMG surface sensors are typically gold or silver plated for enhanced conductivity and, as with EDA, often require a conductive gel to work effectively (Gielen, 2010). Archetypal electrode montages are bipolar with two active electrodes (connected to a differential amplifier) placed upon the most substantial area of muscle under analysis whilst a third electrode (placed on a region with no discernable muscular activity such as the ear lobe or occipital protuberance [back of the head]) acts a reference (Franssen, 1995). Facial electromyography (fEMG) characteristically employs a surface electrode design to detect activation of various regions of facial musculature and it is commonly correlated with the study facial and emotional expression. Research concerning fEMG varies in the exact muscles under observation, however the corrugator supercilii (forehead frown muscle), orbicularis oculi (closes the eyelids) and zygomaticus major (cheek smile muscle) are most commonly utilised within psychophysiological research due to their association to emotional valence (Lang et al., 1998; Larsen et al., 2003). To further support clarity within this chapter, throughout the remainder of this discussion, fEMG will simply be referred to as EMG because the following articles cited within this section either refer explicitly to fEMG or discuss issues that apply as equally to fEMG as they do to any other form of electromyography.

APPLICATION AND LIMITATIONS

Whilst the majority of functional advantages relevant to EDA also apply to skin conductance response (SCR), the reverse is not always true. To support clarity, this section shall focus upon advantages and limitations that, although they may not be explicitly referred to as SCR in the literature cited, are nonetheless equally applicable to this particular subclass of electrodermal activity.

Whilst EDA data collection techniques certainly have merit, they are also not above methodological concerns. The primary benefits of utilising SCR as a biometric include low running costs and easy application (Boucsein, 1992; Nacke & Mandryk, 2010) non-invasive sensors that allow freedom of movement and a well-established link with the common target of arousal measurement due to distinct and exclusive connectivity with the sympathetic nervous system (Fowles, 1986; Lorber, 2004). Another distinct advantage to SCR is that secreted sweat is not required to reach the surface of the skin for a discernable increase to be observed, allowing researchers to identify minute changes that would certainly not be noticeable from visual observation (Bolls, Lang & Potter 2005; Mirza-Babaei, 2011).

In contrast to these advantages, traditional electrodermal sensor setups have been associated with various erroneous factors such as motor activity (Roy et al., 2008) and emotion suppression (Jackson et al, 2000; Wegner et al., 1990). Use of these techniques for the purposes of measuring emotional response has been described as fraught with classification difficulties and it is acknowledged that biometrics alone are not always reliable indicators of discrete emotions (Cacioppo, 2007; Hazlett & Benedek, 2007). However, as discussed below, such concerns are rapidly being addressed and resolved as the technology behind the method advances.

Kivikangas et al. (2010) point to a relatively noise resistant signal as a significant advantage of EDA applications and also support the notion of a distinct association between EDA and arousal, particularly in comparison to the more ambiguous inferences associated with electromyography and heart rate. By way of contextualising arousal response, recent experimentation has revealed EDA to be an effective correlate of aggression and sociopathic tendency. Cacioppo et al. (2007) do, however, balance the argument by suggesting a ‘many-to-one’ relationship in which a single physiological measurement can be attributed to a number of psychological phenomena. From this argument it appears logical to assume that although EDA certainly has the potential to accurately reflect particular psychological structures, an informed and multi-faceted method is required to achieve such goals. One particular success story is that of Gross, Fredrickson and Levenson (1994) who utilised EDA biometrics to test two alternative theories of crying, revealing that when individuals cry they consistently experience increased arousal (as determined by EDA). This knowledge was used to disprove the theory that crying facilitated homeostasis and attenuation of negative affect in favour of the notion that crying instead created an intensely aversive state that motivates the individual to address the source of the sadness.

In their discussion into the limitations of EDA, Kivikangas et al. (2010) suggest that the temporal resolution of 1.0 to 4.0 second delayed responses is slow. Whilst this is certainly true in direct comparison against electromyographic signal data, there remains potential to accurately map events to EDA signal provided the presentation of stimuli is not too temporally narrow. Gilroy et al. (2012) support this notion, asserting that EDA 'has a quick response (onset of 1.0 to 3.0 seconds) with a long decay period'. Whilst the subjective descriptors of *quick* and *slow* arguably depend upon the specifics of the methodology it would be unfair to suggest that EDA lacks the temporal resolution for valid application in all event-related studies.

Lober (2004) refers to the behavioural activation and inhibition systems (see Gray, 1987) and asserts that EDA reflects motivational action systems, suggesting therefore that EDA may have application as a measure of motivation or desire. EDA has also been successfully employed as part of biofeedback systems with medical application and has been revealed to be an effective form of supportive treatment for children within the autistic spectrum (McLeod & Luccy, 2009) and individuals displaying antisocial or psychopathic tendencies (Lorber, 2004). In a similar vein, Nagai et al. (2004) utilised an EDA-based biofeedback system to support patients with drug-resistant epilepsy, revealing significant seizure reduction between the test and control groups.

Whilst traditional EDA hardware setups are non-invasive and the application procedure is not painful, issues with hyper sensitive reactions to electrode gels and movement-restrictive wires that restrict researchers to short-term acquisition procedures are significant concerns (Hedman et al., 2009). Poh et al. (2010) exhibit an intriguing solution to such long-term discomfort and motion artefact issues commonly associated with standard finger-based EDA sensor setups. They present a design in which the EDA sensors are integrated into a bespoke wrist band to obtain measures from the ventral side of the distal forearms. This application is certainly advantageous within a CVG context as the hands are not encumbered with hardware, enabling full freedom of movement, significantly reduced artefact (as the hands are the primary source of physical movement during play), a more natural and immersive gameplay experience, and also a reduced risk of white coat hypertension and greater ecological validity of obtained data.

Wireless connectivity protocols that include infrared and Bluetooth have been integrated into a wide selection of biometric hardware devices (see Biomedical.com; Biof.com; Psychlab.com) and affordable, commercial-grade SCR wireless devices (for a comprehensive description of such a system, see Strauss, 2005) include the *Q Sensor* (Affectiva.com, 2012) and the *GSR Shimmer* (Shimmer-research.com). Hedman et al. (2009) present the iCalm sensor, a similar EDA-based wristband alongside accompanying software that was designed to enable users from the general public to acquire, analyse and interpret their own physiological data without developer or researcher support. Systems such as these provide real portability and high usability, enabling users to provide data from a natural environment, separated from computers and wires to shift the user's focus away from the mind-set of *being tested* towards the activity being undertaken.

EMG provides very high temporal resolution (accurate to the millisecond), removes bias present in visual observation, supports automation and is capable of detecting minute muscular action potentials (Bolls, Lang & Potter, 2001). EMG analysis of particular facial muscles has been described as ‘the primary psychophysiological index of hedonic valence’ (Ravaja & Kivikangas, 2008). Positive emotional valence is typically characterised by a high level of zygomaticus major activity and correspondingly low level of corrugator activation whilst negative valence yields the opposite (Harman-Jones & Allen, 2001; Kallinen & Ravaja, 2007). Countering some of these benefits, EMG measurements are relatively sensitive to noise originating from both muscular cross-talk (action potentials of neighbouring muscles confound the signal stream) and technical issues that include inaccurate sensor placement, loose connections and interference from electrical appliances in close proximity (Kivikangas et al., 2010). Kivikangas et al. cite the FUGA (fun in gaming) project that assessed the validity and reliability of several biometrics (including: EMG, EDA, functional magnetic resonance imaging, electroencephalography and eye-tracking) and concluding that although all approaches came conjoined to methodological pitfalls, such issues could be overcome with careful and informed planning and execution, alongside logical interpretations of obtained data. Research within this project further supported the value of such biometric systems, presenting a prototype system capable of accurately identifying every time an individual was playing a computer video game within a three week period from EMG and EDA data.

BIOMETRICS IN CONTEXT: EMOTION

‘Psychophysiological measures […] can serve as “windows” on the mind and as “windows” on the brain.’ (Coles, 1989)

This section progresses from a more general discussion regarding EDA and EMG biometrics to focus upon specific contexts relevant to the thesis. Commencing with emotion and affective frameworks, this section then addresses research concerning psychophysiology within the contexts of sound and, finally, computer video games. As discussed in chapter 2, affect is positioned as the master-term, under which emotion and mood refer respectively to short-term, event-related and long-term, situation-related responses.

Arguably, one of the principal psychophysiological associations is that between physiology and emotion. Research within this field is concerned with the quantification of human experience; searching for a means to better understand how and why we *feel*. Brave and Nass (2002) posit that ‘emotions can be expressed via several channels, such as voice, speech, facial responses and physiological responses’. Nacke et al. (2009) assert that both EDA and HR are proven successful measures of arousal and emotion but note that this is primarily true within controlled laboratory environments. Ravaja (2004) also testifies as to the inherent value of biometrics in emotion recognition systems, but states that it lacks considerable reliability if used independently. Critchley et al. (2002) support the use of EDA as an indicator of emotion, stating that EDA ‘provides a sensitive and convenient measure of assessing alterations in sympathetic arousal associated with emotion, cognition and attention'. Critchley et al. further state that electrodermal activity can be indicative of many discrete emotions that include pain, excitement, anxiety and apprehension, provided the methodology is properly designed. An 'appropriate' methodology characteristically refers to simultaneous use of several biometrics alongside subjective data collection and cross-examination of all elements before inferring psychophysiological patterns (Drachen et al., 2010).

Biometrics within usability and user experience (UX) studies reveals a powerful practical application of study into the physiology of emotions, an advantage that has been exploited for UX testing in computer video games (Ravaja et al., 2006). Mirza-Babaei et al. (2011) provide a detailed discussion of UX methods and their limitations, asserting that whilst observation and subjective user-feedback can solve the majority of usability issues, biometrics are becoming an invaluable tool for understanding issues related to users' feelings, further stating that 'in certain categories of issue, [biometrics] reveal up to 63% more issues than observation alone'. Drachen et al. (2010) state that the rich level of detail and objectivity of biometrics within UX studies provides researchers with the information required to correct for bias in traditional subjective methods and provides event-related data that, during the course of an experiment, maybe forgotten by the participant at the time of debrief. Psychophysiology and UX/usability has been taken a step further, with recent technologies integrating biometrics into their hardware to increase efficiency of testing and increase product development speeds (Gualeni, 2012).

Mailhot et al. (2008) tested various musical excerpts that had already been subjectively classified along the valence (positive-negative) spectrum; recording EDA, EMG and eye-blink data in response to these excerpts. The results revealed that music (pre-described subjectively as unpleasant) increased corrugator activity whilst greater EDA was recorded in response to pleasant musical excerpts. Ravaja (2002) compared viewer response to static and dynamic facial images; data collected revealed a strong correlation between positive self-report and zygomaticus major activation. Dimberg (1986) documented physiological patterns identified when comparing user response to *fear-inducing* and neutral stimuli. The results detail increased zygomaticus major activation in response to neutral stimuli, compared to increased corrugator activity and EDA in reaction to fearful stimuli.

Such research asserts that activation of particular muscle groups corresponds reliably to valence-charged stimuli, suggesting that EMG data has the potential to identify emotional valence across a broad range of values and can therefore be used to compare not only positive to negative, but also to explore the many varying degrees of these poles (Sato et al., 2008). Recent work by Van den Broek (2006) exposed participants to stimuli pre-classified into four emotional categories and revealed significant difference in the skewness of data distributions (obtained from frontalis, corrugator supercilii, and zygomaticus major EMG) between each of the emotion groups, suggesting that EMG signals that initially appear comparable can, potentially, be clearly distinguished via descriptive statistics.

Existing research has documented increased EDA during exposure to a fear-inducing stimulus (Bradley et al., 2008; Dimberg, 1986; Meehan et al., 2002) and other negative emotional states such as disgust (Jackson et al., 2000), however positive emotional states have also caused significant increases in skin conductance (Mailhot et al., 2008). Whilst such studies do not postulate that such associations indicate EDA as viable sole indicator of fear or disgust, this information does suggest that measuring arousal via EDA with appropriate contextualisation could support artificial fear recognition. Researchers attempting to effectively utilise biometrics for data recognition are typically required to utilise some form of the valence-arousal model (VAM – a dimensional model referred to in chapter 2). The corrugator supercilii and zygomatic major electromyographic approach to the VAM is founded on the principle that the former muscle is activated during negative (frown) affect and the latter in response to positive (smile) emotional experience, a model that takes influence from the facial action coding system (FACS) established by Ekman and Friesen (1978). Activation of the zygomatic muscle has, however, also been associated with negative emotional states, specifically disgust (Mailhot, 2008). Research has revealed substantially low correlations between positive occurrences and smile activation during certain sporting events (Ruiz-Belda et al., 2002) and Russell et al. (2003) document several studies in which smiling appears to be largely a form of conscious social communication rather than reactive expression. A potential solution to this problem is documented by Larsen et al. (2003), stating that the corrugator supercilii is capable of representing both positive and negative valence. Activation of corrugator muscle tissue is potentiated by negative affect but also has been revealed to be inhibited by positive affect (Lang et al., 1993). This information suggests that corrugator activity may provide sensitive readings of valence whilst zygomatic activation could suggest intense disgust, happiness or imply mixed emotions.

The notion of ambivalence have been addressed by Larsen et al. (2003) who suggest that positive and negative affect should be treated ‘as separable components of the affect system, rather than as opposite ends of a bipolar valence continuum’, suggesting that circumstances may arise in which both positive and negative emotions could be received during an electromyogram recording. Corrugator activity is described as ‘sparsely represented in the motor cortex and […] less likely to be involved in such fine voluntary motor behaviours as articulation and nuanced display rules’ (Ekman & Friesen, 1975) suggesting that corrugator activation is unlikely to be affected by conscious suppression or false activation. As with many psychophysiological measurements, corrugator activity has been described as insufficient at identifying discrete emotional states. Within a computer video game context, Hazlet (2003) associates frustration with corrugator activation, identifying increased readings in novice users during failure to complete tasks and during interaction with software rated as difficult to operate. Waterink and Van Boxtel (1994) observed a correlation between corrugator muscle activity and exerted mental effort, whilst some researchers associate sadness and disgust with corrugator stimulation and correlate fear with corrugator relaxation (Lang et al., 1993; Yartz & Hawk, 2002). This information suggests some disagreement with regards to the functionality of EMG (specifically corrugator activity) in emotion recognition. What does appear more consistent, however, is the notion that corrugator activity is less susceptible to suppression, false response and ambivalence.

Also referred to as the circumplex emotional model (Russell, 1980); the VAM plots psychophysiological data onto a two-dimensional (X, Y) construct, positioning the affective experience along a positive-negative (pleasant-unpleasant) and low-high activation (calm-excited) continuum (Ravaja et al., 2004). Utilising both EDA and EMG assessment systems, Bradley and Lang (2000) revealed a significant correlation between negative emotional affect and increased electro-dermal activity, startle reflex potentiation and corrugator electromyographic (EMG) readings, supporting the association between these specific biometric measures and hedonic valence. The valence-arousal model acts effectively as an intermediate approach to emotion recognition, in that it does not have to assume discrete emotions. Both the ratio-scale of the axis and the positioning of emotional states within the 2D space can be determined by the researcher and be based upon experiment-specific contextualisation data.

BIOMETRICS IN CONTEXT: SOUND

Psychophysiological research with a focus upon audio stimuli has explored the physiological effects of speech, music and sound effects to varying degrees. Koelsch et al. (2008) revealed that changes in musical expression could evoke variations in SCR, HR and event-related potentials (measured via electroencephalography). As discussed in chapter 4, quantitative psychophysiological measures have been utilised to assess psychological response to sound in various academic texts (Bradley & Lang, 2000; Ekman and Kajastila, 2009). The arousal and valence experimentation concerning visual stimuli has recently been extended to address audio. Bradley and Lang (2000) collected electromyogram and electro-dermal activity data in response to various auditory stimuli. Experimentation revealed increased corrugator activity and heart rate deceleration in response to unpleasant sounds, and increased EDA in reaction to audio stimuli qualitatively classified as arousing. Jancke et al. (1996) identify muscle activation in the auxiliaries of the forehead as producing significant, high resolution data in response to audio. Electro-dermal activity has been utilised to differentiate between motion cues, revealing increased response to approach sounds (Bach et al., 2008) and event-related potentials (collected via electroencephalography) reveal changes in brain-wave activity in response to deviant sounds within a repeated standard pattern (Alho & Sinervo, 1997).

In an effort to rank the *horribleness* of various sounds, Cox (2008) provides data in support of gender, age, geographical location and cultural biases when assessing affective qualities of a sound. Experimentation data also suggested that '[i]f the source or event is identifiable, than [sic] a respondent's description of a sound is likely to be dominated by the source or event, rather than the properties of the signal'. Cox (2008) suggests that it is the revelation of source (regardless of whether it is correct or not) that strongly determines affective response; however Cox does not discount the intrinsic acoustic properties as potential inducers of negative emotional states. Intense scraping sounds and particular combinations of tones (creating dissonance) are described as intrinsically unpleasant across gender, age and socio-cultural types.

The information documented above suggests that biometric data collection has the potential to reveal emotion states with greater objectivity and temporal precision than that obtained by way of qualitative methodological practice. Utilising EMG and EDA measurements, the affective quality of a sound can be positioned within the two dimensional space of valence and affect, with recent work even alluding towards the potential for discrete emotion classification via physiology data. The use of qualitative information collection alongside the quantitative physiological data is a reoccurring practice. Although the validity of self-report within this research field has been questioned (Kappas & Pecchinenda, 1999), the history of experiments where both methods are employed or such a practice is recommended (Case & Wolfson, 2000; Cox, 2007; Grimshaw, 2008) provides reassurance that self-report data, combined with biometric results, can be reliable and valid.

Nacke, Grimshaw and Lindley (2008) measured tonic levels of EMG and EDA during gameplay, comparing the effects of both sound effects and music upon biometric output. Their results showed no significant difference in tonic physiological data but concluded, in line with many researchers in comparable studies, that analysis of tonic levels is an inappropriate approach to data collection and therefore support the use of event-related approaches.

BIOMETRICS IN CONTEXT: COMPUTER VIDEO GAMES

Research methodologies incorporating biometrics within the field of computer video games are diverse, with studies addressing: the influence of gaming uncertainty on engagement within a learning game (Howard-Jones & Demetriou, 2008), the impact of playing against human-controlled adversaries in comparison to bots upon biometric response (Ravaja et al., 2006) and developing biometric-based adaptive difficulty systems (Ambinder, 2011). Research into the latter has revealed that although non-biometric approaches to adaptive difficulty exist (e.g. Left 4 Dead [Valve, 2008]), those utilising affective physiology systems enhance the gaming experience more significantly (Liu et al., 2009).

According to Gualeni et al. (2012), commercial interest in biometrics has extended to casual and web-mediated gaming, including mobile applications. They describe the Biometric Design for Causal Games (BD4CG) project, an extended research study exploiting biometric technology to better assess player experience of casual and social gaming. Existing research has also supported the merit of biometric data as both a quality control tool, allowing developers an objective insight into the emotional valence and intensity that their game is likely to evoke (Hazlett, 2006; Keeker et al., 2004), and also as part of an integrated gaming system that connects the biometric data to the game engine, thereby creating a game world that can be manipulated by the player’s emotional state (Sakurazawa et al., 2004). There is increased agreement concerning what is meant by *gameplay emotional states* and the game experience questionnaire, or GEQ (IJsselsteijn et al., 2008), is a well-established and frequently employed qualitative debrief tool (Gerling et al., 2011). However, the questionnaire itself is not an exhaustive framework of game experience and it is still argued that there currently exists no commonly agreed upon theory of gameplay experience (Kivikangas et al., 2010).

The advantages documented above are not without counterbalancing limitations, as Kivikangas et al. (2010) state: ‘the various studies using psychophysiological measures do not yet form a common field […] thus, we have number of separate results for any separate research questions but very little accumulated knowledge’. In addition, the task of understanding thought and feeling during computer video gameplay is a grandiose challenge as they: produce at least two sensory modalities at any one time, require complex cognitive appraisals with varied semantic understandings, require the player to formulate strategies at varied time-scales (Klimmt, 2003) and motivations for gameplay can vary both between individuals and sessions (Kallio et al., 2011). Kivikangas et al. (2010) note that a significant proportion of understanding behind psychophysiology comes from more static and simplistic testing stimuli that have themselves been rigorously tested using subjective reporting before physiological factors are considered, such as the International Affective Picture System (IAPS) and International Affective Audio System (IADS) databases. Therefore, immediate research should be concerned with understanding the relationships between dynamic stimuli and physiological effects (Bonanno & El-Nasr, 2012). Gow et al. (2010) testify to the difficulty of inferring specific emotional experience during gameplay due to both the complex nature of the game itself and the presence of erroneous variables outside the gameworld. It must also be considered that the nature of a virtual reality that typifies several game genres (particularly the FPS) may cause established psychophysiological correlations to falter.

Picard (2010) notes that in a previously undertaken assessment of player affective state, the most significant event occurred when the game controller malfunctioned, supporting the notion of a clear distinction between emotions based in reality and those originating from diegetic elements of the game. The former is expected to evoke a significantly more intense emotional response when equated to the latter even if the nature of the event is comparable. For example, witnessing a murder or losing money within a game may produce a muted experience (of fear and frustration respectively) in contrast with a real-life equivalent scenario. Toet et al. (2009) revealed that although darkness within reality is a reliable cause of anxiety measured in HR and cortisol level, the same is not true in an FPS game. Studies correlating gameplay emotions and biometrics have conceded that, upon statistical analysis of obtained data, the strong correlational evidence is somewhat marred by significant variation observed between individual participants (Mandryk et al., 2006). However, this is not to say that entities that exist beyond the veil of what many may describe as ‘reality’ have no capacity to make us feel. Joly (2012) testifies, referring to *Wall-E* (Stanton, 2008): ‘being computer generated does not preclude the elicitation of affective experience’. Certainly, if the computer-generated visual representation of a barely humanoid and almost speechless robot, interacting with inanimate objects as the sole sentient inhabitant of a desolate wasteland can elicit significant affective change, then there must be ample potential for a computer video game to achieve comparable results.

Maintaining immersion and flow during gameplay is jeopardised if requiring the player to simultaneously provide an introspective of their affective state (IJsselsteijn et al., 2007) and post-game debriefing often overlooks details due to a lack of reliability in participant memory recall. Electromyogram and skin conductance hardware can be quickly and easily applied to the participant (and removed), providing a safe, non-invasive measurement that is unlikely to draw user attention away from the test stimuli (Cacioppo et al, 1986; Hazlett & Benedek, 2007; Huang et al, 2004). Both EDA and EMG signals are highly sensitive to small physiological changes and provide a significantly greater temporal resolution than self-report (approximately 10ms, 100 data points per second), allowing player response to be accurately examined along a timeline and connected to game events of matching chronology (Hazlett & Benedek, 2007). Mirza-Babaei et al. (2011) testify to the advantages of EDA almost ideal for games testing, both during experimentation and post-test to support subjective debrief responses, but concede that use of a game control pad is very likely to produce movement artefact. The temporal characteristics of EDA (specifically SCR) have been sourced to support pacing within an adaptive game system to avoid both prolonged periods of low intensity and over-saturation of arousing stimuli (Gilroy et al., 2012). Increased EDA has been presented as a potential indicator of specific in-game events, including: scoring a goal, engaging in a fight and collecting points (Mandryk & Inkpen, 2004). Ravaja et al. (2006) suggest that EMG and EDA are, together, reliable indicators of reaching a goal (as identified by reduced corrugator activity, increased zygomatic activity and decreased EDA). In analysis of an FPS title, Kivikangas and Ravaja (2010) observed a positive biometric response to player-death but a negative response when the player killed an opposing character (though note that in a multiplayer environment, killing an opponent instead elicits a positive response).

The temporal precision of EDA and EMG has facilitated the notions of experimental designs that extract only biometric data that correspond to a pre-defined and repetitive event in the search for patterns within the data (Kivikangas et al., 2010). Weber et al. (2009) analysed the biometrics of 50 minutes of gameplay, utilising data-logging techniques to compare obtained data within different macro-stages of gameplay (e.g. safety/danger, exploration/re-treading, etc.), a systematic approach that has been praised as a progressive and fruitful methodology (Kivikangas et al., 2010). Ravaja and Kivilangas (2008) analysed specific epochs of data (1 second before event and two, 1 second epochs after event onset) as an approach to accurately extracting relevant biometric data with which to correlate against event descriptors. Picard (2010) asserts that biometric testing must focus upon ecological validity, ‘characterizing patterns of data from individuals and clusters of similar individuals experiencing emotions in real life’, an method that, thanks to the recent developments in biometric design and affordability, is becoming an increasingly realistic option. The assessment of biometric methodologies is arguably being approached from many angles, with recent research also questioning the validity of commonly employed statistical analysis tools. Bagiella et al. (2000) argue that use of multivariate and repeated measures analysis of variance (ANOVA) techniques commonly lead to false rejection of null hypotheses (type 1 error) and that mixed-effect models should be considered as a viable analysis alternative.

Cheng and Cairns (2005) argue that facial EMG can effectively measure the intensity of a gaming experience and Ravaja et al. (2004) correlate facial EMG and EDA state changes to gameplay specific experiences; their research identifying both a positive correlation between increased EDA readings and self-report of spatial presence within the game, and a significant association between positively indexed EMG data and positive game events (reaching a goal). Increasing EDA has also been associated with gaming uncertainty (Howard-Jones & Demetriou, 2008), and Drachen et al. (2010) revealed a similar correlation between self-reported gameplay experience and biometrics across three individual AAA (triple-A: a term typically referring to big-budget games produced and marketed by large, established companies) first-person shooter titles. Emotion research specified towards gameplay has utilised similar biometric and subjective debrief methods to recognise game-relevant emotional states, including: frustration, boredom, challenge and fun (Mandryk et al., 2006).

It has been asserted that biometric data collection is sufficient to facilitate improved communication between human and computer (Van den Broek, 2006). Human-computer interaction research in this vein has extended to CVG theory and physiological data has been collected in various experimentation concerning games (Mandryk et al., 2006; Nacke & Lindley, 2008). Hazlett (2006) measured EMG response to varied game events and discovered significant correlation between specific game events identified as positive (using self-report during a video review of gameplay) and zygomatic activity, and analogous relationship between negative events and corrugator activity. An interesting study conducted by Ravaja et al. (2008) provided further evidence supporting the association between increased EDA and gameplay intensity and also discovered a surprising relationship between electromyographic valence data and a first-person shooter (FPS) experience. Standard FPS protocol places the player in a hunter/hunted scenario, requiring the player to kill large numbers of virtual adversaries whilst their avatar is itself under constant threat of being killed. Ravaja et al. revealed that during FPS action, players experienced intensely negative valence whilst shooting an adversary and, comparatively, experienced positive valence as a result of being shot; concluding that the patterns of stress and relief experienced within an FPS environment do not follow the expected success-failure formula, as dictated by other game genres.

The notion of integrating biometrics into a product has also been applied to CVG development with sensors built into the game controller in most cases (Sykes & Brown, 2003). Utilising biometrics in gameplay has also become manifest in adaptive game systems with established research utilising biometrics as an additional modality within game design (Nijholt, Bos & Reuderink, 2009). One notable example being Nacke and Mandryk (2010), who amalgamated ECG, EMG and EDA into a side-scrolling 2D shooter, in which biometrics would control a number of game parameters (including enemy size, enemy speed, weapons statistics and player jump height). The essential premise being to employ biometrics as an enhancement of gameplay rather than a core mechanic, an approach that has much promise if such technology is to be integrated into gaming as an evolution rather than a gimmick-based and mechanically flawed innovation. Gilroy et al. (2012) present a similar approach that exploits biometrics within a passive interaction system that connects user output to non-player character moods/personalities, subtle narrative changes and pacing. Such changes are not required to be predictable or reliable (in fact are likely to require the opposite) in contrast to biometric systems that attempt to control direct and precise player-movement/interaction parameters.

Gualeni et al. (2012) support the integration of biometric technology, stating this will provide opportunity to obtain data from significantly larger sample sizes than with laboratory testing, greatly increasing the power of statistical inferences. Also providing a counter-argument, Gualeni et al. state that (in addition to problems with invasive and distracting hardware) such systems would undoubtedly require additional resources for developers to program into the game and also demand additional cost collating and analysing the collected data. Biofeedback gameplay systems have also proved beneficial as alternative medical treatments, for example Jitaree et al. (2012), who document an EMG-biofeedback game that provides elderly patients an automated exercise program in order to reduce the risk of injuries sustained from falling.

As with the other emotion-related biometric designs, research into computer video games experience must have a solid and informed methodology with carefully crafted and distinct research questions and close examination into experimental design undertaken to address erroneous variables while significant preparation and care must be taken in setup of the sensors/hardware (Kivikangas et al., 2010).

The above sections within this chapter have discussed the applications, advantages and limitations of biometric investigation, primarily electrodermal activity and electromyography. Figure 2 below summarises the key points raised within this chapter. Also deliberated upon was the effectiveness of these biometrics, specifically within the fields of audio, emotion recognition and computer video games. The review of literature revealed that biometrics can be used effectively to distinguish affective states in response to varied acoustic stimuli and gameplay and that carefully designed methodologies have great potential to produce reliable results.

A review of alternate methodologies advocates the valence-arousal model (VAM) as a potentially appropriate foundation for emotion recognition within a gameplay scenario (although comprehensive analysis comparing VAM statistics and qualitative user-response is needed to enable this model to accurately predict discrete emotional states) within which a comprehensive set of qualitative descriptors ranging from individual and compound events to overarching themes, moods and atmospheres will flesh-out the VAM framework ultimately increasing the accuracy of a CVG emotion recognition system. The discussion presented within this chapter advocates biometrics within an array of CVG applications that includes product development, adaptive gameplay mechanics, additional control modalities, Biometrics is also asserted to have significant future potential within mobile technologies, such as tablet computers handheld consoles and mobile communication devices. Although a number of limitations to this technology are presented, most are counterbalanced with promising current and future developments.

Figure 2: Summary chart of EDA and EMG

Electrodermal Activity (EDA)		
Advantage	***Limitation***	***Application***
Non-invasive	Erroneous motor activity	Stress reduction
Low running costs	Emotion suppression	ADHD/Autism
Easy application	Weak classification	Socio/Psychopathology
Freedom of movement	Temporal factors	Brain damage
Established connection to arousal	Sensitivity to electrode gel	Attention
Can identify minute changes	Awkward with games controllers	Arousal
Noise resistant		Aggression
Good onset temporal resolution		Motivation/desire
Affordable wireless		Biofeedback systems
Real-time information		Usability / UX
Electromyography (EMG)		
Advantage	***Limitation***	***Application***
Non-invasive	Weaker signal strength	Valence
Painless	Limited to surface muscles	Usability / UX
Reproducible sensor montages	Emotion suppression	Product development
Can identify minute changes	Weak classification	Biofeedback systems
Excellent temporal resolution	Sensitive to noise	Exercise training
Sensors don’t require gel	Can restrict movement	
Established connection to valence	Expense of pro. systems	
Real-time information		

ELECTROENCEPHALORGRAPHY

Electroencephalography (EEG) is the recording of electrical activity that is achieved by way of electrodes, placed in specific arrangements across the scalp. The flows of ionic current within the neurons of the brain cause voltage oscillations that can be observed with EEG signal acquisition equipment. Although EEG study has been traditionally associated with medical research (most notably the diagnosis of epilepsy), there is a growing body of research that has great interest in exploiting EEG technology to better understand and, ultimately, to communicate directly with the human mind. This chapter documents the potential of EEG in this latter regard and presents an argument for this particular method of psychophysiological data acquisition as both a robust and reliable approach to computer video game biofeedback systems. Commencing with an overview of the advantages and limitations of EEG (within both general and game contexts), this chapter explores the associations of audio to EEG data, documents the competing methods of signal acquisition and filtration, highlights prominent feature extraction techniques and also emotion classification systems. A related analysis of current consumer grade EEG hardware, discussing the potential of such devices to create affordable and accessible biofeedback systems is presented within the conclusions in chapter 9.

ADVANTAGES, LIMITATIONS AND APPLICATIONS OF EEG

When considering which method of biometric data collection is more appropriate it is important to first have a clear understanding of the purpose for which this data is to be used. Biometric researchers often favour EEG for the purpose of obtaining direct brainwave data that, unlike other approaches (electromyography and respiration for example) is less susceptible to subject biases such as emotion suppression and false response (Murugappan et al., 2009). Direct brainwave analysis bypasses conscious input and enables the researcher to observe internal or covert processing (Mulholland, 1973). If a direct analysis of brain-centred neural activity is necessary, EEG boasts advantages over neuroimaging alternatives that include functional magnetic resonance imaging (fMRI), positron emission tomography (PET) and magnetoencephalography (MEG). This is primarily in terms of the significantly lower expense of EEG equipment (Vespa, Nenov & Nuwer, 1999), but also due to substantially greater portability and ease of use (Hamalainen et al., 1993). Higher temporal resolution (potentially several thousands of samples per second) is a substantial advantage (Fisher et al., 1992) with particular value for computer video game play analysis, as responses can be accurately be mapped to game events/transitions even if they occur in quick succession. EEG is comparatively less invasive for the participant and does not expose them to damaging radiation or magnetic fields. Unlike fMRI and PET, EEG has no associations with claustrophobia (Murphy & Brunberg, 1997). An advantage that is of particular interest to auditory research is that EEG equipment emits minimal noise and wireless capabilities of modern headsets facilitates the separation of the participant from the receiving computer, enabling tests to occur in potentially silent environments.

EEG is, of course, not without disadvantages. The positioning of the electrodes (irrespective of positioning system employed) are focussed mainly on the higher, cortical regions of the brain and as a result, are not ideal for measuring lower regions such as the medulla, diencephalon, or pons. Perhaps the most significant issue with EEG is low spatial resolution (Srinivasan, 1999), a characteristic that severely limits our potential to accurately determine the location the electrical activity is originating from. Signal to noise ratio is an additional problem (Schlögl, Slater & Pfurtscheller, 2002) due to the various sources of signal artefact such as eyeblink, facial muscle contraction and electronic interference from proximate devices. Whilst EEG and fMRI have been recorded simultaneously to combine the spatial and temporal resolutions (DiFrancesco, Holland & Szaflarski, 2008), such an approach then negates many of the benefits of EEG and is certainly inaccessible to the majority of compter video game and audio researchers.

The limitations and obstacles documented above have arguably not dissuaded researchers from using EEG for a range of purposes that include: robotic control by way of brain computer interfacing (Ranky, 2010), determination of meditation and attention levels (Crowley et al., 2010) and assessment of the mindsets of athletes (Stanley et al., 2004). EEG study has also provided correlations between brain activity and task efficiency (Chouinard et al., 2003), perceptual feature binding (Schadow et al., 2007), emotional valence (Crawford et al., 1996), and discrete emotional states (Takahashi, 2004). Seigneur (2011) utilised EEG to develop a brain-computer interface that had the potential to recognise discrete emotional states (specifically happiness) and transmit that information great distances by way of a web-based network. It was revealed that the system could be integrated into any web service, but was intended for popular social networking sites in which users would automatically generate positive feedback (Facebook *likes*) in response to particular EEG data patterns. It was theorised that this system could ultimately facilitate an ‘economy model in which people pay depending on the emotions they have experienced’. Another internet-based biometric setup utilised EEG-based emotion recognition to control a commercial music site in which the determined emotional state would regulate the particular style, genre or individual track being played (Liu et al., 2010).

Campbell et al. (2010) employed a bespoke classification algorithm to discriminate P300 signals (event related potentials observable as positive deflections in voltage with latencies of approximately 300ms) for the purposes of partially controlling a mobile phone (specifically initiating the dialling process in response to the P300, which is itself initiated by visual recognition of the desired recipient). Ismail et al. (2011) utilised EEG data in tandem with eye tracking to automatically generate emotion-related tags (boredom, joy, etc.) in real-time as the participant was reading a segment of text. Emotion-related classification algorithms have also been employed within video game contexts. Gonzalez-Sanchez et al. (2011) utilised EEG data (again, alongside eye tracking) to identify frustrating gameplay events within Guitar Hero (Red Octane, 2005). Bespoke games have even been developed around an EEG driven brain-computer interface (BCI) as a core gameplay mechanic (Qiang et al., 2010). Chanel (2009) developed an EEG biometric measuring system that was integrated into a classic puzzle game (reminiscent of Tetris) to differentiate between emotional states experienced at varying levels of difficulty, working towards a biofeedback system capable of managing the adaptive difficulty of gameplay in real-time.

Improving technology is gradually solving many of the characteristic limitations of EEG, as increasingly multi-channel systems are developed and sensor arrangement models are continually refined, spatial resolution of EEG is arguably increasing (Vaisanen, et al., 2008). Coyle et al. (2008) present a potential solution in reducing EEG artefacts within a game-relevant biometric system. EEG data is synchronised with infra-red tracking of the head, wrists, feet and torso to enable automatic identification and removal of muscle activity-caused artefacts (a system that itself could be achieved with consumer grade equipment – specifically the infra-red Microsoft *Kinect* game controller or the gyroscope mechanism within the Emotiv headset). The account of recent EEG related experimentation supports the assertion that although this particular approach to a biometric affect measuring system is not without problems; there nonetheless remains a strong confidence amongst researchers in this method. The proceeding section will return to the difficulties and methodological barriers associated with EEG, to explore the alternative strategies employed by researchers to circumvent these issues and work towards the development of an accurate and reliable interpretative system.

PERSPECTIVES ON EEG ACQUISITION AND FILTRATION

Continuing from the assertion that, despite some methodological concerns, EEG remains a biometric medium with significant future potential and what could be described as a fan-base of researchers across various disciplines, this section outlines the process of data acquisition and initial processing to firstly reveal how many of the concerns associated with EEG can be overcome, but also to support a new strategy of EEG acquisition/processing that could form part of the gameplay-biofeedback system that has been theorised upon throughout this thesis.

As stated earlier, EEG recordings are obtained by way of electrodes placed across the scalp. In most cases a conductive gel or paste is used and participants are required to prepare the scalp with light abrasion, reducing the impedance and improving signal to noise ratio (SNR). One of the most well-established approaches to electrode placement is the international 10-20 system (Jasper, 1958), an arrangement that has transcended EEG to be used in other forms of biometric data acquisition (Herwig et al., 2003). This system typically incorporates 21 electrodes, of which some are placed precisely at identifiable anatomical locations and consecutive electrodes are placed at fixed distances from these points in steps of 10% to 20%, accounting for variations in cranial size (Herwig et al., 2003). Chatrian et al. (1985) were the first to propose a higher-resolution 10-10 (also known as the 10%) system which increased the number of electrodes to 74. The approach consequently gained recognition as the new standard in EEG placement (Klem et al., 1999). Oostenveld and Praamstra (2000) supported the continuing resolution evolution with a 10-5 system that provided a potential placement structure for over 250 individual electrodes. Such dense electrode EEG caps are now commercially available (Pflieger & Sands, 1996), suggesting that although increased spatial resolution does dictate a greater monetary cost, the financial burden of a current flagship system will decrease significantly upon release of a superseding design. With reference to more relevant research, the international 10-10 system appears to be popular for the purposes of emotion recognition systems (Murugappan et al., 2009; Murugappan et al., 2010; Rizon 2010; Silva et al., 2002). In parallel with these developments, a differentiated research track exists that concerns developments of a more recreational nature. Discussed in greater depth later in this chapter, low-cost consumer grade headsets are evolving in the opposite direction; utilising fewer electrodes to exploit the benefits of portability, ease of use and affordability. Such devices feature prominently in recreation-focussed research projects (for example: Crowley et al., 2010; Ismail et al., 2011; Ranky, 2010; Sourina & Liu, 2011).

This variation suggests a divergence of opinion dependent upon the goals of the research, with medical applications prioritising spatial resolution to enable more accurate diagnoses whilst recreational purposes favour systems with greater potential for integration into commercial entertainment systems. Despite such divergences in hardware design, several other characteristics of EEG acquisition remain relatively constant. Pre-test preparation of the participant by way of skin abrasion is recommended in academic texts (Teplan, 2002) as a way of improving signal quality. However, this is not always consistent and it is argued that particular EEG setups (such as those incorporating active or spiked electrodes) can produce a usable signal without skin preparation (Griss et al., 2001;). External signal noise generated by electric devices is typically attenuated via a simple band-pass filter (Chanel et al., 2005). Other common causes of signal noise include ocular, muscular and vascular interference that commonly occur below 4Hz and above 30Hz (Murugappan et al., 2010) that, if removed completely, may severely impact upon the Delta and Gamma frequency bands, and therefore a more complex approach is needed. The most common solutions to this problem are preparatory steps (e.g. encouraging minimal movement from participants) and simultaneous acquisition of biometrics from interference generators, such as electromyography to identify ocular or muscular activity and electrocardiography to identify vascular activity (Murugappan et al., 2010). Spatial filtering technique (a mathematical process that focuses upon the central distribution of an EEG waveform to attenuate noise) is employed regularly within relevant research (Rizon, 2010). Surface Laplacian (SL) filtering, first presented by Hjorth (1975) computes the averages of a set number of nearest neighbours (in relation to the EEG signal) and removes the resultant values from the signal. Such a process is relatively simple to execute and consequently is a favoured form of spatial filtering in emotion recognition systems (e.g. Levis, 1995; Takahashi, 2004). From this we can infer that research tracks relevant to this thesis prioritise simplicity and efficiency in their data processing systems, most likely to minimise computational processing and system hardware demands. Much as the acquisition hardware is required to integrate successfully into a variety of commercial applications, so too is the software that interfaces between them.

EEG FEATURE EXTRACTION AND EMOTION CLASSIFICATION

In continuation from the preparatory and pre-processing phases of EEG recording practice, it is then required that the raw signal be transformed into inferential data to support the purpose of the acquisition. This section explores both well-established and experimental approaches to such transformations, and concludes with a discussion regarding which of these approaches could be most beneficial for an emotion-classification feedback system within a computer video game context.

Before feature extraction and classification methodologies are discussed, EEG channel representations, or *montages*, are briefly addressed. As with all aspects of EEG acquisition and processing, the montage selection is another point of contention between researchers and often determined by the specific purpose(s) of the system. Common montages include bipolar (the difference between two adjacent electrodes), referential (the difference between an electrode and a designated reference), laplacian (the difference between an electrode and the weighted mean of its surrounding electrodes) and average reference (collective outputs of all electrodes are summed and averaged). Electrode arrangements (such as the international 10-20 system) have also been referred to in research as montages. This complicates our understanding. Because a system such as the 10-20 can arguably be employed with several of the montages detailed above, this chapter refers to the electrode placement systems as *arrangements* and the interrelations between electrodes and signal amplifiers as montages. Whilst a specific justification for their choice is not regularly prevalent, emotion recognition research appears to characteristically favour referential montage setups (Campbell et al., 2010; Chanel et al., 2005; Ekanayaki, 2010; Ismail et al., 2011) although examples of bipolar montage (Bos, 2006) and average reference (Achaibou et al., 2007) are still present and often dictated by the hardware employed. It should also be mentioned that the two commercial headsets under scrutiny later within this chapter both employ the referential montage system.

Commencing with what is one of the most commonly employed analysis tools, the *Wavelet Transform* primarily serves to separate raw EEG into component frequency (sinusoidal) bands. An EEG signal consists of δ (Delta: <4Hz), θ (Theta: 4-8Hz), α (Alpha: 8-13Hz), β (Beta: >13-30), ΄Y (Gamma: 30-100+Hz) and μ (Mu: 8-13Hz) bands. Berger (1929) argued that frequency analysis was crucial to meaningful EEG appraisal and this notion remains valid, as can be observed from the numerous research projects that incorporate frequency analysis methods. Details on these bands of frequency and summaries of common associations believed to exist between individual bands and specific activities/thought processes have already been documented (Sanei & Chambers, 2007). Graps (1995) presents an online introduction to wavelet analysis history and developments that concisely differentiates between the original Fourier transform (continuous transformation of signal-time domain to signal-frequency domain), discrete Fourier transform (a sampled equivalent of the standard Fourier transform) and windowed Fourier transform (an approach to frequency analysis of aperiodic signals). An arguably more relevant differentiation made within this document is that between the fast Fourier transform (FFT) and the discrete Wavelet transform (DWT). Graps (1995) identifies the key difference between FFT and DWT to be that ‘individual wavelet functions are *localized in space*. Fourier sine and cosine functions are not’. In condensed terms, FFT processes all elements of raw EEG data within a fixed space whereas DWT provides a space that is flexible. The practical consequence of this difference is that DWT resolutions are variable, enabling both detailed analysis processing and signal discontinuity isolation. These advantages have resulted in DWT being advocated for use in a range of research interests, from speech signal noise reduction (Fan et al., 2004; Wieland, 2009) to characterisation of transient random processes in oceanic engineering (Gurley & Kareem, 1997). Both FFT and DWT processes appear to reoccur habitually within emotion-recognition EEG systems (Flórez et al., 2007; Levis, 1995; Murugappan et al., 2010; Rizon, 2010; Takahashi et al., 2004) and a review of related literature does reveal a general preference towards wavelet-based analysis.

Probing deeper into utilisation of wavelet transform processing, sub-categories of DWT (typically *db4, db8, sym8 and coif*5 algorithms) are revealed within emotion recognition EEG systems (Levis, 1995; Murugappan et al., 2010; Murugappan et al., 2011; Rizon, 2010) suggesting a lack of consensus regarding the relative advantages and disadvantages between the wavelet functions and also inferring that a strong methodology should include various functions to provide a more comprehensive analysis. Whilst frequency analysis is clearly a form of feature extraction, a much wider array of statistical tools have been utilised within EEG research in the quest for more reliable and accurate approaches to EEG signal interpretation. Murugappan et al. (2010) provide a concise overview of various feature extraction methods that include: common spatial patterns, asymmetrical power of specific frequency bands, and power of each frequency band alongside mean of raw signal.

Established statistical techniques, which include mean, standard deviation, power, analysis of variance (ANOVA) and multivariate analysis of variance (MANOVA), also make appearances within relevant experimental research methodologies (e.g. Jones et al., 2001).

Classification systems provide the next logical step within EEG analysis processing, using data generated by way of feature extraction to generate output data that are essentially an artificial replication of our brain's cognitive process (of course only within this highly specific context and circumstance). Within the emotion-recognition system, classification algorithms assess the processed EEG data and make a predetermined judgement based upon parameters and thresholds designated by the researcher. As with many of the steps already discussed, EEG classification algorithms vary significantly between research projects and currently there is no distinct consensus regarding optimum approaches to classification methodologies.

One of the most conceptually accessible classification systems is the arousal-valence model (AVM) associated with frontal EEG asymmetry. AVM essentially identifies human emotions by correlating an obtained EEG reading against a pre-established programmable statement that connects discrete emotion tags (fear, joy, disgust, anger, etc.) to points along a two-dimensional plane. Cacioppo (2004) asserts that frontal asymmetry can be viewed to act as either a moderator ('differential activation is […] instrumental in the production of tonic affective states') or mediator (differential activation is 'thought to dampen or augment the process') of physical response to emotion-evoking stimuli. Which perspective is adhered to will define whether frontal asymmetry (or indeed any electrical impulse obtained via EEG) is believed to be crucial to the response occurring at all, crucial to the scale or finer specifics of the response, or merely a by-product of the response. Currently, research cannot ascertain a causal connection between frontal asymmetry and response (specifically, affective state) and evidence that is in support of this connection is largely correlational (Allen et al., 2001). Irrespective of the exact nature of frontal asymmetry, the AVM has been described as 'one of the most promising and fertile in the field' (Cacioppo, 2004) and has proved effective in distinguishing various valence-related affective states, such as fear from joy in response to musical excerpts (Schmidt & Trainor, 2001) and attraction from withdrawal (Coan & Allen, 2003). Jones et al. (2001) identified frontal asymmetry as a reliable indicator of depression and similar studies have reliably utilised this classification system to identify anxiety (Wiedemann et al., 1999). The AVM is effectively elucidated in an article by Liu et al. (2010), who visualise an adapted AVM based upon Russell's Circumplex Model (Russell, 1980). In summary of the process, the majority of relevant research asserts that heightened left hemisphere activity is indicative of positive emotional states and conversely, right hemisphere activity is indicative of negative emotional states. In addition, greater amplitude of neural activity indicates intense emotional states (fear and joy, as opposed to sadness and satisfaction). Whilst significant evidence supports this model, acceptance of this rule as an absolute has been contested (e.g. Liu et al., 2010).

A Support Vector Machine (SVM) is a non-probabilistic linear classifier that traditionally exists as a binary model; able to distinguish between two discrete categories (though they may be adapted for multiclass use through approaches such as the one-verses-all calculation [Chapelle, Haffner & Vapnik, 1999]). SVM classifiers feature in emotion recognition systems frequently (e.g. Flórez et al., 2010; Sourina & Liu, 2011; Takahashi, 2004). SVM classification is a relatively simple approach and consequently less likely to demand high computer processing resources. Chanel (2009) asserts that strong generalisation of datasets and ‘interesting performances in high-dimensional feature spaces’ are characteristic advantages of SVM processing. Whilst this may advocate SVM as a viable approach to classification, emotion recognition accuracy ratings vary (for example, 41.7% [Takahashi, 2004], 64-71% [Flórez et al., 2010]). Murugappan et al. (2010) implicitly reject SVM in favour of K Nearest Neighbour (KNN) and Linear Discriminant Analysis (LDA) approaches. KNN and LDA classification algorithms also feature in several emotion-recognition models (Levis, 1995; Murugappan et al., 2011; Rizon, 2010). The dates of these publications suggests that the developmental history of classification systems does not disregard one approach in favour of another but, instead, researchers appear to be focussed upon improving the various approaches simultaneously, with greater attention paid to the minute details. This research track has led to the employment of various subclasses of classification formulas, including Relevance Vector Machines (Chanel, 2009) and Absolute Logarithmic Recoursing Energy Efficiency (Murugappan et al., 2010).

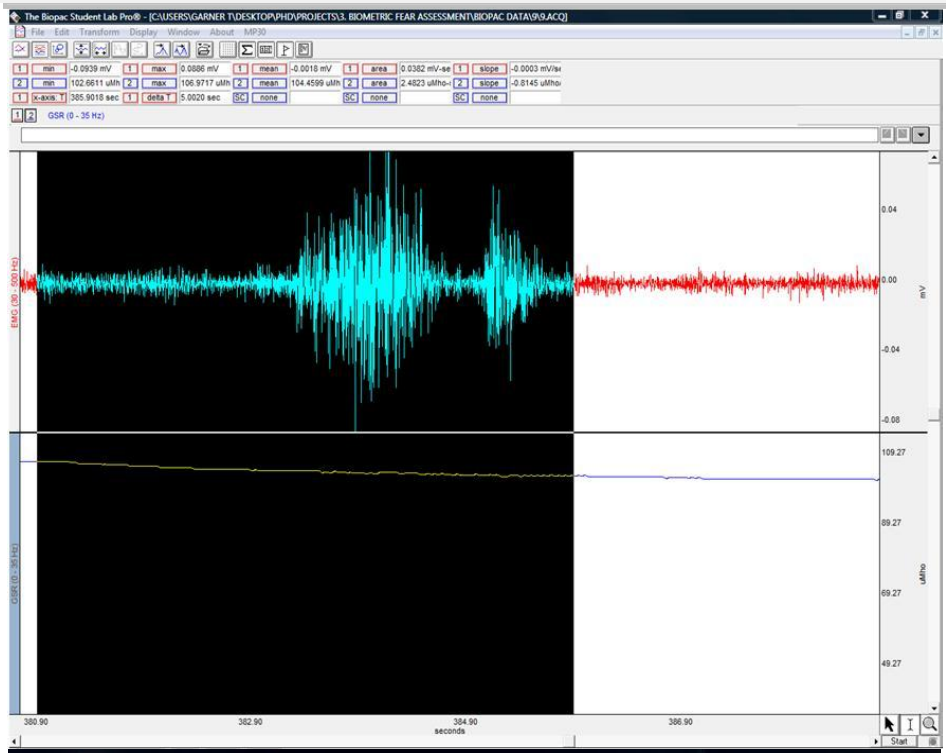
Whilst it could be asserted that to properly support any EEG biofeedback system, a comprehensive evaluation of all models of processing is required. Of course such an approach would be extremely time-consuming and from an overview of relevant literature it is clear that algorithms, classification frameworks etc. are subject to ongoing development and any comprehensive evaluation would quickly become outdated. In response to this argument, the notion that a restricted or windowed evaluation of methodologies would provide a compromise between informed design and practical efficiency is arguably appropriate. It could further be posited that, due to the multitude of variables that potentially influence best processing method (equipment, context, desired output, etc.), comprehensive pre-testing is advised to enable the direct comparison of a range of processing approaches within a controlled scenario.

CONCLUSIONS AND CHAPTER SUMMARY

From the discussions throughout this chapter EEG, EDA and EMG psychophysiological measures show significant potential for accurate and reliable quantitative assessment of player affect. Although there are clearly no perfect systems currently available, the research conducted so far strongly advocates biometrics as a key component of emotion recognition. The key problem lays in the translation between quantitative physiology and qualitative psychology, highlighting the difference in embodied existence between man and machine. Appropriate contextualisation is arguably the solution, artificially embodying the biometric data via attachments to emotion-related language and expression. Chapter 6 presents methodology designs for three related preliminary experiments, all of which focus upon assessment of affective experience in response to sounds modulated by way of digital signal processing (DSP). The intention of these experiments is to discover if such detached modulations (the DSP effects have no predefined contextual association to the situation, theme or atmosphere of the testing environment/game) are capable of intensifying/ attenuating a fearful experience, or if context is indeed essential to successful manipulation of an individual's emotional state.

Chapter 6

Methodology Designs


The Biopac Student Lab Pro® - [C:\USERS\GARNER T\DESKTOP\PHD\PROJECTS\3. BIOMETRIC FEAR ASSESSMENT\BIOPAC DATA\9\9.ACQ]

1 min -0.0939 mV 1 max 0.0886 mV 1 mean -0.0018 mV 1 area 0.0382 mV-se 1 slope -0.0003 mV/s

2 min 102.6611 uMh 2 max 106.9717 uMh 2 mean 104.4599 uMh 2 area 2.4823 uMho- 2 slope -0.8145 uMho

1 x-axis: T 385.9018 sec 1 delta T 5.0020 sec SC none SC none SC none

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2012

Chapter 6: Methodology Designs

INTRODUCTION

To better understand the interrelationships that exist between sound and emotion, three preliminary experimental trials were built, the intention being to assess the potential of objective acoustic parameters to evoke and/or modulate fear during computer video gameplay. One key hypothesis raised from the literature reviews and discussions of previous chapters is that the embodied nature of listening dictates that objective acoustic parameters, if mechanical in nature and detached from semantic meaning, are incapable of altering a player's emotional state. If it is accepted that all listening is embodied, then such a thing as a completely objective acoustic parameter cannot exist, as it is inappropriate to suggest that a listener could not attach their own connotations to even the most discrete quantitative parameter. This differentiates objective from quantitative and within the contexts of acoustics, parameters (including volume, reverberation, delay, attack, etc.) can be measured in quantitative scales (primarily seconds, hertz and decibels), yet cannot be labelled objective. However, as with the concept of virtuality, objectivity/subjectivity can arguably be understood as a continuum, within which particular acoustic factors can possess a higher *objectivity value*. The sounds utilised within these experiments are treated with a range of quantitative digital signal processing (DSP) effects with minimal intended semantic attachment. The source sounds themselves (particularly within experiments 1 and 2) arguably also possess limited connotative information, as there is no discernible connection to the sounds heard and the circumstances (both diegetic and extra-diegetic) the listener is placed in. Should the obtained data reveal statistically significant difference between treatment groups, then the evidence would support that sound is capable of modulating emotion without distinct contextual support.

EXPERIMENT 1:

1.1 WEB MEDIATED ASSESSMENT OF AFFECTIVE GAME SOUND

The preliminary testing documented within this thesis utilises the internet as a platform for data collection. Collections of sampled audio files that feature in both the biometric pre-trial and the real-time intensity experiment are also presented in two internet-mediated tests. The full details of these internet trials are disclosed later in the chapter. The following three sections examine existing relevant theory and experiment-obtained information to contextualise a subsequent empirical investigation and also establish a theoretical foundation to support the methodology (documented later within this chapter).

Using the internet to cast a wider net and access millions of potential participants has a significant appeal but is, however, fraught with methodological difficulties. This section provides an assessment of electronic research (incorporating internet-mediated testing) reliability, comparing online internet responses with data collected in traditional testing environments and presenting an overview of the advantages and limitations of using the internet to perform various forms of data collection. The focus of this review is upon internet-mediated approaches to experimentation methodologies for primary research, not conducting secondary research (such as literature reviews). The information presented within this literature review then feeds into the methodology for a bespoke internet-mediated testing environment, in which quantitative data is collected in response to a variety of audio samples to evaluate perceived user-defined fright, emotional valence and arousal. Results, documented in the next chapter (7), support the hypothetical frameworks that are presented in chapter 9.

The primary test hypothesis for Experiment 1 states that both intensity and valence measures of user-affect will differ significantly between control (untreated) and test (DSP treated) sounds. It is further expected that there will be significant difference between individual source sounds. The secondary hypothesis asserts that there will be no significant difference between online and offline test group results.

1.2 THE POSSIBILITIES OF E-RESEARCH

‘[*The internet*] *holds the promise to achieve further methodological and procedural advantages for the experimental method and a previously unseen ease of data collection for scientists and students*.’ (Reips, 2002)

The internet provides an ever-increasing wealth of possibilities for psychological research and the number of legitimate web-based experiments is growing significantly (Birnbaum, 2004; Lewis et al., 2008). Online technology supports the hosting of highly interactive test environments, provides a dialogue between researcher and participant, can deliver surveys and complex tests to a great audience, and even supports real-time access to physical laboratory environments from a remote location. Received data obtained from both a traditional (pencil and paper) and electronic (online network) method yielded comparable results and it has been suggested that the internet is the next step forward in developing and presenting survey materials (Lewis et al., 2008). Progress appears set to continue and it has been posited that the Internet ‘will decisively shape the nature of psychological research’ (Nosek & Banaji, 2002)

This chapter specifically addresses web experiments, first by way of outlining the substantial benefits then proceeding to address methodological concerns and potential solutions. A range of relevant literature is documented and cross-examined alongside current technological and socio-cultural circumstances. The term *web experiment* here refers to an online task that requires participants to interact with web-based materials (images, audio, video, etc.) and provide response data either directly from the task (e.g. response time, task actions) or post-task (e.g. opinion obtained in debrief). Although varied terminology for this online medium of psychological experimentation exists, Reips (2002) argues that *web experiment* is the preferred term, being historically the first term implemented for this purpose.

Web experimentation requires no physical space or materials (excluding client side hardware) and is unlikely to require additional personnel for operations, development or maintenance (Stanton & Rogelberg, 2001). The cost of web space is becoming increasingly affordable and domains can be continually reused for new web experiments, whilst professional grade web authoring software is becoming increasingly powerful, accessible and affordable. The nature of web experiments requires that the entire process be displayed and open, providing accesses for anyone who may wish to replicate or develop an existing test (Reips, 2002). Furthermore, online participation bypasses scheduling difficulties and supports the simultaneous input of multiple users and provides continuous access to web experiments, facilitating significantly fast delivery of data from large samples (Reips, 2002). The opportunity for anonymity during participation provides access to individuals/groups that would refuse to take part in an offline equivalent test (Schmidt, 1997). Integration of pre-established online protocols can facilitate the automation of data collection and storage; in addition, obtained data can be refined by elimination of incomplete or undesired responses and additional information (reaction time, response time/date) can be collected and stored automatically (Reips, 1995).

Generating powerful datasets that inspire confidence in research conclusions is a highly desirable characteristic of both academic and commercial research. Large sample sizes also support increased generalisability of results to the general population (Horswill & Coster, 2001) and will increase the statistical power of obtained results. The internet offers a potential solution and has been described as an ‘inviting opportunity to reach large numbers of people’ (Welch & Krantz, 1996). In some cases the internet has proved to be the single solution for academic researchers who require large sample numbers and have limited resources (Klauer et al., 2000). The increased accessibility and relative ease of data input in computer-based psychological tests (compared to traditional pencil and paper methods) enables higher response rates and more comprehensive information to be received (Kiesler & Sproull, 1986). In addition to connecting the researcher to large sample sizes, relatively rare and highly specified populations may also be accessible (Schmidt, 1997). Web experimentation has the potential to overcome geographical distances and provides links to a wide variety of societies and cultures that maybe inaccessible by other recruitment solutions (Reips, 2002).

The online adaptation of existing field or laboratory research has the potential to increase the external validity of such prior experiments by way of providing a more natural environment (most likely the participant's home), where the participant completes the experiment in comfortable and familiar surroundings (Reips, 1995). Reduction of experimenter effects and wider participant access to increase representativeness of the sample supports external validity further (Reips, 1997). Nosek and Banaji (2002) argue that it is the removal of experimenter-based coercion effects that grant internet methodologies this increased validity. A suitably constructed web experiment may provide anonymity for the participants, reducing potential deception and encouraging input of sensitive information that a participant may feel uncomfortable revealing (Reips, 2002). Welch and Krantz (1996) noted that a significant number of participants comfortably provided critical feedback by way of a networked system, suggesting a greater willingness to criticise through an indirect medium compared to direct interfacing with the researcher. It has also been asserted that anonymous and indirect participation reduces the tendency to respond in a socially desirable way, providing freedom from social convention bias (Booth-Kewley, Edwards, & Rosenfeld, 1992).

Stanton and Rogelberg (2000) argue that modern computing technologies support increased interactivity in web experimentation. Graphics, animations, video, sound and images are all supported by the modern internet and consequently are available to utilise within web experiments (Mutz, 2011: p.7). The internet also exists as a component of remote-distance laboratory interaction, a substantial evolution in laboratory experimentation with significant application potential in industry, academic and education contexts (Schauer et al., 2007). Although the premise is over a decade old, it is still undergoing regular development and gaining in popularity. *LabVIEW* (www.ni.com/labview) is a long-running solution, essentially providing an online graphical user interface (GUI) representative of a real laboratory environment. Users can consequently interact with a physical laboratory environment in real-time and receive experiment data from their remote location. Modern computer technology enables these interfaces to present realistic virtual worlds in which high quality graphic representations of physical equipment and devices support increased immersion, and consequentially high user-confidence and performance whilst operating the program (Scheucher et al., 2009).

1.3 THE METHODOLOGICAL PERILS OF E-RESEARCH

To effectively utilise the internet for conducting web experiments it is vital that a number of technical, methodological, procedural and ethical concerns be addressed (Reips, 2002). Walsh et al. (1999) propose that the perceived credibility of information obtained from the internet varies substantially depending upon demographic variables, and that many perceive internet-based research to be significantly less credible than that conducted using printed media. Whilst this arguably applies mainly to secondary research practices, it is still conceivable that such negative attitudes may also extend to web experimentation. With almost 60% of the United Kingdom accessing the internet daily and consistent increases in internet usage (ONS, 2010), it is conceivable that confidence in the internet as a viable medium for academic study is growing. However, it remains likely that many would still maintain distrust towards internet-mediated research, and consequently it is strongly advisable that every precaution be made to strengthen the validity, reliability and generalisability of any web experiment methodology.

With the ultimate purpose of this section being to support the development of a web experiment pertaining to variation of audio samples, it is important that possible variances in the presentation of audio via the web be addressed. Roychoudhuri et al. (2003) state that the ‘human ear is more sensitive to quality degradation than the human eye’, and therefore every effort should be made to maintain audio quality. This problem can be extended further with regards to client side variances (hardware, browser, etc.), raising the concern that such differences all have the unwanted potential to alter the presented sound. Roychoudhuri et al. (2003) provide a detailed description of the quality and performance of various audio compression formats presented through a number of connection types and speeds, their work suggesting that various formats and compression types should be pre-tested on a range of connection speeds to confirm uniformity.

The nature of computer-mediated web experiments allows a researcher to overcome geographical and logistical barriers to connect participants to tests without necessitating a physical presence. It is, however, this absence of researcher presence that generates significant methodological issues, whereby validity becomes increasingly questionable due to lack of control over erroneous variables. In the place of a traditional and controlled laboratory environment, web experiments are completed in various different surroundings with the researcher unable to directly control; the participant, any characteristics of the room (temperature, light, humidity, acoustics, etc.), the presence of distracters (other people, background noise, participant multi-tasking, etc.), the time of day or the equipment (hardware, operating system, software, etc.) used. This presents additional concerns with regards to testing sound by way of a web experiment, as participants may use an array of alternative sound outputs (speakers, headphones, surround sound systems, etc.) and specific control parameters (user-set volume, equalisation, stereo panning, etc.).

Without interaction between participant and researcher, confirmation that the participant fully understands the requirements of the tasks is very difficult to obtain and participants may (accidentally or deliberately) confound results by completing the task with another individual also present, by accidentally leaving questions unanswered, or by intentionally providing false information (Nosek & Banaji, 2002; Reips, 1997: p.381; Reips, 2002). Krantz (2001) suggests that precise control of how test materials are presented and perceived without the attendance of a researcher is particularly difficult. Several potential solutions for this specific problem include: a list of requirements as part of the briefing (complete the task alone, be in a quiet place, etc.), utilising web scripting to limit the allocated time for task completion, and debrief questions asking the participant to report on their environment (Nosek & Banaji, 2002).

The attendance of a live researcher characteristically imposes social pressure upon the participant that, although it may be treated negatively as a form of bias, may also contribute towards reduction of deliberate deception (Nosek & Banaji, 2002). Without careful participant observation, there is a notable risk of participants missing a crucial requirement of the task or performing an action that disrupts the experimentation procedure. Participants may use web controls (back, forward, refresh, etc.) in a way that compromises the experiment (Nosek & Baniji, 2002), or they may neglect an option from a drop-down menu, causing a missing or incorrect response (Reips, 2007: p.375). Such problems can, however, be easily addressed with careful design and pretesting. Modern web authoring software such as *Dreamweaver CS6* (Adobe, 2012) provides accessible and powerful tools to enable discrete control over participant input. Text input fields can require precise numbers of characters or digits and specific formats (email, web address, etc.), whilst access to browser control functions can be limited, hidden time limits applied to interactions and input validation tools confirm that all data has been correctly entered before the user can continue. Scripts can facilitate immediate written feedback should a participant make a mistake or leave a page incomplete.

Producing datasets that can be confidently extrapolated beyond the confines of the experimental context in which they were obtained is best achieved by way of cross-validating results using alternative research modalities (Cho & LaRose, 1999). Stanton and Rogelberg (2000) suggest that ‘research comparing browser-based results with other modalities paints an optimistic picture’, referencing a number of experiments that reveal notable consistency between results obtain via web experimentation and alternative mediums. It may however, be inappropriate to rely solely upon cross-modal testing to confirm generalisability without also addressing the related generalisation issues intrinsically associated with web experimentation and their potential solutions.

A significant asset of internet-mediated research, such as access to large sample groups, can only be fully exploited at the cost of significantly increased risk to the generalisability of obtained results. Depending upon the specific details of the recruitment method, the nature of web experimentation has the potential to generate a sample of participants that do not adequately represent a target population and, therefore, obtained data lacks generalisability. It has been suggested that because web experimentation inherently requires participants to have internet access, obtained results are likely to become skewed towards overrepresentation of particular demographics (Stanton & Rogelberg, 2000). Subsequent survey studies have suggested that such effects (geographic location, age, gender, financial status, etc.) are diminishing as the global penetration of the internet is exponentially increasing (Nielsen Net ratings, 2000). However, demographic diversity has been revealed to significantly skew data from online studies if specific differences, relevant to the research question are not controlled (Stamler et al., 2000; Yost & Homer, 1998).

The absence of human contact within a computer-mediated web experiment also has the potential to weaken generalisability if the study relates to any form of human interaction (Reips, 2002). However, if the research is concerned with human computer interactions, then it would be logical to assume that computer-based methodologies support, rather than hinder, ecological validity. Within the context of the Experiment 1 research question, several aspects of the web experiment methodology support the generalisability of obtained data. Personal computers (PCs) used for web browsing are also commonly employed for gaming and consequently the same hardware (monitor, speakers/headphones, control interfaces) is increasingly likely to feature in both the web experiment and in recreational gameplay. In order to maximise upon this opportunity, participants should be required to indicate if their preferred platform for gaming was a PC or a console.

Furthermore, the separation between participant and researcher may result in a greater risk of participant-sourced bias. Reips (2002) highlights multiple submissions as a common problem due to the difficulty in identification of participants, suggesting that the same participant may provide multiple datasets that cannot be separated by IP address (if using different terminals or a connection that refreshes the IP address). Such an event may occur innocently (the participant was unaware that they were not to repeat the test), maliciously, or as a result of weak website design. A simple and efficient solution to innocent participant error and website design could be to incorporate an explicit request to participants that they must only perform the test once, explaining the reasons and importance of this; also to control data submission (e.g. avoiding several sets of data being sent via multiple clicks of the submit button) whilst ensuring that participants are given immediate feedback after submission of data (Cho & LaRose, 1999). It could also be suggested that the data collected from an expert in the field may also affect the generalisability of the data. Reips (1997) argues that providing an opportunity for such an expert to identify themselves and their data is a viable solution to this problem, allowing such persons to explore such experiments and provide feedback without affecting the data.

Whilst such identification measures are logically sound for establishing some control, they do not account for deliberate participant action. Stanton and Rogelberg (2000) refer to *access control* (restriction of admission to web materials) and *authentication* (verification of participant identity) as potential solutions to participant sourced bias; however, this raises further questions regarding how to implement such control, who is worthy of access and what impact will such a method have upon sample size. Existing research fortunately argues that relatively low rates of multiple submission do not compromise reliability of results; however, Frick et al. (2001) strongly advise identification data be collected before users begin experimentation and Reips (2002) further suggests repeated questioning of standard information (age, date of birth, etc.) to support the truthfulness of the participant. Generating a comprehensive account of participant information may significantly reduce the risk of such problems; however (as will be elaborated later in this section), methods of obtaining and storing individual participant records present further difficulties in the form of ethical concerns.

In addition to participant demographic issues, significant dropout rates may also negate the generalisability of obtained results (by way of selection bias) if the causes of dropout discriminate for or against specific population groupings. A study conducted by Buchanan and Reips (2001) revealed that personality differences existed between Mac and PC users and documented a correlation between JavaScript-enabled users and lower average education levels. Their research argues that web experiments should employ only basic and widely available technology, suggesting that rich multimedia websites could alienate particular demographics. This is regrettable, because the incorporation of *Flash* (Adobe) and streaming audiovisual materials supports the production of attractive and engaging web pages which could arguably serve to increase participant uptake and retention throughout the experiment. In agreement with Buchanan and Reips (2001), it has been suggested that such materials require specific software and greater hardware resources to operate; subsequently causing variation in user experience due to alternative connection speeds, client-side equipment (Schmidt, 2000) and negatively impacting upon both experimental validity and generalisability.

Addressing the above concern, modern internet and personal computer capabilities have arguably reduced compatibility concerns considerably. A Millward Brown (2011) survey claims that 99% of web browsers are compatible with Flash technology with 80% Java-enabled. Flash, in particular, could be positioned as a fundamental internet technology, with both YouTube (averaging 2 billion views per day) and Facebook (more than 2 billion videos watched per month) requiring flash technology (Internet in Numbers, 2010). Although this cannot account for potential variations in browsing and multimedia playback speeds, comprehensive pre-testing of web materials, (accounting for potential variations in hardware, operating system, web browser, security software, third party plugins, connection type, and connection speed) goes a great distance towards administering control over such systematic biases (Stanton & Rogelberg, 2000), ultimately reducing both dropout risk and erroneous variation in between participant experiences.

Dropout *curves* should be differentiated from dropout *rates*, and are a measure of when a dropout occurs during the process of experimentation. Dropout curves risk a compromise of validity via analysis bias if incomplete data sets are not identified and discarded (Reips, 2002). Although removal of incomplete responses may solve this concern, methods of reducing dropout are preferable, as they serve to retain the potential of large sample sizes. Acting upon the notion that dropout rates are highest during the opening few minutes of a web experiment, Reips et al. (2001) suggest implementing a warm-up phase, utilising several incidental tasks/questions before proceeding to the *experimental phase*.

1.4 ETHICAL CONCERNS

Participant privacy and anonymity are arguably the primary ethical concerns associated with web experimentation (Cho & LaRose, 1999) and any research conducted through this medium must carefully adhere to appropriate conduct whilst enrolling participants and handling personal data (Davidson, 1999). Indirect approaches to recruitment (registering with a search engine, advertising banners within other sites), although unobtrusive and ethically preferable, are relatively ineffective in recruiting large numbers of individuals (Tuten et al., 2000). Comparatively, direct requests by email, post or phone may yield greater responses but may be perceived by some as invasive. Careless recruitment practices may have a negative impact upon participant privacy, and also encourage malicious response from individuals who feel angered by persistent and/or intrusive requests for participation (Cho & LaRose, 1999). *Viral* advertising is believed by some to be the most effective approach to enrolling participants (Nosek & Banaji, 2002) and, if conducted appropriately via word of mouth and an attractive, interesting website, it may be the ideal approach to satisfying both ethical and sample size criteria.

The selecting of participants for interactive web experiments offers a diverse range of options. Of these, *self-selection* supports larger sample sizes, but in addition to associations with socio-cultural biases (discussed earlier) raises ethical concerns due to researchers utilising internet-mediated methods of collecting participant identity information (Reips, 2002). Identification of the participant is invaluable when attempting to control self-selection bias, multiple submissions and sample characteristics. However, direct requests and subversive automatic collection of identification data greatly threatens a participant's anonymity whilst also raising concerns regarding vulnerability towards potential fraud and identity theft (Stanton, 2008). Such fears are becoming increasing justified, with 2005 seeing 56 billion US dollars lost to corporate and consumer identity theft (Romanosky, 2011) and UK fraud associated with banking information generating £609.9 million in consumer losses in 2008 (ONS, 2011). Failure to account for such concerns may severely deter potential respondents and dramatically reduce response rates (Bartel-Sheehan & Grubbs-Hoy, 1999). As a result, it has never been more crucial that participants' personal information be securely handled or not required during web experimentation. Nosek & Banaji (2002) argue that the storing of sensitive material on internet servers leaves the data vulnerable to theft if not meticulously protected. Although modern protection services do exist, which offer strong (but not necessarily impenetrable) security, it could still be suggested that transferring server-stored material to off-line devices is the only way to guarantee protection from online data theft.

Analysis of existing research suggests an unfortunate obligation to compromise between validity, ethics and generalisability. For example, automatically collecting an array of participant information (IP address, operating system, screen resolution, browser type) requires the use of plug-in based procedures such as JavaScript which have been revealed to produce variation in browsing speeds and compatibility issues, leading to systematic bias and increased dropout rates (Schwarz & Reips, 2001). Although both Java and JavaScript procedures have become increasingly common, with over 82% of United States based internet browsers compatible (WebKnow, 2011), significant issues remain, with both *YouTube* and *Facebook* forums documenting problems associated with this technology. This creates a genuine concern as, without secure knowledge of client-side software, the researcher cannot account for variations in participant experience derived from these differences. Reips (2000) provides a potential solution in *multiple site entry technique*, a log file setup facilitating the collection of hyperlink information, allowing the researcher to observe what site led the participant to the experiment. Unlike plugins using JavaScript, log-based automated data collection procedures have not been associated with website variation. However, most information collected using this method is inferential and although systematic variation is unaffected, ethical issues (participants may not wish researchers to know details of other websites they have accessed) remain present. Conducting a web experiment that is unsuitable for children or that wishes to collect data from only adult respondents is fraught with additional ethical difficulties. Nosek & Banaji (2002) suggest a range of potential solutions, including minimising features that might appeal to children, recruiting from adult-dominated sources, direct invitation only, and authentication by way of a centralised registering process.

Additional care must also be taken to ensure that participants fully understand the nature of the experiment and are willing to contribute. In a laboratory environment, a researcher has the opportunity to brief the participant, obtain informed consent and respond to any unforeseen issues that cause discomfort or distress. The absence of a researcher in web experiments means that real-time feedback is not possible and, consequently, briefing should be comprehensive and consent forms should be transparent, with possible participant questions anticipated and answered (Nosek & Banaji, 2002). This raises questions regarding the ethical acceptability of duplicity or intentional withholding of information during the briefing process. Whilst such actions may support the requirements of the experiment and reduce participant bias, the risk to a participant's wellbeing is greater when compared to an equivalent scenario with a researcher present.

In summary of this review, internet-mediated experimentation can clearly overcome barriers associated with traditional laboratory experimentation, providing access to large sample sizes via a medium that is highly cost effective. High participation rates increase the potential for external validity, and more statistical power is afforded during data analysis. Large quantities of data can be collected, pre-processed, stored and even analysed automatically using server-side routines. This enables the design of increasingly efficient and, consequently, desirable methodologies. Such benefit does naturally not come devoid of cost, and careful attention to methodological pitfalls is essential during the design stage. For the purposes of audio-based experimentation; variations in hardware, settings, connection speeds, audio compression and encoding formats must be addressed to support any conclusions drawn from obtained datasets.

The methodology below consolidates most of the theory presented thus far (specifically the discussions relating to internet-mediated research discussion, fear theory and the emotion potential of sound) to support the development and execution of an online interactive testing environment built to assess the impact of digital signal processing effects upon users' subjective emotional experience. Online and offline testing methods are also compared to evaluate both the advantages and limitations of internet-mediated testing, as already discussed within this chapter.

1.5 METHODOLOGY INTRODUCTION

The methodology of *experiment 1* takes its influence from both the preceding internet-mediated experimentation literature review and the chapters concerning sound, perceptual listening and affective states. Data is obtained by way of both online (internet-mediated, uncontrolled testing environment) and offline (local-network, maintained environment) methods to simultaneously provide information regarding the ability of digital signal processing (DSP) effects to alter the emotion evocation potential of a sound whilst also comparing online to offline environments to test the assumptions regarding web-mediated limitations documented earlier in this chapter. Experiment 1 is split into two separate tests, the purposes of which are to exploit existing theoretical and applied research for the function of developing an internet-mediated audio testing environment within which the affective quality of preselected sounds can be assessed and recorded as quantitative measurements. The specific interest of this research is in the potential of variable audio parameters to influence the valence and intensity of a listener's fear sensation in response to a presented sound. Selections of acoustic parameters that can be easily manipulated using DSP are employed. DSP selection is supported by research documented earlier within the thesis (chapter 3), that asserts manipulation of these parameters may have the capacity to alter the *fear potential* of a *source sound* (a term used within this chapter to refer to the original, unprocessed incarnation of a selected sound). The information gathered from this experiment feeds into the development of the final experimental trial documented within this thesis; a bespoke computer video game level incorporating these sounds and measuring the affective states of participants by way of psychophysiological measures to further explore which sounds are most suitable for evoking a particular emotional state during gameplay.

1.6 WEBSITE DESIGN

Two separate web experiments (referred to on the website as *online tasks*) were developed and hosted on *gameresearchers.co.uk* (site no longer live), a bespoke academic website constructed exclusively (and in its entirety) to support these tests. The design language is primarily Extensible Hypertext Markup Language (XHTML) 1.0 and Cascading Style Sheets (CSS), defining the basic structure and appearance of the web pages. PHP (version 5.3.4) scripting was employed specifically within the web experiment pages to enable collection and processing of user-inputted data between web pages, and transfer of information to a designated email account. All programming and debugging tasks were carried out using *Dreamweaver CS4* (Adobe, 2008) with additional programs enlisted to develop assets and materials. Graphical images were processed in *Photoshop CS4* (Adobe, 2008), animations developed using *Flash CS5* (Adobe, 2010), video clips developed in *Vegas Pro 9* (Sony, 2009) and audio files edited with *Cubase 5.1* (Steinberg, 2009), all of which were then imported into *Dreamweaver* before uploading onto a hosting domain.

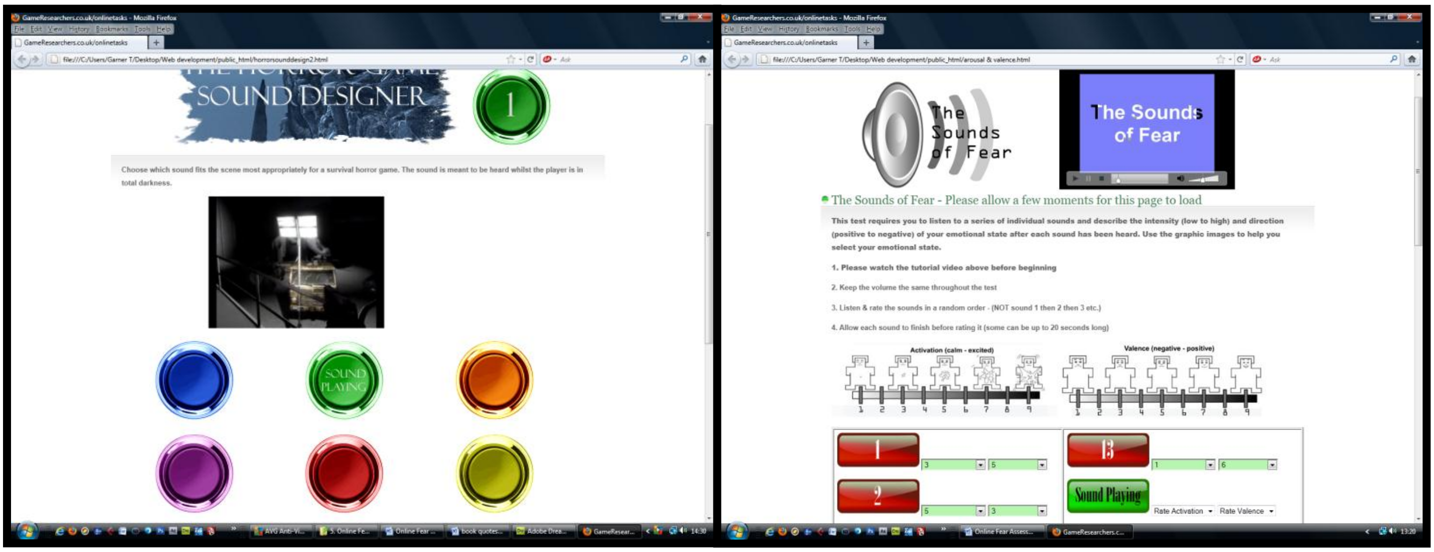
Despite existing concerns that rich web content may both exclude potential participants, and generate variation between user experiences (Buchannan & Reips, 2001), current statistical information (Millward Brown, 2011) supports the implementation of *Flash* as a highly compatible format for *iOS* (Apple), *Windows* (Microsoft) and Linux operating systems. In comparison, accessible alternative formats of audiovisual playback including *QuickTime* (.mov/.mp4), *Windows Media* (.wmv/.avi) and *RealPlayer* (.rm) were all revealed in pre-tests, to be more likely to require installation of additional software (particularly between alternative operating systems). *Gameresearchers.co.uk* heavily utilises the Flash (.flv/.swf) formats for animations, interactive buttons, audio triggers and full motion videos (FMV). In addition to providing a reliable platform, Flash allows significant control over how online media can be interacted with, enabling greater researcher control over the website environment.

Van Duyne et al. (2007: p.10) insist that website design should first and foremost reflect the needs and preferences of the user, a concept referred to as *user-centred web design*. Pertinent design specifications associated with this concept include ease of use, performance, satisfaction, and content. Van Duyne et al. differentiate this design mode from *technology-centred design* (a showcase of web technology and technical mastery) and *designer-centred design* (prioritising the aesthetic and creative image of the website); they assert that both technical and design aspects should be chiefly governed by user requirements. Walsh (2009) outlines several development points and asserts that such considerations are vital to the production of a good website. Precedence (dominance of visual material that directs the attention of the user), clear spacing, orientation, typography (font, colour, size, paragraphing), usability, alignment, clarity and consistency criteria emphasise the considerations that must be made to accommodate potential users and support the assertion that accessibility and function should be prioritised over aesthetics and technology. Responding to the above specifications, gameresearchers.co.uk adopts a contemporary, two-tone colour scheme with limited text, padding (clear space between elements) and a consistent style. Animated flash sequences are positioned to direct user attention towards the desired links and a particular emphasis is placed upon the links to the two web experiments.

1.7 THE HORROR GAME SOUND DESIGNER (HGSD)

The intention behind this online task was to place the participant in the role of sound designer for the development of a fictitious project. Various contextual circumstances were presented alongside alternative sounds (in some sections, DSP variations of the same sound; in others, entirely different sounds) and the participant was required to select the sound that they believed best supported the relevant context. The inspiration for the design of this task is largely accredited to the Participatory Audio Research Tool (PART), developed by the interactive institute, Sweden (www.tii.se). PART utilises video to depict a situation and contextualise the associated audio. Participants are required to manipulate the audio by various parameter changes and then submit the processed sound they believe would most suit the circumstances (Fagerlönn & Liljedahl, 2009; Fagerlönn, 2010). Such freedom for audio manipulation is beyond the scope of this chapter and consequently, HGSD user input is restricted to selection of a single sound from a collection as opposed to submitting customised audio.

Figure 1: Screenshots for *Horror Game Sound Designer* (left) and *Sounds of Fear* (right)



Choose which sound fits the scene most appropriately for a survival horror game. The sound is meant to be heard whilst the player is in total darkness.

The Sounds of Fear - Please allow a few moments for this page to load

This test requires you to listen to a series of individual sounds and describe the intensity (low to high) and direction (positive to negative) of your emotional state after each sound has been heard. Use the graphic images to help you select your emotional state.

1. Please watch the tutorial video above before beginning
2. Keep the volume the same throughout the test
3. Listen & rate the sounds in a random order - (NOT sound 1 then 2 then 3 etc.)
4. Allow each sound to finish before rating it (some can be up to 20 seconds long)

Within HGSD, eight individual web pages host interactive audio-visual material and request participant feedback. All sections require the participant to view a video clip to establish context, then listen to a selection of audio samples and decide which sound is most appropriate. Only one sound can be selected within each section and the participant is not required to rank the sounds but select a single sound that they deem the most suitable within the presented context. Each sound is embedded within an animated (Flash) button, responsive to the mouse. Placing the mouse over a button activates the sound (alongside a visual cue to reinforce usability) whilst leaving the button space terminates and resets the sound to remove the potential for multiple sounds overlapping, ultimately supporting accessibility. The video material can be controlled (play, pause, stop, tracking, audio mute and volume control) via a standardised control panel integrated into the video boxes. This allows the participant to activate and replay the video at their discretion, ultimately providing them ample time and flexibility to thoroughly compare and evaluate the sounds. Browsing movement throughout the task is restricted to limit variation between user experiences; browser navigation (back, forward and refresh) is disabled so users can only progress via purpose-built navigation icons embedded into the pages, five minute viewing limits are applied to each page and confirmation windows are activated if the participant closes the browser.

During the pretesting phase (documented in more detail below), respondents were asked to rate the sensitivity of several personal questions to provide an approximation of which questions were likely to increase dropout rates by raising security concerns. The results revealed that although date of birth was rated as highly sensitive, identification of age grouping (18-25, 26-30, etc.) rated low. Gender, marital status and nationality also rated low whereas income and contact information rated high. Specific information relevant to the research question (hours spent playing games per week, number of games bought in a month, preferred gaming platform, computer specification, operating system, web browser, audio hardware) all received low ratings, whilst over 90% of respondents revealed they would prefer to volunteer such information rather than have it taken without their knowledge via web technology. A username identification system, in which participants created a 7-9 digit memorable identification tag (to separate individual datasets), 3 replaced the original email request in response to the pre-test findings. Following from the eight sections within HGSD a final debrief page is presented that requests additional information. In response to pre-test information, this page requests user age group, gender and nationality, number of hours spent playing games per week (0, 1-5, 6-10, 11-15, 16-20, 21+) and sound hardware used during testing (stereo speakers, stereo headphones, surround compatible speakers, surround headphones). Javascript processes and IP address logs are not used at any point within *gameresearchers.co.uk*.

1.8 THE SOUNDS OF FEAR (SOF)

In contrast to the Horror Game Sound Designer, SOF utilises the Self-assessment mannequin (SAM), a scale system that relates quantitative measurements to emotional experience by way of graphical representations (Bradley & Lang, 1994). Although the original SAM scale utilises a three-dimensional model (activation, valence and dominance), it is the former two measurements that are employed within this online task. This is because the information retrieved from SOF would ultimately serve the development of an electromyography-related emotion measurement framework which characteristically exists within a two dimensional model of activation and valence (Ravaja et al., 2004; Russell, 1980). Subsequently, users were required to rate each of the 24 sounds (12 sources, each in treated and untreated incarnations) for both intensity (measured on an ordinal scale from 1 [low] to 9 [high]) and valence (same ordinal scale, 1 = highly negative, 5 = no clear valence, 9 = highly positive).

With the exception of a debrief questionnaire (identical in both form and content to that which is utilised in HGSD) that is presented after the main task, *The Sounds of Fear* web experiment is contained within a single HTML page to facilitate accessibility and allow participants to observe the test environment whilst simultaneously viewing the tutorial video. The SOF page hosts twenty four individual audio files, embedded within interactive flash buttons that activate the sound when the mouse is positioned over the button and reset the sound if the mouse leaves the button proximity (much the same way as in HGSD). Adjacent to each sound button are two dropdown menus requiring a numerical (1-9) selection relative to both activation and valence. *Spry* Validation tools (established in *Dreamweaver*) ensure that all required fields are completed before information can be submitted, presenting a warning to the participant if a section is incomplete. Copies of the SAM activation and valence image are presented both above and below the sound buttons, allowing participants to easily refer to the scale whilst listening to the audio. Limited browser controls and the username identification procedure employed within HGSD are also present in SOF.

1.9 SOUND DESIGN

The audio samples embedded within both online tasks were sourced from pre-existing game titles: *Half-life 2* (Valve, 2004), *Doom 3* (ID Software, 2004), and *Amnesia –The Dark Descent* (Frictional Games, 2010). Prior to uploading, all sound files were treated using *Cubase 5.1* (Steinberg), a digital audio workstation software title hosting various third-party plugins to support audio editing. All sounds were compressed via Cubase into CD quality, MP3 format (256kbps, 16 bit resolution, 44.1 kHz) stereo samples averaging around 500 kilobytes of required disk space per minute of audio by way of a 5:1 compression ratio. Figures 2 and 3 document all sounds embedded within both task webpages; outlining the audio variations, parameter settings and processing details.

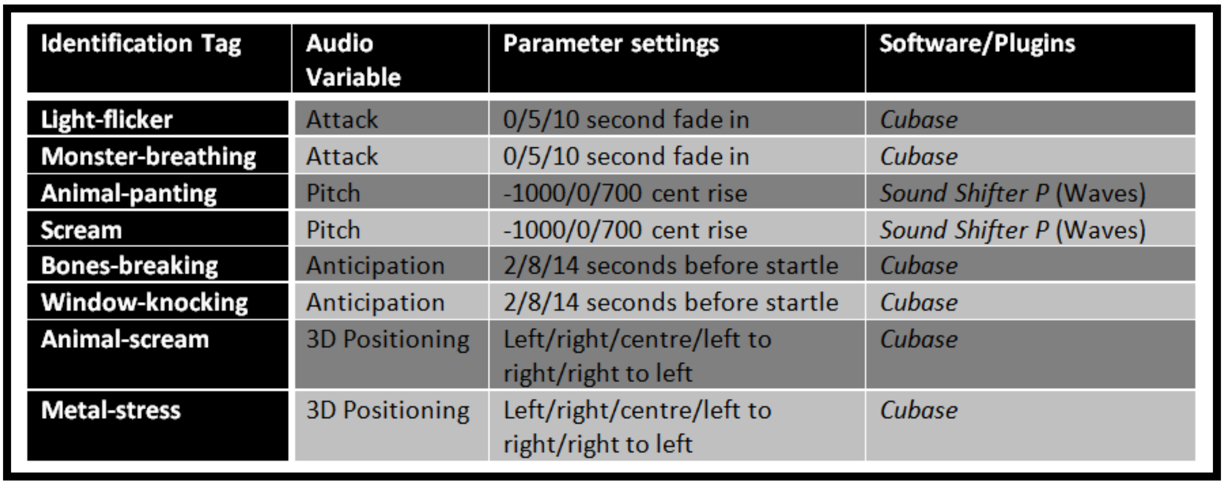
The *Sounds of Fear* assessed the affective participant responses to variations in six preselected sound parameters: 3D positioning, anticipation period, attack, loudness, pitch and sharpness. Each of the six sound variations were tested twice (to support the assertion that a particular processing effect would alter emotional response in the same way, irrespective of the source sound) and both a treated and untreated version was presented, generating a total of twenty four sounds. 3D positioning is also referred to as localisation; a psychoacoustic perception of the location of an audio source, gained from both acoustic and environmentally sourced information (Grimshaw, 2009). Both the ease of identifying a source and the positioning/movement of a sound have been associated with manipulation of the fear response (Ekman & Kajastila, 2009; Bach et al., 2009). 3D positioning of audio samples was achieved using a 5.1 surround processor within Cubase. Untreated audio variations were equally balanced across all channels to centralise the location, whilst the treated variation manipulated the surround output to simulate movement. In one instance the sound was panned from front-right to rear-left and in the other, from rear-left to front right (ensuring that the effect would be almost identical between surround and stereo outputs). Attack refers to the difference (in time) between the onset of a sound and the initial intensity peak. Research relating to this parameter suggests that short attack periods (sudden, immediately intense) potentiate greater startle responses that are likely to be interpreted as frightening events. In contrast, long attack periods slowly introduce a sound to the listener thereby greatly reducing startle potential (Parker & Heerema, 2007). Horror-themed sounds with an attack of less than 100ms were selected as untreated audio variations and a volume envelope within Cubase was employed to overlay a fade-in effect, effectively increasing the attack value.

Anticipation period refers to the temporal distance between the onset of an emotional priming cue and a stimulus. For the purposes of the SOF task, both cues are presented within a single audio sample, commencing with a priming sound of predetermined length immediately followed by a startle cue. Relevant research has revealed that such *pre-startle* stimuli have considerable potential to augment a subsequent startle probe (Bradley et al., 2005) by raising our alert level and preparing us for immediate and direct response behaviour (Smith, 1999). Preliminary testing of various priming sounds supported the selection of two comparatively different ambient sounds (a high-pitched, continuous alarm and a reverberated water drip), both of which could be looped to create samples of any required length. Cubase was used to loop and blend the audio priming samples, generating two variations (one a 5 second prime, the other a 20 second prime) for both sounds.

As previously referred to in chapter 3, Parker and Heerema (2007) suggest that evolutionary development may have instilled instinctive fear responses to extreme pitches. Low frequency audio may encourage a fear response by way of association with predator growling, whilst comparatively, high-frequency sounds may evoke the same response by way of instinctive connotations to human screams. The *Sound Shifter P* plugin (Waves) manipulated the pitch of the treated audio samples, creating the most achievable difference between treated and untreated variations without significantly distorting the sample. Research by Cho et al. (2001) revealed that increased loudness and sharpness (higher frequency and purer tone) both have the potential to produce discomfort and negative affect for the listener. This concept has not yet been directly related to the emotional experience of fear. However, it is possible that within a horror context, an increasing discomfort induced by audio could potentially be perceived by the listener as a more catalytic emotional induction. A simple digital signal boost within the Cubase native mixer was implemented to increase the decibel level enough to create a significant difference, without distorting the sample or generating a volume level that would be highly uncomfortable for the listener. The *Q10* parametric equaliser plugin (Waves) was used within Cubase to boost a high frequency channel (2 kHz) whilst attenuating the overall volume to emphasise the tonal sharpness whilst ensuring that loudness could not be a simultaneously contributing factor.

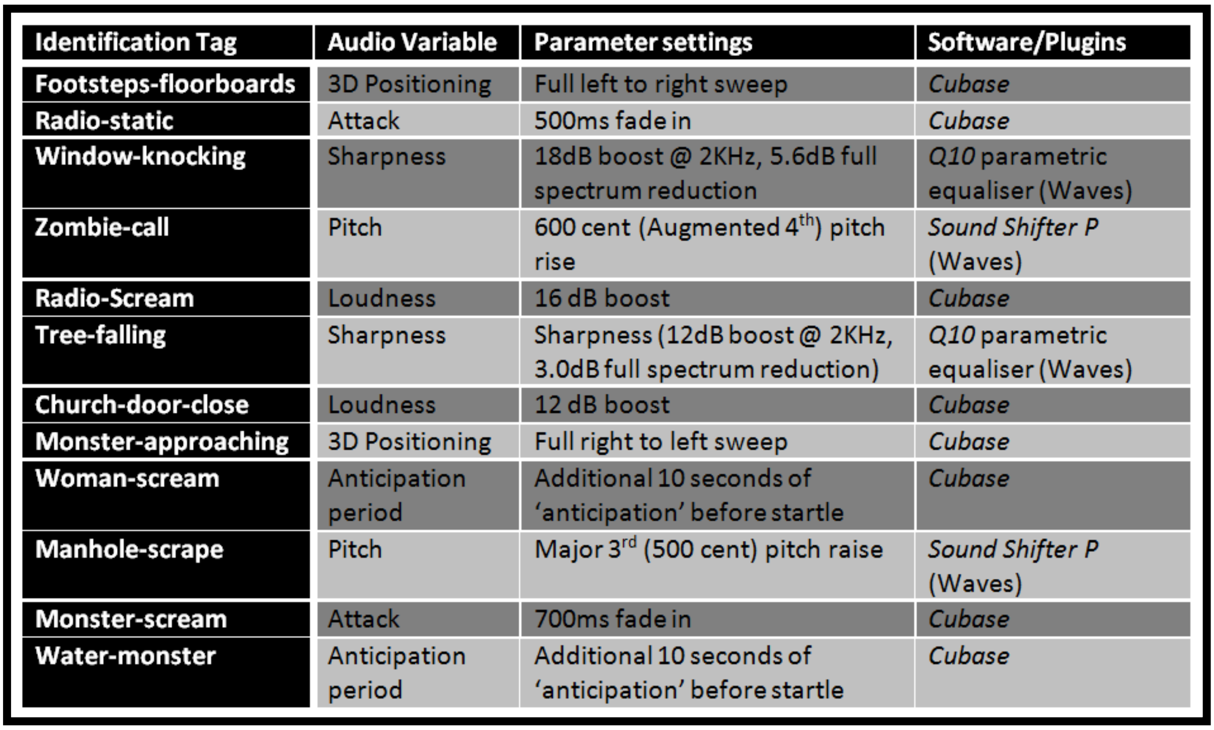
Audio treatment in the *Horror Game Sound Designer* incorporates greater numbers of variations per audio parameter; between three and five in comparison to the two variations presented in SOF. Increasing the number of variations per parameter enabled greater detail in the assessment at the potential risk of generating alternative sounds that participants would be unable to differentiate between. The digital processing of sounds was accomplished using the same equipment and techniques as the sounds utilised for the SOF task.

Figure 2: Audio variations presented in the Horror Game Sound Designer task



Identification Tag	Audio Variable	Parameter settings	Software/Plugins
Light-flicker	Attack	0/5/10 second fade in	*Cubase*
Monster-breathing	Attack	0/5/10 second fade in	*Cubase*
Animal-panting	Pitch	-1000/0/700 cent rise	*Sound Shifter P* (Waves)
Scream	Pitch	-1000/0/700 cent rise	*Sound Shifter P* (Waves)
Bones-breaking	Anticipation	2/8/14 seconds before startle	*Cubase*
Window-knocking	Anticipation	2/8/14 seconds before startle	*Cubase*
Animal-scream	3D Positioning	Left/right/centre/left to right/right to left	*Cubase*
Metal-stress	3D Positioning	Left/right/centre/left to right/right to left	*Cubase*

Figure 3: Outline of audio variations assessed in the Sounds of Fear task



Identification Tag	Audio Variable	Parameter settings	Software/Plugins
Footsteps-floorboards	3D Positioning	Full left to right sweep	*Cubase*
Radio-static	Attack	500ms fade in	*Cubase*
Window-knocking	Sharpness	18dB boost @ 2KHz, 5.6dB full spectrum reduction	*Q10* parametric equaliser (Waves)
Zombie-call	Pitch	600 cent (Augmented 4th) pitch rise	*Sound Shifter P* (Waves)
Radio-Scream	Loudness	16 dB boost	*Cubase*
Tree-falling	Sharpness	Sharpness (12dB boost @ 2KHz, 3.0dB full spectrum reduction)	*Q10* parametric equaliser (Waves)
Church-door-close	Loudness	12 dB boost	*Cubase*
Monster-approaching	3D Positioning	Full right to left sweep	*Cubase*
Woman-scream	Anticipation period	Additional 10 seconds of 'anticipation' before startle	*Cubase*
Manhole-scrape	Pitch	Major 3rd (500 cent) pitch raise	*Sound Shifter P* (Waves)
Monster-scream	Attack	700ms fade in	*Cubase*
Water-monster	Anticipation period	Additional 10 seconds of 'anticipation' before startle	*Cubase*

1.10 PRETESTING AND PARTICIPANT RECRUITMENT

In addition to gathering qualitative data regarding potential participants' opinions of privacy and identity issues, both the online tasks and hosting website were rigorously assessed for compatibility, speed, accessibility, navigation and aesthetic quality. All pages within *gameresearchers.co.uk* were tested for variances across several operating systems, connection types/speeds and web browsers. The configurations that produced no noticeable variation in comparison to the offline version were detailed on the website and participants were asked to only continue if their system was compatible. Both the PHP scripting (employed to transmit data from the site to a designated email address) and Flash content proved compatible with no significant performance variation across all pre-test computers. Provided the internet connection was broadband, specific types including cable, Asymmetric Digital Subscriber Line (ADSL), Symmetric Digital Subscriber Line (SDSL) and Local Loop Unbundling (LLU) revealed no noticeable differences in performance or compatibility (this includes both wired and network variations). Interaction with the online tasks whilst other internet activities were occurring via the same connection did however diminish the browser speed of both experiments and consequently, participants were requested to close all other internet functions (including other users accessing the same connection from another location) during completion of the test. Sample sizes varied between HGSD (N = 38, male = 25, female = 13) and SOF (N = 28, male = 16, female = 12) despite multiple requests within the website for participants to complete both tests.

1.11 OFFLINE TESTING

In recognition of the importance of cross-validating results using alternative research modalities (Cho & LaRose, 1999), an offline version of the entire website was constructed. Every aspect of this version was identical to the online website and with the single exception that submitted participant data was transferred directly to a log file rather than an email account. Participants (N=6, 1 female and 5 male – completed both experiments) were all students from a college in North West England who met the same filtration criteria as that set in the online experiment. Participants navigated the site and completed the tasks using an *Apple MacBook* (2.4 GHz Intel Core 2 Duo processor, 2 GB RAM) running at 1280x800 visual resolution and *Triton AX pro* 7.1 surround headphones. The test environment consisted of an indistinct, small classroom space (low artificial light and only an internal observation window) containing a single desk and chair. Participants were given two minutes to navigate around the website with a researcher available to address any concerns. The researcher remained present during the tutorial video, and each participant was asked if they had any further questions before providing written consent and beginning the experiments (during which the researcher left the room, returning between tests and for the debrief). The completion time for setup, both tasks and debrief averaged 10 minutes 26 seconds (mean).

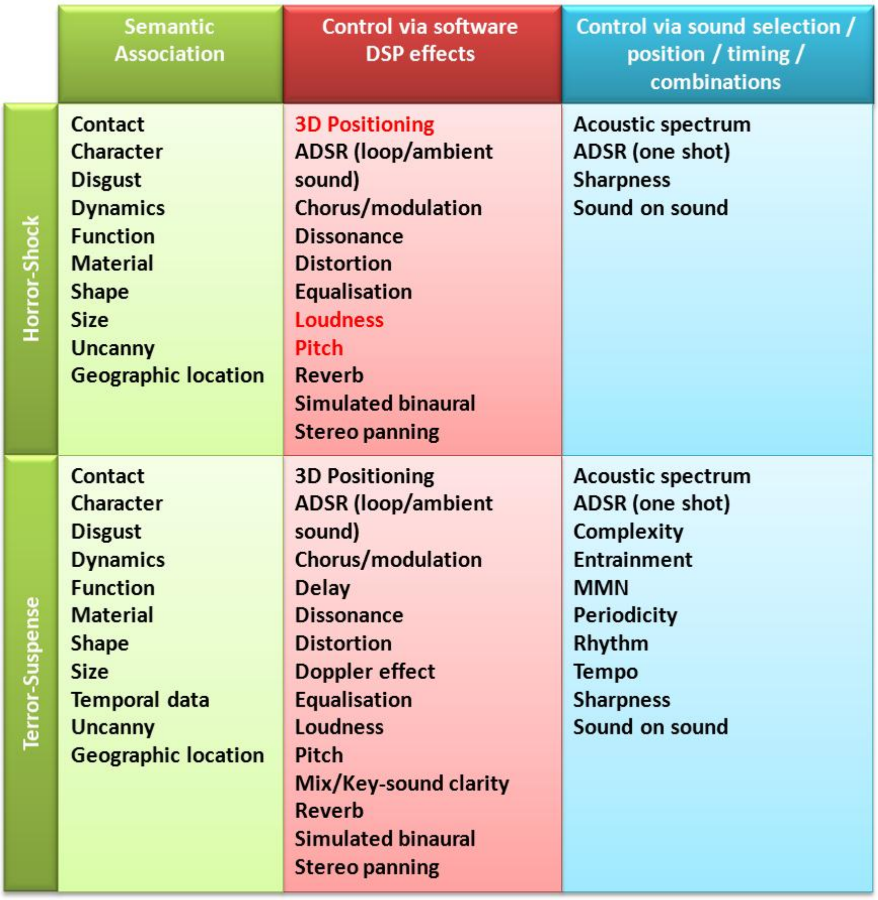
EXPERIMENT 2:
2.1 REAL TIME VALUE OF PRESELECTED SOUND PARAMETERS DURING GAMEPLAY

Although revealing significant difference in qualitative affect between DSP audio treatment groups in a controlled, audio-only, environment does provide invaluable evidence relevant to the thesis, it must be acknowledged that the results documented within the previous section cannot be automatically applied to a computer video game context. Within such circumstances an array of additional complex stimuli are presented to the player alongside additional goals and motivations. The presented sounds when experienced during gameplay are susceptible to various contextualising elements, from synchresis with visual information to a player motivation to impress the researcher. Bearing this in mind, the following sections document the second of three preliminary trials, an assessment of players' subjective self-report of fear intensity in response to varied audio treatment groups (specifically pitch, loudness and localisation) within an interactive gameplay environment. The initial hypothesis For Experiment 2 reflects that of Experiment 1, asserting that a significant difference will be observable between DSP treated sound and control groups. In addition, it is expected that the real-time qualitative responses will not significantly interrupt gameplay and will correlate with players' post-gameplay analysis of their emotional state.

2.1 PRELIMINARY TESTING

Table 1 represents a range of sound properties and effects organized according to their objective/subjective parameters, their potential (based on the literature review) for inducing different types of fear and the ability for a game procedural audio engine to manipulate. Several preliminary trials were conducted using the same game level and selection of sounds used for the experiment described below. These preliminary trials utilized the same procedure that is outlined in section 1.5 below and similar equipment was used, but data was collected entirely using debrief self-report. In these trials, participants were asked to complete a modified version of the questionnaire that was to be used in the main experiment. 20 individuals participated and 3D positioning, distortion, chorus/modulation, equalization, loudness, reverberation, stereo panning, ADSR, dissonance, and pitch were selected as treatments. Each treatment was applied to a separate sound and players compared the original to the treatment once in each trial. Mean participant results revealed, 3D positioning (particularly sound coming from a sharp left or right), pitch (particularly high pitched sound) and loudness (specifically greater relative loudness) to be notably effective in increasing participants' perceived intensity ratings. These three treatments were consequently selected for the experiment and are shown in red in figure 1.

Figure 1: Potential affective properties of sound with those currently under investigation highlighted in red



	Semantic Association	Control via software DSP effects	Control via sound selection / position / timing / combinations
Horror-Shock	Contact Character Disgust Dynamics Function Material Shape Size Uncanny Geographic location	3D Positioning ADSR (loop/ambient sound) Chorus/modulation Dissonance Distortion Equalisation Loudness Pitch Reverb Simulated binaural Stereo panning	Acoustic spectrum ADSR (one shot) Sharpness Sound on sound
Terror-Suspense	Contact Character Disgust Dynamics Function Material Shape Size Temporal data Uncanny Geographic location	3D Positioning ADSR (loop/ambient sound) Chorus/modulation Delay Dissonance Distortion Doppler effect Equalisation Loudness Pitch Mix/Key-sound clarity Reverb Simulated binaural Stereo panning	Acoustic spectrum ADSR (one shot) Complexity Entrainment MMN Periodicity Rhythm Tempo Sharpness Sound on sound

2.2 PREPARATION OF SOUNDS

The 5 sounds utilized in the experiment were all taken from the Source engine originally created for *Half-Life 2* (Valve, 2004). In its untreated state, each sound is presented as a single monophonic channel. In addition to the 5 test sounds, avatar footstep and vegetation rustling sounds can also be heard during gameplay.

2.3 GAME LEVEL DESIGN

A bespoke game level was judged to be the most appropriate choice of presentation medium for the sounds. Because the specific interest of this research is to develop the audio within a survival horror computer game, contextualization is therefore the key to producing results with ecological validity. Whilst this method could allow several non-sonic variables (particularly audio/visual synchresis and gameplay-related emotional experience) to impact upon the results, it should be acknowledged that any correlation/data patterns drawn from this experimentation must be observed within the context of a computer video game as this is the only environment in which the research aims to apply gained knowledge.

Figure 2: Overhead view of test level

The custom level was built using the unmodified *CryEngine 2* (Crytek, 2007) game engine and sandbox level editor. Although the game engine supports third-person and first-person perspective play, research suggests that a first-person display can increase the sense of urgency and immersion (Calleja, 2007). The avatar is not completely absent however, and (in traditional first-person shooter (FPS) style) visible forearms, hands and a pistol are outstretched into the virtual world. The level was non-linear with no suggested direction and could be completed by reaching one of three evacuation points. To achieve the desired aesthetic and encourage any negative player valence to be fear-related, certain survival horror conventions were utilized, including a night-time setting and a dense forest environment. Near-zero visibility without the aid of a flashlight restricts the field of vision (Perron, 2004), creating large volumes of 'blind space' (Bonitza, 1982). In keeping with not only survival horror convention but also traditional FPS formats, the player was pursued during the level by an unknown creature which facilitates the *hunter and hunted* principle (Grimshaw & Schott, 2008). This creature was, however, only implied through the narrative in the level introduction and the sounds heard during gameplay.

Control layout was addressed to support gameplay accessibility and increase the chance of participants using tacit knowledge to control their avatar and keeping their focus more explicitly on the sound, graphics and atmosphere (Cunningham, Grout & Hebblewhite, 2006). The default controls followed the standard setup found on most FPS games and the participant was given the opportunity to customize the controls before playing. The audio for the level differs depending on the level type. Type 1 used untreated audio whilst types 2, 3 and 4 used treated audio (pitch shift, 3D and loudness respectively). All level types housed the same group of 5 source sounds (a distant zombie call, a nearby twig snap, a woman's scream, a monster's attack scream and a sudden distorted monster scream) activated by a series of proximity triggers built in concentric circles. Regardless of gameplay, a minimum of 5 seconds of silence was guaranteed between sounds. All sound points were fixed and always produced the same sound (not accounting for treatment variations). All sounds within a specified type were treated with equal parameter settings of the same DSP process). This treatment was one of the following: 3D (Binaural processing placing the sound to the right side of the player), loudness (an intensity increase of 25dB), or pitch (300 cents rise in pitch compared to the untreated sound). Given that this is a preliminary experiment to assess which factors, easily processed by a game audio engine, might be most emotive in the survival horror game context, such differences were designed to be noticed without being too obvious – the fine-tuning is for later experiments.

2.4 ENVIRONMENT AND GAME EQUIPMENT

The game level ran on a bespoke 32-bit PC with *Windows Vista* (Service Pack 2) operating system, *AMD Phenom 2* (3.2GHz) quad core processor, 8GB RAM, *ATI Radeon* 4850 (1.5GB) GPU. At time of writing, this is a mid-level gaming specification PC able to run most new release games at medium/high settings. The PC monitor was a *LG*, 22” LCD screen, supporting the game level’s 1920x1080 (full HD) graphics resolution. This configuration was designed to resemble a typical consumer home setup that was powerful enough to run a game representative of current gaming technology, whilst avoiding an elite specification that would be likely to exclude the majority of the casual gaming community. The testing was executed in a small studio space, providing natural light and a glass partition window through which participants could be observed without disruption.

The sound was processed and reproduced via an *Asus Xonar* 7.1 sound card and *Tritton AX Pro* 7.1 headphones. It has been suggested that the choice of headphones or speakers could be a significant contextual variable (Cox, 2008) particularly in terms of localization and immersion (Grimshaw, 2007) and impact. In a comparable study, Murphy and Pitt (2001) show a preference towards headphone use, arguing that it ‘enables the designer to incorporate more complex sound objects whose subtleties will not be lost due to background noise, speaker cross-talk, etc.’. The nature of headphones (namely speakers very close to the ear, attenuating background noise and limiting acoustic effects that may distort/alter the sound between the speaker and the ear) suggests that they are more likely to produce a more immersive experience, and the commercial availability of a range of headphones (many specifically designed for computer video games) suggests that headphone use is common within a player’s typical environment.

2.5 PARTICIPANTS

Similar experiments in related fields of study reveal a large range of participant numbers, with smaller numbers ranging from 15-25 and larger numbers reaching 100. Although practical constraints for this experiment set the participant number at 12, a number of relevant published experiments reveal that statistical significance is possible with relatively small participant numbers (Moffat & Kiegler, 2006; Nacke & Lindley, 2008; Ullsperger et al.,2007). The 12 participants each experienced a different order of the 4 level variations (untreated audio, pitch shift, 3D surround and loudness increase). This structure was implemented to reduce order effects which have been identified as a further possible cause of bias (Nacke & Lindley, 2008). All participants were students or recent university graduates aged between 18 and 55, 9 male and 3 female. Participants were asked for their gender, age, ethnic background and game playing proficiency. Each participant was also required to complete an ethics form that informed them of the horror themes of the game and also asked them to document any visual or hearing impairment and sign a disclaimer stating that they consented to the information they would provide being used for the purposes of the experiment. No sensitive personal information was collected.

2.6 PROCEDURE

Before playing, each participant was given a brief detailing the exact procedure, along with game instructions and control information. Participants were aware that they needed to rate the emotional impact of a sound, but not that fear (or negative valence) was under investigation. Participants were required to provide their own single word descriptors to illustrate the emotion they perceived, thereby not biasing subjective response towards fear. The game level took between 50 and 140 seconds to complete and each participant played 3 variations which, including the brief and debrief time, set the total typical completion time at 10 minutes for 1 audio property. Testing four separate treatments in a single sitting would take approximately 55 minutes (allowing 5 minute breaks between each treatment test). The debriefing questionnaire required immediate response after each play-through, followed by a more detailed set of questions to be answered after the last level was completed.

2.7 DATA COLLECTION

Moffat and Kiegler (2006) argue that, although 'physiological measurements […] can be valuable in helping to read the emotional state of game players', the links between emotion and physiological response are currently unreliable and psychophysiological data collection alone cannot provide a complete account of a participant's emotional state. An overview of psychophysiology suggests that quantitative response measurement (heart-rate, galvanic skin response, electromyography, etc.) is capable of providing accurate emotional valence and intensity data (Cacioppo, Tassinary & Bernston, 2000), but cannot distinguish between different emotional states of the same valence. Research has attempted to counter this problem via near-simultaneous collection and correlation of objective physiological response and subjective player responses (Bach et al., 2009; Grimshaw, Lindley & Nacke, 2008).

Cacioppo, Tassinary and Bernston (2000) admit that 'specific types of measurement of different physiological responses…are not by themselves reliable indicators of well-characterized feelings', suggesting that empirical data must be cross-examined alongside additional data sources. To provide supporting data, direct participant opinions were collected using a real-time vocal response system. A software-based digital audio workstation (Pro Tools LE 8) synchronized to the game engine recorded participants' vocalized input via the integrated headset microphone whilst they played the game. The initial participant mandate requests that the player rates the 'emotional impact' of each sound heard using a specified scale and then communicates that score vocally. During gameplay (all types) a visual prompt [1-2-3-4-5] appeared on the screen for 2 seconds immediately after a key-sound was triggered. The headphone setup (section 2.4) recorded the vocal responses via a microphone integrated into the headset. Audio data was recorded as a separate channel and synchronized to a video recording of the in-game performance. The exact time of the vocal response was recorded as text data in the game event log. The rationale for this approach comes from two concepts: memory and flow. Rugg and Petre (2007) argue that a participant's explicit knowledge regarding information they have recently received is stored in short-term memory (STM), requiring rehearsal or meaningful association to migrate towards long-term memory (LTM). Whilst it may be a fair assumption that an intense emotional response could facilitate such a memory translation there are no guarantees, and the possibility that participants could forget a number of the sounds by the end of the level presents a genuine risk. Conversely, requesting that the participant break from the game to respond immediately to each stimulus severely diminishes the potential for flow. Flow is central to attention and, consequently, a break in flow negates immersion (Brown & Cairns, 2004; Csikszentmihalyi, 1990).

Because the intention is to evaluate sounds' emotive potential within a game environment it is vital, in order to achieve contextual validity, that the player feels that they are playing a game. Real-time vocalization is an attempt to find a middle-ground between the two extremes. The number of audio samples used obeys *Miller's law* (Miller, 1956) and subjects were asked to rate each sound using a 5 point scale (1=least emotive, 5=most emotive), in keeping with recommendations suggested by recent research (Gillham, 2000) and experimentation (Steele & Chon, 2007): subjects spoke or shouted the appropriate number while playing in response to the visual prompt [1-2-3-4-5]. Freeze, fight and flight are response actions associated with fear-inducing stimuli (Bracha, 2004). Perron (2005) argues that such response actions can be applied to the experience of fear in a computer video game. Reversing this, an analysis of player action and performance might reveal insight into their emotional state. Case and Wolfson (2000) suggest that emotional arousal can greatly impact upon performance: '[W]hen highly aroused, people tend to be faster but less accurate, and they focus mainly on the most salient aspects of a task'. Currently there is no existing framework correlating player performance and fear-related arousal; a broad analysis of performance may help further support the other data (user-input, psychophysiological response) and provide a launching pad for further study within this specific area. To this purpose, *Fraps* (v.3.2, 2010) real-time video capture software was implemented to provide a complete visual recording of each participant's actions within the game.

The debrief questionnaire requested only explicit knowledge from participants and was in 3 sections. Section A required participants to provide individual words that they felt reflected the atmosphere of the game and the emotional content of the sounds and then to rate the perceived 'scariness' and difficulty of the level overall using 5 point ordinal scales. This section was answered immediately after the player had completed each game level and was repeated for each play through. Section B requested each participant to rank the 3 levels in order of perceived 'scariness' and provide quality control information regarding sense of immersion, flow and general game experience using the same 5 point scale system. Section C asked the participants to state how often they played computer video games and if they suffered from any visual or hearing impairment. They were also asked their age, gender, nationality and country of origin. Subjects' participation and the data collection were conducted in accordance to Aalborg University's Research Ethics Framework.

EXPERIMENT 3:
REAL TIME BIOMETRIC FEAR ASSESSMENT OF GAME SOUND

The preliminary experimentation documented within this section takes influence from the previous biometrics discussion and advances upon results and conclusions obtained from the previous two trials. Electrodermal activity (EDA) and electromyography (EMG) signal data is collected from two groups of participants; both playing a bespoke game level. The design of both the control (group A) and test game (group B) levels is identical with the exception of DSP sound treatments that overlay particular sound events in the test group. Acoustic treatments (pitch shift, sharpness, tempo, distortion, attack time, localisation and signal to noise ratio) are then compared to control datasets in a search for significant difference in arousal, corrugator supercilii activity and qualitative post-play feedback. It is hypothesised that both EDA and EMG measures will reveal significantly different datasets between groups. It is also expected that the physiological data will reflect subjective responses presented by participants in the debrief.

3.1 BESPOKE GAME DESIGN

To enable effective comparison of the desired audio variables (outlined in section 1.2), a bespoke first-person perspective game level was developed, entitled *The Carrier*. This game places the player in the dark bowels of a sinking ship, with a race against time to reach the surface. The presence of a dangerous creature is alluded to via scripted animation sequences within the gameplay, and the intention is for the player to feel that they are being hunted. The level was produced primarily using the CryEngine 2 sandbox editor (CryTek, 2007) and all in-game graphical objects, characters and particle effects are taken from the associated game, *Crysis*. The game level designs follow a sequence of prescribed events designed to subtly manipulate the player’s actions. Plausible physical barriers, disabling of the *run* and *jump* functions and a logical progression of game scenes restricts the player to following a more uniform direction and pacing. These constraints are complemented by the reduced visibility settings, which provide plausibly restricted vision and movement to encourage (rather than force) players to follow the desired linear path. Graphical elements orientate and direct the player and invisible walls are utilised where (absolutely) necessary to avoid players straying or accidentally becoming locked between objects. Ambient atmospheres and sound events of indeterminate diegetic status, positioned in the darkness further the perception of a larger, open world to add some credibility and realism to the game environment, despite its notably linear design.

As the player progresses through the game level they are subjected to several, crafted in-game events utilising sound as the primary tool for evoking fear. During these events, user control is sometimes manipulated to ensure that player focus can be directed appropriately (this takes the form of forcing the player-view towards an event and then freezing the controls for a short time). The decision to use this technique is arguably a point of contention between first-person shooter titles. For example, *Half-life 2* (Valve, 2004) was recognised for never manipulating the player's perspective during single events, whilst *Doom 3* (ID Software, 2004) takes full control, manipulating the camera angle to create a cut-scene effect. The former title prioritises flow and consistent diegetic narrative at the risk of the player missing parts of (or even the entire) event, whilst the latter places a precedence upon accentuating the scene and creating a filmic style with the possibility of reducing gameplay-cohesion and immersion. Other games attempt to present a compromise, such as in Crysis 2 (Crytek, 2011) where the player is presented with an icon that indicates a significant event is occurring (nearby building collapsing, alien ship passing overhead) and if the player selects that option their viewing perspective is automatically manipulated to best observe the event. The custom game level built for this experiment therefore is intended as a compromise, ensuring that the player will fully observe the stimuli whilst minimising the disruption to flow. The manipulations themselves are relatively subtle, and occur only three times within the game.

The opening scene of the level presents the premise and endeavours to create an initial sense of familiarity and security via recognisable architecture and everyday props. This atmosphere is juxtaposed against a dark and solitary environment to create a sense of unease from within the familiar. Subsequent scenes utilise conventional survival horror environments whilst implied supernatural elements and scenarios also draw heavily from archetypal horror themes. First-person perspective is retained but the customary FPS heads-up display and weapon wielding is omitted, giving the player no indication of avatar health or damage resistance, and also removing the traditional ordnance that increases player coping ability and diminishes vulnerability-related fears. The avatar has no explicit appearance, character or gender and is anchored into the gameplay via physics-generated audio (footsteps, rustling of vegetation, interactions with objects, etc.) and the avatar's shadow. The player is required to navigate the level and complete basic puzzles to succeed. Unbeknownst to the player, their avatar cannot be killed or suffer damage to ensure that load/save elements are unnecessary and that no player will repeat any section of gameplay, thus further unifying the collective experiences of all participants.

3.2 SOUND DESIGN

The Cryengine2 (Crytek, 2007) integrates the FMOD (Firelight Technologies, 2007) game audio management tool and consequently provides advanced audio development tools including occlusion simulation, volume control, three-dimensional sound positioning and physically based reverb generation. These features allow custom sounds to be easily incorporated into the game and controlled without the need for third-party DSP plugins or resource costly audio databases. Unfortunately, the engine has understandable limitations and processing modalities such as attack envelopes and pitch shifting cannot be achieved with the same level of precision as could be achieved with a professional digital audio workstation. To this end, the custom sounds were pre-treated and separate sound files were generated for both variations of each key sound. For the purpose of this experiment, the 7 modalities (attack [AT], distortion [DN], localisation [LN], pitch [PT], sharpness [SH], signal to noise ratio [SNR] and, tempo [TP]) generated 12 key sounds (two sounds for each modality – to support the argument that if a DSP effect were to generate a significant difference, this would be observable when tested on two different sounds). Due to time limitations and gameplay restraints, SNR and TP parameters could only be tested once per game type. Two variations of each sound were developed (group A the control and group B the treatment) as contrasting extremes of each modality, producing a total database of 24 audio files per game. Figure 1 outlines the use of audio employed throughout both test levels.

Figure 1: Custom Audio Databases, Variables and Parameter Details

Sound Name	DSP modality	Control (group A)	Variant (group B)
Diegetic Music	Distortion	No additional DSP	Frequency distortion
Ship Voice	Distortion	No additional DSP	Frequency distortion
Heavy Breath	Localisation	Centralised	Left to right sweep
Monster Scream	Localisation	Centralised	Full left pan
Woman Screams	Pitch	No additional DSP	300 cent pitch raise
Ship Groans	Pitch	No additional DSP	500 cent pitch drop
Man Screaming	Sharpness	No additional DSP	12 dB gain @ 1.7kHz with 1 octave of bandwidth (7.0 dB gain reduction)
Man Weeping	Sharpness	No additional DSP	12 dB gain @ 5kHz with 1 octave of bandwidth (4.0 dB gain reduction)
Chamber banging	Attack	2 second linear fade-in	0 second attack
Monster Growl	Attack	1 second linear fade-in	0 second attack
Bulkhead Slams	Tempo	20 BPM	30 BPM
Engine Noise	Signal to noise ratio	No noise present	Noise present

3.3 PILOT STUDY

In preparation for the main trial, participants (n=8) played through a beta version of the test game whilst connected to EMG and EDA hardware. Following the trial, each participant was debriefed and asked to disclose their opinions regarding gameplay and biometric hardware experience. Recurring feedback from the players included orientation difficulty due to over-contrast and low brightness of graphics, difficulty in solving the puzzles and absence of player damage/death resulting in lack of a convincing threat. Preliminary testing aided calibration of standard decibel levels and several participants revealed difficulties operating the control interface, notably coordination of the mouse (look) and keyboard (movement) functions. In response, the final version: operated using a simplified keyboard-only WSAD (basic movement controls: forward, backward, left strafe and right strafe respectively) control layout (the space bar was the only other control button, used to interact with objects), reduced the colour saturation and increased overall brightness. There remained no player death due to the significant variation in completion time it would cause in addition to requiring players to revisit sections of the level. Puzzles were simplified and steps were taken to increase usability during these sections, clarifying the correct route/action via clearer signposting. Pilot-test biometric data revealed spikes in both EMG and EDA measures immediately after application of the sensors and following being told that the test had started.

3.4 TESTING ENVIRONMENT AND EQUIPMENT

The game level ran on a bespoke 64-bit PC with *Windows Vista Home Premium* (Service Pack 2) operating system, *AMD Phenom 2 X4 955* (3.2GHz) quad core processor, 8GB RAM, ATI *Radeon* 4850 (1.5GB) GPU. At time of writing, this is a mid/high level gaming specification PC able to run most new release games at high settings. Peripheral specification includes *LG* 22” LCD Monitor (supporting 1920x1080 output resolution), *Microsoft Wireless Desktop 3000* mouse and keyboard, *Asus Xonar* 7.1 sound card and *Triton AX Pro* 7.1 headphones. During the pilot tests, facial expression was collected using a *Technet USB* webcam and *Camtasia Studio 7*, which enabled the recording of in-game activity with facial observations presented as picture-in-picture. However, it was revealed that running this system in tandem with the game and biometric acquisition software severely reduced the frame rate of the video recording. As a result the webcam element was removed and *Fraps* (Beepa, 2007) was employed as a lighter consumer of processing resources. Biometric data was collected using a *Biopac MP30* data acquisition unit and *Biopac Student Lab Pro v3.7* interface software. Experimentation was carried out in a small studio space, providing only artificial light and attenuation of outside environment noise.

3.5 PARTICIPANTS, PROCEDURE AND ETHICS

10 participants (9 Male and 1 Female) were recruited for this experiment, none of whom was involved in the preliminary testing. All were volunteers; undergraduate students studying information technology or audio engineering and were aged between 18 and 27. All participants rated their prior experience and gaming confidence as moderate or high and stated familiarity with FPS type games and PC standard gaming controls. Participants were in the majority British but also present were one Portuguese and one French individual (both of whom were fluent in English). Experience in survival-horror games revealed some variation however, with self-report ratings ranging from 1 to 10 (1-10 scale) with a mean score of 4.7.

Participants were informed that the research aim was to explore the emotional potential of sound within a computer video game context. Each individual was also made aware of strobe lighting, visual images that may be perceived as frightening or upsetting and the full biometric data collection procedure. Participants were asked to sign a disclaimer stating they were willing to continue, were handed an instruction card outlining the game controls and were supervised as the data collection and peripheral equipment was setup. The supervising researcher ensured that each participant was ready and that a satisfactory EMG/EDA baseline was displayed before leaving the testing room. Synchronisation of gameplay with both the biometric and video recordings was achieved by mapping the respective *start* and *stop* actions to the same key, allowing the participant to automatically synchronise the entire data collection process with little difficulty. Upon completion of the game levels, the researcher would re-enter the room to begin the test debriefing; including participant completion of a brief questionnaire to assess perceived difficulty, overall experience intensity, immersion, disruption caused by the biometric sensors, and past gaming experience. Participants were also asked to watch the video of their gameplay performance and provide a voice-over commentary, with focus upon their developing emotional state and identification of discrete emotions. Average completion time for setup, trial and debrief was 45 minutes per person.

3.6 DATA COLLECTION

Electro-dermal activity and Electromyographic hardware were configured to synchronise with the game engine timestamp, allowing significant biometric readings to be accurately matched with their corresponding chronological point of gameplay. The event logging system was utilised to identify overall completion time. The *Fraps* (Beepa, 2007) screen capture software was utilised to generate a video render of the participants' performance which was then incorporated into the test debrief, in which participants were required to observe their gameplay, the intention being that participants would re-experience the affective states felt during the game and be able to more accurately describe their emotions in reference to specific game events. The test debrief replayed the video capture to the player, who was required to describe his or her experience in real-time, generating an audio commentary that was overlaid with the original video. Participants were asked to classify any events perceived as emotionally relevant, describe their affective state and identify any individual sounds perceived to be incongruous (specifically; low quality, inappropriate distortion, or unbefitting connotations) within the gameworld. Debriefing was concluded with several closed questions to establish variation between participants, reveal any prior game playing experience/skill, and assess the comfort, intrusion and flow interruption of the psychophysiological hardware using a generic 5-point scale. EDA data was collected from the right index and middle fingers of each participant by way of a SS57L Biopac EDA sensor lead and isotonic electrode gel. BSL shielded SS2LB leads connected to trimmed, disposable EL501 electrodes were utilised to collect facial EMG data. Existing research warns that precise positioning of EMG electrodes is a difficult task (Huang et al., 2004), therefore upmost care was taken to apply the hardware to each participant. A light abrasive treatment was applied to the skin in and around the areas on which the sensors would be placed to reduce electrode-skin impedance (Hermens et al., 2000). Electrodes were then applied across the midline of the muscle (De Luca, 1997) and surgical tape was used to reduce motion artefact (Huang et al., 2004)

CONCLUSIONS AND CHAPTER SUMMARY

The intention of these three experimental trials is, primarily, to assess the capacity of sound to evoke/modulate a fearful response without distinct semantic association. In addition, the divergence between the methodologies is intended to provide valuable information regarding various stimuli setup and data collection techniques. The following chapter therefore discusses not only the results based upon the primary goal, but also evaluates the effectiveness of these three separate testing approaches to support future experiment design.

Chapter 7

Experiment Results and Discussions

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Chapter 7: Experiment Results and Discussions

INTRODUCTION

This chapter documents the analysed results from the three preliminary experiments, previously detailed in chapter 6, alongside a retrospective evaluation considering both the results and the successes/limitations of the methodologies employed. The final conclusions extracted from these discussions are then to be correlated with the information within the earlier, literature review chapters to collectively support the design of the final hypothetical frameworks: an ecology of fear within a virtual environment, a fear-based classification system for game sound, a model visualising the interactions between real and virtual acoustic ecologies in a gameplay context and a framework for an embodied virtual acoustic ecology.

EXPERIMENT 1:

1.1 HORROR GAME SOUND DESIGNER RESULTS

Data collection for HGSD testing was retrieved from the same automated email system utilised for the SOF experiment. The characteristics of the obtained data required primarily non-parametric testing and consequently the asymptotic chi-squared test was employed, again using *PASW* (v.18: IBM, 2009). The nominal nature of sound localisation preference first required that the data be reclassified along a numerical scale (numbered 1-2-3-4-5, referring to left, left to right, centre, right to left and right respectively). The same procedure was also required for general preferred sound (numbered 1-2-3-4-5, referring to thunder, insect, train, gunshot, and door slam) and audio output (1-2-3-4, encoded from stereo speakers, stereo headphones, surround speakers, surround headphones respectively). Figures 2-5 below represent the three categories of DSP treatments in which significant difference was observed.

Figure 1: Chi-square analysis of cumulative results

	Attack 1	***Attack 2***	***Pitch 1***	***Pitch 2***	***Delay 1***	***Delay 2***	***Pos. 1***	***Pos. 2***	***Diff. Sounds***
X^2	5.737	24.368	.842	2.579	.211	.684	13.053	4.895	32.789
df	2	2	2	2	2	2	4	4	4
Sig.	.057	.000	.656	.275	.900	.710	.011	.298	.000
	Attack 1 dif.	***Attack 2 dif.***	***Pitch 1 dif.***	***Pitch 2 dif.***	***Delay1 dif.***	***Delay 2 dif.***	***Pos. 1 dif.***	***Pos. 2 dif.***	
X^2	25.158	13.789	4.316	19.158	8.737	18.842	15.053	12.842	
df	5	5	5	5	5	5	5	5	
Sig.	.000	.017	.505	.002	.120	.002	.010	.025	

Figure 2: Histogram representation of favoured individual sound based upon user-selection

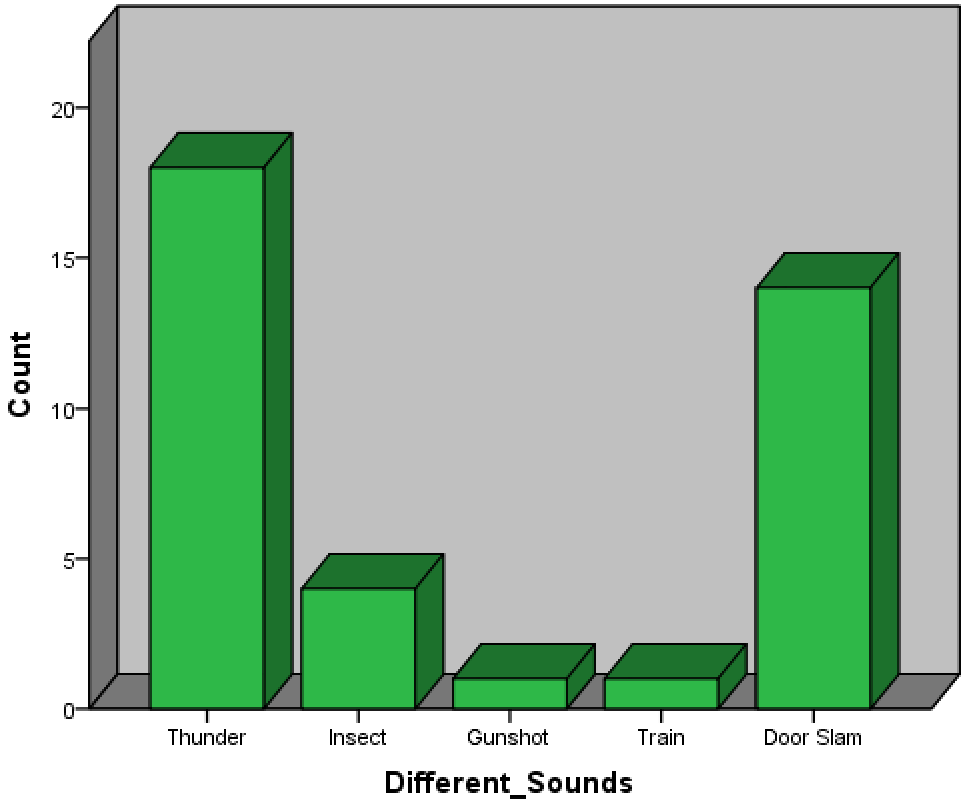


Figure 3: User-preference regarding localisation DSP upon animal-scream sound

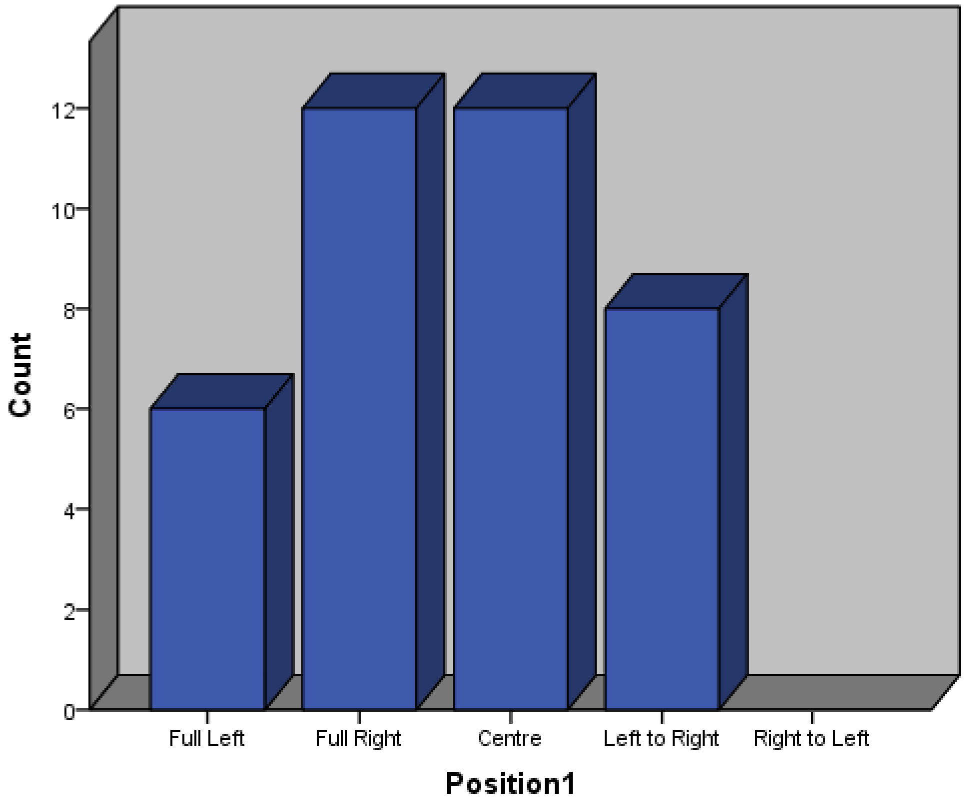
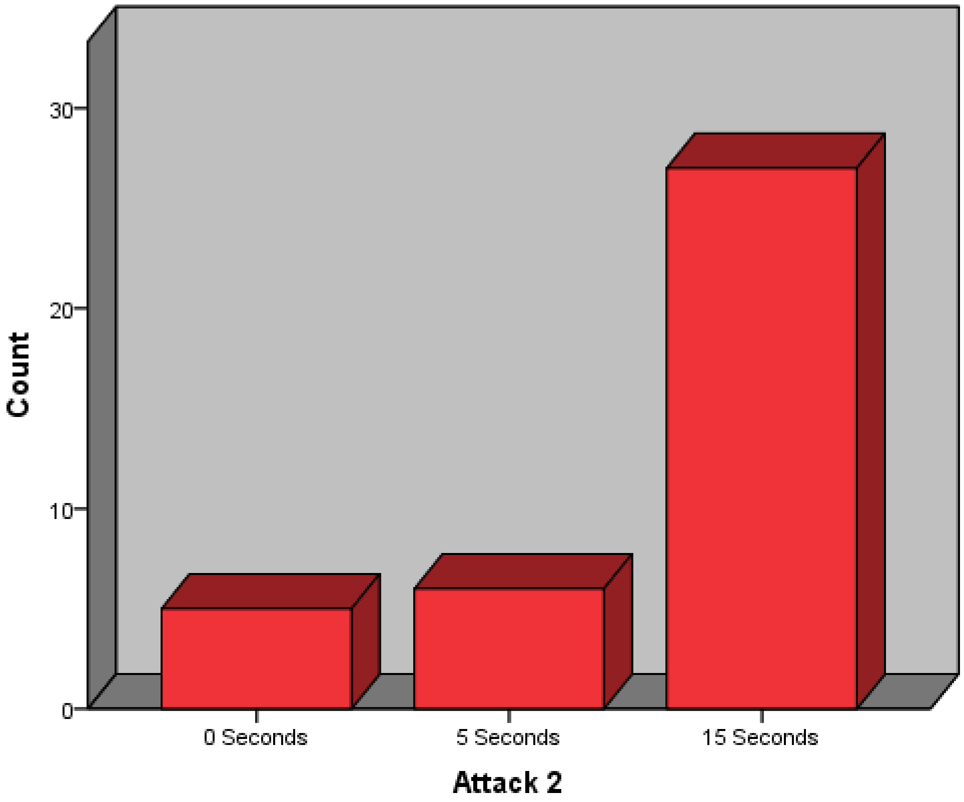


Figure 4: User-preference regarding attack DSP upon monster-breathing sound



Analysis reveals statistical significance for preferred general sound (diff. sounds), localisation DSP upon an animal scream sound (position 1) and attack time upon a heavily breathing monster sound (attack 2), revealing a significant preference towards thunder and door slam in the first measure, towards centred and left to right moving localisation in the second and, towards a slow-building 15 second delay in the third. Qualitative difficulty ratings relating to each preference-measure reveal significance in several places. *Attack 1* and *attack 2* difficulty ratings follow a normal distribution around a central tendency, indicating that the majority perceived the task to be 'moderately' difficult. *Pitch 2* and *position 1* difficulty ratings, however, reveal a left-skewed curve, indicative of an easy task whilst *delay 2* and *position 2* indicate easy/moderately easy. Accounting for alternative independent variables, the Chi-Squared test of independence of categorical variables (Pearson Chi-Square test statistic) analysed the effects of gender, audio output, gameplay experience and online/local variation. The *gender* independent variable (IV) revealed significant difference within the *pitch 2* (x^2=6.957, p=.031), *position 1 dif.* (x^2=12.505, p=.028) and *position 2 dif.* (x^2=13.150, p=.011) measures. The *online/local* IV revealed statistically significant difference within the *attack 1 dif.* (x^2=11.050, p=.05), measures. The *hours playing games* IV presented significance within the *attack 2* (x^2=19.960, p=.03) and *position 1* (x^2=29.344, p=.015) measures. The *audio output* IV revealed no significant effect upon any of the dependent measures.

1.2 SOUNDS OF FEAR RESULTS

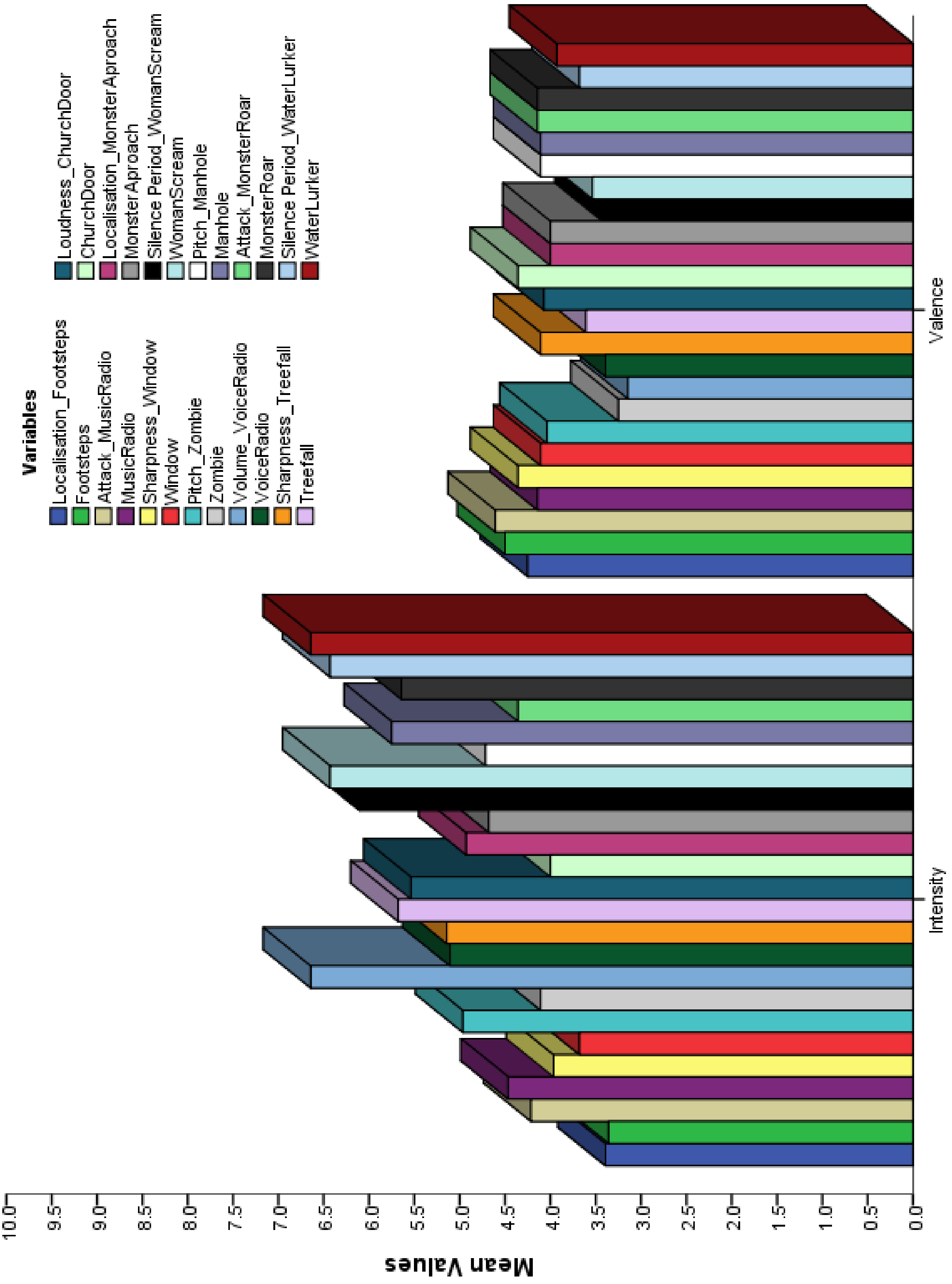
The data collected from both the online and offline versions of this test were sent via an automated email service to a designated address. Upon completion, the information was transferred to PASW for analysis. In accordance with standard analysis procedure, the repeated measures nature of the experiment dictated employment of paired samples t-test analysis (two-tailed) to distinguish between treated and untreated groups across all 12 sound sources and repeated measures ANOVA to present pairwise comparisons, testing for significant difference between all 24 presented sounds. Both analysis measures were utilised for intensity and valence separately. The results from both online and offline testing were collated together to analyse the effects of DSP as the independent variable (IV) and were separated later for direct comparison of the online/offline IV.

Figure 5: Snippet of ANOVA results. Green highlights significant difference between sources irrespective of treatment. Red highlights circumstances in which difference is only significant with one treatment type

Intensity Measure				
Sound Type (1)	**Sound Type (2)**	**Mean Difference (1-2)**	**Std. Error**	**Sig.**
1. Footsteps - DSP	09. Voice Radio - DSP	-3.250	.691	.019
1. Footsteps - DSP	13. Church Door - DSP	-2.143	.465	.024
1. Footsteps - DSP	17. Woman Scream - DSP	-2.714	.570	.016
1. Footsteps - DSP	18. Woman Scream - Untreated	-3.036	.572	.004
1. Footsteps - DSP	20. Manhole - Untreated	-2.357	.449	.004
1. Footsteps - DSP	23. Water Lurker - DSP	-3.036	.596	.007
1. Footsteps - DSP	24. Water Lurker - Untreated	-3.250	.531	.000
2. Footsteps - untreated	09. Voice Radio - DSP	-3.286	.709	.022
2. Footsteps - untreated	12. Tree fall - Untreated	-2.321	.434	.003
2. Footsteps - untreated	13. Church Door - DSP	-2.179	.451	.013
2. Footsteps - untreated	17. Woman Scream - DSP	-2.750	.481	.001
2. Footsteps - untreated	18. Woman Scream - Untreated	-3.071	.568	.003
2. Footsteps - untreated	20. Manhole - Untreated	-2.393	.492	.012
2. Footsteps - untreated	23. Water Lurker - DSP	-3.071	.595	.005
2. Footsteps - untreated	24. Water Lurker - Untreated	-3.286	.539	.000

Descriptive statistical analysis of the intensity dependant variable revealed relatively low standard deviations between participants (minimum = 1.647, maximum = 2.78) but also small variations in mean responses between treated and untreated groups. The paired differences t-test revealed statistically significant difference between groups in the following sound sources: Voice Radio (*t*=2.743; *p*=.011), Church Door Slam (*t*=2.698; *p*=.012), Manhole Cover Scrape (*t*=-2.333; *p*=.027) and Monster Roar (*t*=-2.698; *p*=.012). Valence dependent variable standard deviations were lower than for intensity (between 1.162 and 2.457) but initial analysis of mean distributions suggested a similar pattern to that observed within the intensity group.

Figure 6: Bar chart representation of intensity and valence mean results from SOF experiment



Descriptive statistics revealed a full range of valence responses (1-9) and a clear majority preference (prominently 3's 4's and 5's) for most of the 24 sounds. The paired differences t-test revealed statistically significant difference between groups for only the Zombie sound (t=2.091, p=.046).

Repeated measures ANOVA testing utilised Mauchly's test to check the sphericity assumption and Greenhouse-Geisser for corrections. Multivariate tests for the intensity measure revealed significant difference between sounds (F=32.96, p<.001). In contrast to the result obtained from the paired samples t-test, ANOVA pairwise comparisons of the intensity measure identified no difference of statistical significance between paired treated and untreated sounds. However, significant difference was identified between large numbers of individual sound types (summarised in figure 5 and visualised in figure 6). The notable observation presented in this data is that for some of the sound sources, both variations of the sound are significantly different to both variations of another (examples highlighted in green in figure 5). However, some sounds only reveal significant differences between a single variation of each paired source, suggesting that (in that particular instance) it could be the DSP effect that generates the perceived difference in intensity. Figure 7 exemplifies this difference, revealing that without DSP treatment (in this case, a loudness boost) the voice radio sound cannot be statistically differentiated from any of the other 24 sounds in terms of intensity. In comparison, with DSP treatment the same sound reveals significantly greater intensity means than five other sounds. The same repeated measure ANOVA testing for the valence variable revealed no statistical significance between any specific pairings of the 24 sounds, nor was any difference overall presented. Figure 6 presents both intensity and valence measures adjacently, revealing the limited range of mean responses within the valence group compared to the intensity group.

Finally, to compare the online to the local network datasets, a random sample of the 22 online participants was taken to compare equivalent sized online/local samples and one-way ANOVA was employed. Results indicated significantly greater mean responses for online datasets in the following intensity measures: *untreated voice radio* (F=15.244, p=.003), *untreated woman scream* (F=6.659, p=.027) and *untreated water lurker* (F=12.987, p=.005) whilst *pitch treated zombie* (F=7.313, p=.022) revealed a greater mean intensity response for the local dataset. With regards to valence measures: *untreated footsteps* (F=5.548, p=.04), and *sharpness treated tree-fall* (F=9.308, p=.012) revealed greater mean response for the online dataset whilst *localisation treated footsteps* (F=5.976, p=.035), *untreated voice radio* (F=12.8, p=.005), *untreated woman scream* (F=5.74, p=.038) and *untreated monster roar* (F=7.71, p=.02) all received greater mean valence responses from the local dataset. Descriptive statistics also revealed greater range and frequency of extreme responses in the online group. One-way ANOVA comparison of the local and online dataset ranges confirm the difference as significant (F=7.059, p=.009)

Figure 7: Table revealing substantial effect DSP has had on differentiating source from other sounds

Sound Type (1)	Sound Type (2)	Mean Diff. (1-2)	Std. Error	Sig.	Sound Type (1)	Sound Type (2)	Mean Diff. (1-2)	Std. Error	Sig.
9	1	3.250^{*}	.691	.019	10	1	1.714	.570	1.000
9	2	3.286^{*}	.709	.022	10	2	1.750	.548	.986
9	3	2.429^{*}	.432	.002	10	3	.893	.557	1.000
9	4	2.179	.517	.069	10	4	.643	.497	1.000
9	5	2.679^{*}	.542	.010	10	5	1.143	.577	1.000
9	6	2.964^{*}	.528	.002	10	6	1.429	.550	1.000
9	7	1.679	.669	1.000	10	7	.143	.648	1.000
9	8	2.536	.676	.233	10	8	1.000	.686	1.000
9	10	1.536	.560	1.000	10	9	-1.536	.560	1.000
9	11	1.500	.576	1.000	10	11	-.036	.541	1.000
9	12	.964	.645	1.000	10	12	-.571	.553	1.000
9	13	1.107	.578	1.000	10	13	-.429	.645	1.000
9	14	2.643	.630	.073	10	14	1.107	.645	1.000
9	15	1.714	.537	.979	10	15	.179	.540	1.000
9	16	1.964	.656	1.000	10	16	.429	.616	1.000
9	17	.536	.521	1.000	10	17	-1.000	.517	1.000
9	18	.214	.500	1.000	10	18	-1.321	.499	1.000
9	19	1.929	.600	.928	10	19	.393	.618	1.000
9	20	.893	.483	1.000	10	20	-.643	.502	1.000
9	21	2.286	.563	.104	10	21	.750	.650	1.000
9	22	1.000	.463	1.000	10	22	-.536	.489	1.000
9	23	.214	.594	1.000	10	23	-1.321	.604	1.000
9	24	.000	.575	1.000	10	24	-1.536	.528	1.000

1.3 DISCUSSION

Results obtained during the collective analysis of SOF data revealed statistically significant differences between paired variations of some, but not all source sounds. Unfortunately there was little consistency between source sounds for single DSP effects with the exception of loudness that revealed a statistically significant difference in both associated sound sources (*voice radio* and *church door slam*). This would suggest that an increase in loudness has greater potential to consistently impact upon the perceived intensity levels of a sound, whilst the effectiveness of pitch and localisation (the other DSP effect to reveal significance but only on a single source sound) is more context-dependent. The *zombie call* sound (treated with a pitch raise) was revealed to be the only significant valence-related pair, suggesting that DSP effects are unlikely to have a significant impact upon perceived valence ratings. The contextualisation of the *zombie* sound is arguably responsible for the effectiveness of pitch in this example and the distinct raise in pitch creates both a notable distortion capable of breaking the immersive flow and a distinctly comedic effect reminiscent of parody-horror stylisation.

The descriptive statistical analysis indirectly presents evidence in support of the power of contextualisation in that, despite the theme of fear/horror being descriptively prominent throughout the web-testing, the sounds are not given clear context in terms of their source or purpose. The perceived context of these sounds primarily relates to a neutral, relaxed and comfortable testing environment with no inherent threat or risk. This is revealed in the presence of multiple valence responses of 8 and 9 (high to very high positive valence) across all test sound groups and the mean range being just off-centre (3.14 – 4.61). One-way ANOVA testing across all SOF results revealed statistically significant differences in user intensity-responses between many of the 24 presented sounds. Although no pairwise differences yielded significance, the notable quantity of distinguishable sounds within a controlled context certainly supports the assertion that individual sounds are capable of generating different perceptual intensity responses. It does not, however, support the same assertion in relation to valence.

Results obtained from the online/local comparison ANOVA test provide some insight into the impact of inconsistencies between testing environments within this context. Both intensity and valence responses appear to have been affected by online-based variables but again, this is not consistent across all sound groups and no clear association is discernable between online/local environments and treated/untreated sound sources. The absence of both treatment groups being significantly affected by the online/local variation suggests that DSP effects may impact upon the potential of online variations to alter intensity responses. Alongside the comparison of range and extreme response frequency, this data analysis suggests that there is a small but nonetheless; significantly lower reliability rating for web-based experimentation.

Analysis of the HGSD data presents an expected preference towards more easily identifiable sounds with sudden attack times and inherent horror significations. Preference towards centred localisation is surprising, primarily because of the assumption that full left/right would defy expectation as few sounds are presented in such a way. The data could be questioned upon further overview of the *position 2* group which reveals that although the *centred* position is clearly the majority selection, if extreme left and right were combined, the difference then would be marginal. Although the observed data differed significantly from the Chi-Square expected result, both centred and left to right moving localisation scoring equal values unfortunately reveals no real preference. The attack test matches the expectation of the hypothesis, revealing a preference towards a gradually building 15 second attack, a DSP effect that clearly alters the connotations of the sound to imply that the source is approaching.

Data regarding qualitative difficulty participants experienced in differentiating and selecting sounds provides no conclusive evidence to support the hypothesis that increased difficulty of task could have an erroneous impact upon participants' selections. Incorporation of the gender, audio output and gameplay experience/history data revealed strong potential for such factors to significantly influence dependent results and highlight them as variables that must be actively controlled to ensure accurate and reliable data in future experiments. That the participants' audio hardware did not produce significantly different data in any of the groups is surprising, however the preliminary nature of this experiment suggests that it should not be discounted as a potentially erroneous factor and more definitive testing would be required before an evidenced statement could be made.

One of the primary issues with this trial has been the lack of local participants (N=6). This concern reduces the statistical power of the analysis but also reminds us of the inherent value of web-mediated testing environments with regards to participant access. Other limitations lie within the nominal and ordinal nature of most DV groups. Future experimentation should undoubtedly explore pitch, attack and preceding silence period via ratio scales and compare larger numbers of alternative parameters than are presented here. Localisation could also be extended by comparing dependent measures in degrees within a surround sound environment to explore both static and dynamic localisation effects.

1.4 CONCLUSIONS AND EXPERIMENT SUMMARY

This chapter presented the first of three preliminary experiments contained within the thesis. Obtained results suggest a requirement for more stringent testing and, ideally, larger sample sizes to confirm some of the concepts the data analysis has suggested. Results also signify that contextualisation may be a decisive factor in the potential of a sound to evoke affective response but this experiment has also highlighted particular DSP effects that have greater potential to support a context-driven psychoacoustic characteristic (such as immediate loudness reflecting a powerful danger or attack envelope connoting an approaching threat). The subsequent chapter will take influence from assertions presented here with regards to the methodology for a second preliminary trial, this time incorporating various sounds into a bespoke game environment and assessing participants' emotional states by way of a real-time vocalisation approach to affective data collection.

EXPERIMENT 2:

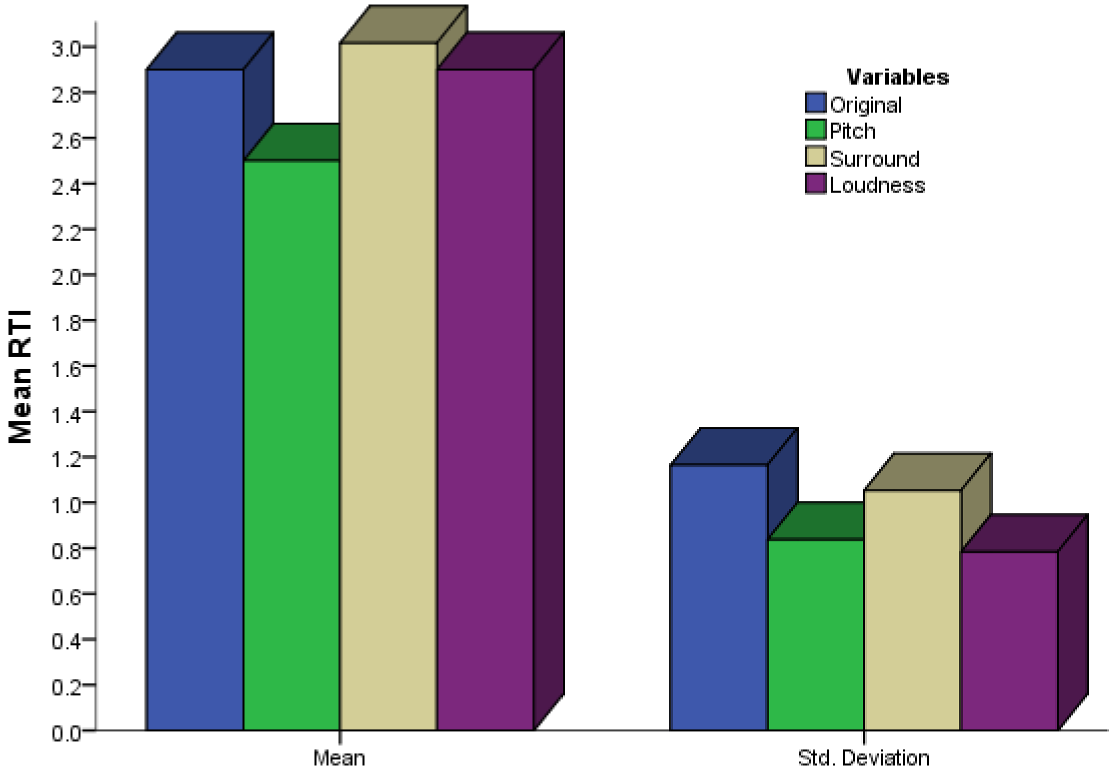
2.1 RESULTS

Each participant (N=12) completed the four game segments featuring the four alternative sound treatments, completing questionnaire sections between levels and provided demographic and further data in the debrief at the end of the session. All participants were White British, 9 male and 3 female, with ages ranging from 18 to 55. During the debrief participants rated the immersive quality of their overall experience and how disruptive to flow providing the real-time audio responses was (figure 8).

Figure 8: Mean/Standard deviation of participant ratings of immersion/flow disruption

	N	*Range*	*Min.*	*Max.*	*Mean*	*SD*
Immersion	12	2.00	2.00	4.00	3.25	.621
Disruption	12	2.00	1.00	3.00	2.33	.7785

Figure 9: Bar chart representation of average RTI measures between control and treatment groups



In terms of descriptive statistics, figure 9 elucidates the average RTI responses between sound treatment groups, revealing little difference between the treatments or control group. To test the statistical significance of the results, one-way repeated measures ANOVA was employed via *PASW/SPSS v.18* (IBM, 2010), with sound treatment type as the within subject factor for the dependent variable data collected. The dependent variable classes tested were completion time and 3 measurements associated with player in-game use of the run function (total activation number / total time run was activated / mean run time).

Figure 10: Mean (+ standard deviation) of DV measurements for four sound modalities

	Sound treatment factors			
DV measures	**Untreated**	**Pitch**	**Surround**	**Loudness**
Completion time	244.348 (184.823)	136.735 (89.453)	217.997 (182.061)	178.137 (114.879)
No. of RUN activations	2.08 (1.929)	2.67 (3.393)	1.42 (2.021)	2.17 (2.823)
Total RUN time	21.606 (23.894)	29.969 (34.836)	23.856 (32.757)	23.41 (32.621)
Mean RUN time	13.518 (19.97)	15.324 (20.206)	15.028 (24.56)	17.744 (26.563)

Mauchley’s test of the DV measurements completion time ($\chi^2(5) = 7.157$, $p > .05$) and total run time ($\chi^2(5) = 9.529$, $p > .05$) signified that the assumption of sphericity had been met. However, number of run activations ($\chi^2(5) = 13.108$, $p < .05$) and mean run time ($\chi^2(5) = 123.203$, $p < .05$) indicated a violation. The Greenhouse-Geisser estimates of sphericity were employed to correct the degrees of freedom ($\varepsilon = .671$, $\varepsilon = .598$ respectively). One-way repeated measures ANOVA revealed no statistically significant difference between the four sound treatment factors when measuring number of run activations ($F_{2.041, 22.15} = .954$, $p > .05$), total run time ($F_{3, 33} = .953$, $p > .05$) or mean run time ($F_{1.794, 19.736} = .608$, $p > .05$). Completion time did indicate significance ($F_{3, 33} = 2.888$, $p < .05$) revealing that the objective DV measurement of level completion time was significantly affected by the different sound treatment factors.

Measurements associated with the run function were tested further to assess correlation between use of the run function and RTI. The Spearman’s Rank correlation (two-tailed) was selected to test the relationship between these variables ($R_{(\text{RTI, number of run activations})} = -.483$, $p < .001$, $R_{(\text{RTI, total run time})} = -.634$, $p < .001$, $R_{(\text{RTI, mean run time})} = -.55$, $p < .001$) indicating a moderate/strong *RTI-total time* correlation, a weak *RTI-number of runs* and a moderate *RTI-mean run time* correlation. The debrief questionnaire also revealed variation in PC player experience and confidence (PEC) *prior to testing* between participants. These grouped differences were evenly distributed and ranked (25%, R = 1-4) across the total sample. Multivariate variance analysis (MANOVA) assessed the significance of variation between PEC groups when measuring completion time and RTI ($F_{(3, 44)} = 20.616$, $p < .001$). Bonferroni post hoc revealed specific significant difference lay between PEC levels 1 and 3 ($\bar{x}_1 - \bar{x}_3 = 247.831$, $p < .001$), 1 and 4 ($\bar{x}_1 - \bar{x}_4 = 233.606$, $p < .001$), 2 and 3 ($\bar{x}_2 - \bar{x}_3 = 216.728$, $p < .001$) and between levels 2 and 4 ($\bar{x}_2 - \bar{x}_4 = 202.503$, $p < .001$) with completion time the dependent variable. Comparable results were obtained in post hoc with RTI the dependent variable ($\bar{x}_1 - \bar{x}_3 = 1.55$, $p < .001$), ($\bar{x}_1 - \bar{x}_4 = 1.8$, $p < .001$), ($\bar{x}_2 - \bar{x}_3 = 1.217$, $p < .001$), ($\bar{x}_2 - \bar{x}_4 = 1.467$, $p < .001$).

Comparisons between real-time intensity averages and debrief intensity ratings averaged across all treatment types revealed a moderate/strong correlation via Spearman’s Rank Coefficient ($R_{(\text{RTI, debrief intensity})} = .694$, $p < .001$), suggesting that although players reported similarly both during and after playing the game, the 30% margin of error arguably supports the use of vocal intensity responses collected during the game. The final analysis tests searched for difference (measured in RTI) between the game level source-sounds (figure 11). A series of Freidman’s tests of variance for repeated measures were employed to identify significant difference between source-sounds, and search for any interaction between source-sound factors and sound treatment factors. Results revealed significant difference between source sounds across all treatments: untreated ($\chi^2(4) = 20.593$, $p < .001$), pitch ($\chi^2(4) = 16.964$, $p < .01$), 3D ($\chi^2(4) = 16.176$, $p < .01$), loudness ($\chi^2(4) = 22.545$, $p < .001$) and when tested across all treatments ($\chi^2(4) = 71.891$, $p < .001$). As with earlier tests, no significant difference was identified between treatment type ($\chi^2(3) = 2.123$, $p > .05$).

Figure 11: Results of Friedman's test series

	Sound Treatment Factors			
Sound Name	**Untreated**	**Pitch**	**3D**	**Loud**
Zombie Call	2.75	2.63	2.25	1.81
Twig Snap	1.38	1.56	1.69	1.69
Woman Scream	2.69	3.31	3.44	3.38
Monster Attack	3.75	3.38	3.31	3.69
Intense Scream	4.44	4.13	4.31	4.44

2.2 DISCUSSION

Whilst this chapter has identified a great number of audio parameters that have the potential to affect player intensity response, the scope has currently limited this study to only three. The results obtained present no significantly conclusive evidence to support the hypothesis that pitch alteration, decibel level or binaurally processed panning techniques affect player intensity response. One initial possible explanation is the set levels for the 3 treatments were too conservative to trigger significantly different intensity readings and that a more focussed analysis on an individual parameter across a greater range of treatment values would be of profit to further investigations. Within the remit of a preliminary test, such lack of significant conclusiveness is not unexpected.

Incorporation of real-time audio responses and game engine event logging allowed an accurate synchronisation of several data sets and provided an opportunity to analyse data at (and around) specific points of gameplay. Testing sound treatment modalities via various measurements of in-game avatar *running* action revealed no significant difference between groups for any of the three measures (number of run activations, total time spent with run engaged, average length of run time). Several possible reasons lie in alternative player motives for activating the run function (accelerating the player once the level exit has been visually identified in order to vary gameplay when the player experiences frustration or boredom) and inexperienced player difficulties in coordinating both run and movement controls simultaneously. Event logging provided a data filtration system, only recording data if certain criteria were met. Parameters of this logic-gate were set to record run associated data only between activation of a key sound and for the subsequent five seconds of gameplay (the logic suggesting that any run activity occurring during this time would be more likely to be a response to the key sound). This system unfortunately did not reveal any further insight due to too little data recorded (under such stringent filters) to perform any statistical analysis, suggesting that the run function was not used as an evasive player movement in reaction to any key sound. The Spearman's Rank Correlation test provided further analysis of data regarding possible relationships between the *emotional intensity ratings* (RTI) and the three *run-function* measurements. Results identified a strong link between the participants' RTI and *total run time*, and a moderate relationship between RTI and *mean run time*; suggesting that analysis of the run function may have future potential as an objective measurement.

Results of the data analysis also suggest that other critical factors were affecting the dependent variables, most notably player experience and confidence (PEC) prior to experimentation. As previously asserted in chapter 3, fear cannot be experienced without a genuine perception of threat and that perception can alter in both presence and intensity depending on the appraised severity of threat and the individual's capacity to overcome that threat. It is therefore argued that high levels of experience (knowledge of game conventions, a variety of fear induction tactics, etc.) coupled with confidence and adept skill in game controls is very likely to reduce the threat severity and increase the coping ability. The test results presented above support this, presenting a highly significant negative correlation between PEC and RTI. At both a qualitative and quantitative level, the testing revealed that players with very little gaming experience were more likely to struggle to reach the level exit when they were feeling more intense fear, to an extent that they reported frustration and dislike towards the game. Quantitative data analysis supported this finding, revealing a significant correlation between RTI and completion time. The causal nature of completion time as a variable becomes a matter of opinion, with a logical assertion being that because sensation of fear-intensity positively correlates with completion time, which variable is the cause and which is the effect may fluctuate throughout the game. Taking longer to reach the level exit may increase negative emotional valence (worry, fear, frustration) which in turn creates a feedback loop as increased negative valence causes the player to lose their way or begin travelling in circles (as we observed in several of the gameplay capture videos). It is also observed that completion time can impact upon the potential of a sound to evoke increased fear response. Existing literature has suggested that forewarning cues which signify that a frightening event is imminent (such as extended periods of unexpected silence), may significantly increase the impact of a sudden sound (Perron, 2004), and increased completion time dictates a greater mean time between key sound events. Such an aspect of sound design shows great potential to manipulate player fear response and is certainly a candidate for further study.

The nature of the experimental design afforded the opportunity to run statistical analysis of variance between each of the 5 alternative sounds heard in every play-through. Because each player reported an emotional intensity rating for each sound for four repetitions (across the 4 treatment types) order effects can arguably be dismissed alongside audio/visual interaction effects due to the repetitive and low visibility graphic environment. Results posited that despite contaminating variables (alternative audio treatments, PEC), a significant difference in RTI existed between groups and an ordinal rank and specific mean differences between each sound were also identified. Such findings provide a strong argument for the value of game sound in manipulation of player emotional states, and calls for the continuation of this research line of enquiry to establish exactly what sonic differences caused these significant and substantial variances in fear-response intensity.

The results of this experiment confirm that differences between sound parameters can affect the degree of intensity an individual experiences whilst playing a survival horror game. The specific measures tested (3D, loudness and pitch), although not statistically significant, do reveal potential if subject to greater parameter extremes. Although not formally analysed via statistical data, initial observation posits periodicity (specifically, the length of silence experienced before a key sound) as a good candidate for individual study. The statistically significant difference observed between source-sounds further identifies timbre and attack (ADSR) as strong potential candidates for further study. Future experimentation will explore each of the above sound parameters individually, assessing each parameter across a detailed number of measures rather than a single measured difference between the treatment group and the control. Psychophysiological measurements to increase objectivity will also be integrated into all further experiments.

The results support documented above support the notion that the experience of fear is (at least within the confines of this context) a complex matrix of interacting variables. Whilst real-time intensity response and event logging have proved substantially valuable the exact execution of this approach requires minor alteration. Real-time audio responses collected during periods of silence in the game, in addition to immediately after each key-sound, could provide a more detailed account of player emotion, but at the risk of further interrupting immersion and flow. The substantial interference effect of player experience and confidence prior to testing is acknowledged however, future experiments should endeavour to focus upon increasing breadth and depth, testing with both a wider range of DSP effects and a greater number of parameters within each effect.

In terms of the test game itself, the substantial difference between players’ completion times (both between participants and between separate playthroughs) could arguably be an erroneous source of tension, capable of increasing the RTI responses. Players lost and struggling within the game level may experience greater fear elicitation as their circumstance acts as an affective primer. The open-world style of level design is likely responsible for this issue and presents a compromise between level design that reflects modern games (but leaves substantial room for variation in the player experience) and linear design that provides greater control of variation between gameplay experiences (but may be perceived as sterile and non-representative by the player).

2.3 CONCLUSIONS AND EXPERIMENT SUMMARY

Results obtained from this study support data event logging as an effective way to collect detailed gameplay statistics in an efficient manner. The lack of conclusive or statistically significant evidence strongly supports the notion that a more systematic methodology (controlling for erroneous variables such as player-experience/confidence) is more likely to yield greater results. The issues with level design may not necessarily require severe compromise on either extreme and the results from this experiment have since informed the level design of subsequent experiments (primarily encouraging deceptively linear environments with significantly more distinct and frequent navigational signposts integrated within the set pieces).

In preparation for the final preliminary experiment, the upcoming chapter hosts a detailed analysis of psychophysiological approaches to data acquisition with regards to a range of general and specific, thesis-relevant applications. The concept of biometrics is addressed in greater detail and electrodermal activity (EDA: skin conductance) and electromyographic (EMG: muscle activity) measures are scrutinised in terms of their advantages and limitations in comparison to alternative psychophysiological methods. This discussion will then lead to the final trial, within which EMG and EDA biometric data alongside qualitative debrief player responses, shall reveal the effects of a new set of DSP treatments upon objective and subjective measures of fear elicitation.

EXPERIMENT 3:

3.1 RESULTS

Data obtained from both EDA and EMG acquisition was initially extracted in 5.00 second epochs. The baseline epoch for each participant was collected between 30.00 and 35.00 seconds of the 1 minute rest period before the game began. This was to allow time for the signal to stabilise after inevitable rises immediately after applying the sensors whilst leaving time before the test began so to avoid test-start anxiety. Data relevant to each test sound was extracted, also as 5 second epochs, but each one commenced in synchronisation with the sound onset. Integrated signal analysis tools within BSL Pro v.3.6.7 (Biopac, 2001) enabled both biometric signals to reveal descriptive statistical data across each epoch. Both electrodermal activity and electromyographic data were measured for minimal and maximum peaks within the 5 seconds, plus a mean, area and slope output.

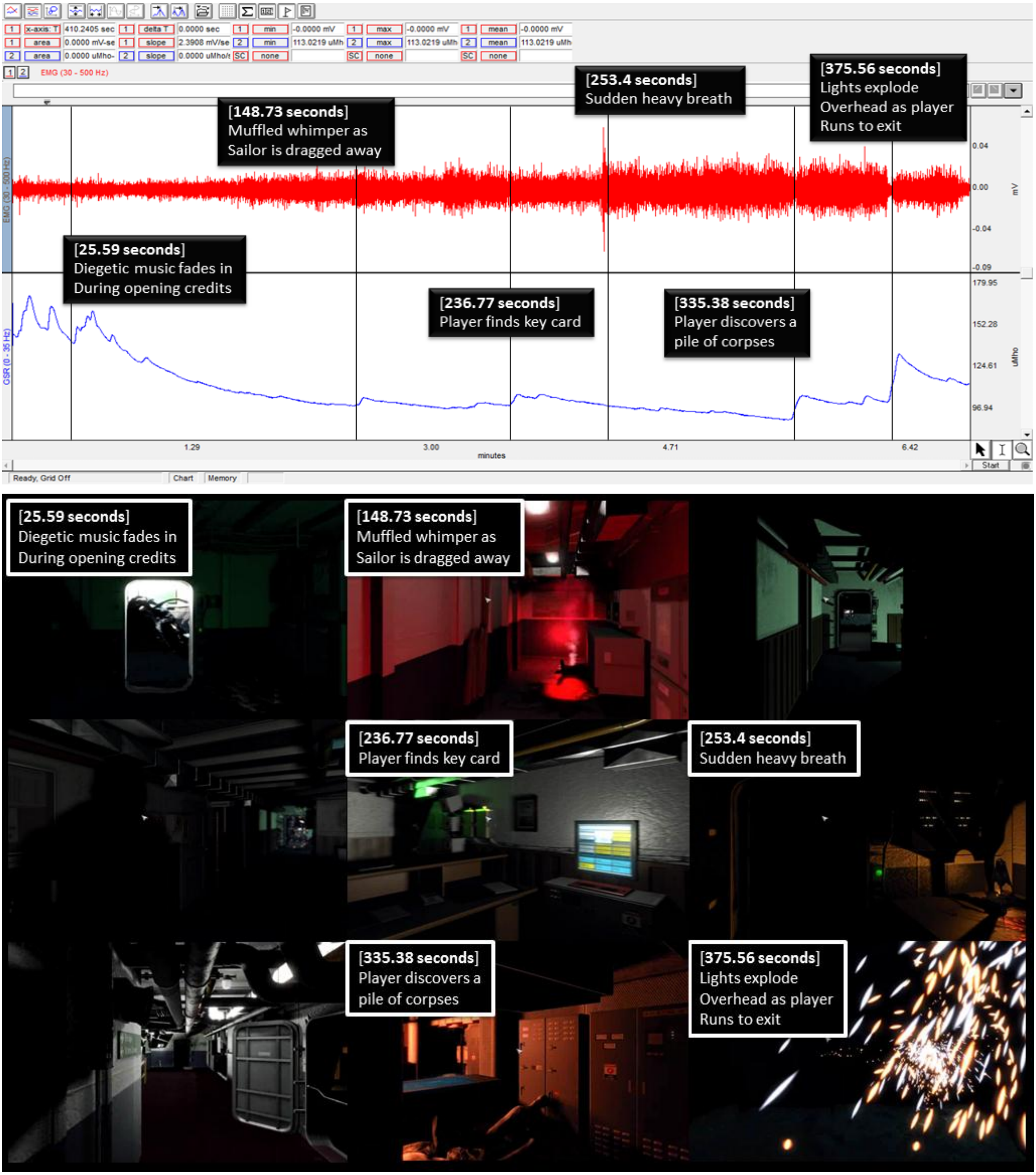
The next step (along with all subsequent analytical processes) was carried out with PASW statistics (v.18, IBM, 2009) and was to calculate the difference between the baseline and each test epoch to generate a differential dataset (see figure 1). The final step produced descriptive statistics of the differential dataset and then utilised the statistical t-test for independent samples to search for statistically significant difference between the means of the control and treatment groups for each test sound. Results of the t-test revealed significant difference between groups of the *muffled scream* (sharpness treatment) sound in the EDA-mean (t=-2.377, p=.045), EDA-max (t=-2.357, p=.046) and EDA-min (t=-2.457, p=.039) dependent variables and was the only notable difference in the EDA output measures. Of the EMG outputs, only EMG-max revealed a significant difference between groups, at the *muffled whimper* (also sharpness treatment) sound (t=2.669, p=.028). Each individual sound (both treated and untreated) was separately tested but revealed no statistical significance between any of the sounds for any measure of EDA or EMG. An overview of the descriptive statistics suggests that overly high variance between players, present even when testing the differential data, is the likely cause of an absence of significant difference between sounds.

Figure 13 presents a visual overview of the EMG and EDA signal data with notable increases in either biometric synchronised to an event. Overlaying biometric output with event data reveals that the majority of EDA/EMG spikes and peaks can be attributed to specific events within the game, however, not all of these events are directly tied to a sound and more often probably relate to a visual entity such as a lifeless body or flash of light. Visual analysis of the overall biometric signal also reveals significantly raised skin conductance levels during the first 60-80 seconds of gameplay, and a steadily increasing rate of EMG activity from commencing gameplay to completing the level. These trends are generally representative of all players' test results (particularly the initial high EDA and steadily increasing EMG).

Figure 12: Extract of collated dataset – differential data for all measures of EMG

Group A Mean	**EMG**				
	Min	Max	Mean	Area	Slope
Music	-0.01786	0.00398	-0.0002	0.00216	-0.00008
Ship Groan	-0.02888	0.01376	-0.00018	0.01312	0.00032
light explosion	-0.02186	0.00902	-0.00014	0.01158	0.00194
Muffled Scream	-0.01954	0.01128	-0.00016	0.0076	-0.00048
Man Whimper	-0.01762	0.00654	-0.00012	0.01156	-0.00074
Pipe Banging	-0.03338	0.02134	-0.00012	0.01662	0.00002
Breath	-0.0142	0.01126	-0.00014	0.0193	0.00194
Ship Voice	-0.03244	0.02026	-0.00012	0.01438	0.00042
Scream	-0.0217	0.00772	-0.00014	0.0231	0.00026
Animal Scream	-0.02594	0.01472	-0.00014	0.01426	0.00008
Monster Roar	-0.02264	0.01354	-0.00016	0.01536	0.00002
Door Slams	-0.0233	0.0131	-0.0001	0.01734	-0.00134
Group B	**EMG**				
	Min	Max	Mean	Area	Slope
Music	-0.0013	-0.00492	-0.00016	-0.00554	0.00052
Ship Groan	0.0036	-0.00456	-0.00016	-0.00266	0.00044
light explosion	-0.00756	0.00672	-0.00018	-0.00268	0.00002
Muffled Scream	-0.0036	0.00282	-0.00006	-0.00574	-0.0003
Man Whimper	0.00128	-0.00366	-0.00012	-0.00166	0.00008
Pipe Banging	-0.00452	-0.00076	-0.00014	-0.00036	-0.00018
Breath	-0.00086	0.0033	-0.00012	0.00338	0.00022
Ship Voice	-0.01362	0.00702	-0.00014	0.00812	0.00182
Scream	-0.0062	0.01298	-0.0001	0.00338	-0.00074
Animal Scream	-0.01012	0.02012	-0.00016	-0.0002	0.00028
Monster Roar	-0.02568	0.01352	-0.00016	0.00704	0.00212
Door Slams	-0.00636	0.00264	-0.00018	0.00488	0.0008

Figure 13: Full EMG(red)/EDA(blue) signal output + synchronised events/related screenshots



```
1 x-axis: T 410.2405 sec 1 delta T 0.0000 sec 1 min -0.0000 mV 1 max -0.0000 mV 1 mean -0.0000 mV
1 area 0.0000 mV-se 1 slope 2.3908 mV/se 2 min 113.0219 uMh 2 max 113.0219 uMh 2 mean 113.0219 uMh
2 area 0.0000 uMho- 2 slope 0.0000 uMho/s SC none SC none SC none
```

[25.59 seconds] Diegetic music fades in During opening credits

[148.73 seconds] Muffled whimper as Sailor is dragged away

[236.77 seconds] Player finds key card

[253.4 seconds] Sudden heavy breath

[335.38 seconds] Player discovers a pile of corpses

[375.56 seconds] Lights explode Overhead as player Runs to exit

Figure 14: Descriptive statistics & Chi-Square analysis of qualitative debrief responses

Descriptive Statistics					
	N	Mean	Std. Deviation	Minimum	Maximum
Comfort	10	7.1000	.73786	6.00	8.00
Flow disruption	10	2.7000	.82327	2.00	4.00
Intensity	10	6.7000	1.33749	4.00	8.00
Difficulty	10	3.3000	.67495	3.00	5.00
Frustration	10	2.2000	.78881	1.00	3.00

Chi-Square Test Statistics					
	Comfort	Flow disruption	Intensity	Difficulty	Frustration
Chi-square	28.000^{a}	28.000^{a}	18.000^{a}	56.000^{a}	26.000^{a}
df	9	9	9	9	9
Asymp. Sig.	.001	.001	.035	.000	.002

a. 10 cells (100.0%) have expected frequencies less than 5. The minimum expected cell frequency is 1.0.

Non-parametric analysis compared the control and test groups via the Mann-Whitney U test for two independent samples to assess if any significant variation existed between the groups with regards to subjective intensity, frustration and difficulty ratings. Results revealed no statistical significance between groups for any of the three dependent variables. Descriptive statistics and the Chi-Square test was administered, including all ten players' results, to assess comfort of biometric sensors, perceived difficulty of the game itself, subjective frustration levels and the extent to which the sensors and wires obstructed the flow of gameplay and sense of immersion. The results (shown above in figure 14) reveal statistical significance for all measures and the descriptive means reveal a relatively high level of comfort and low disruption during gameplay alongside moderately high intensity ratings, low difficulty and very low frustration levels. Information collected from qualitative discussion with participants revealed that context/situation heavily influenced how they felt about a sound. For example, many commented that the consecutive slams at the end of the level created suspense and fear by signifying urgency and a time-limit to reach the level end. Participants also commented that the alien roar sound was very intense and discomforting. Participants did not comment directly upon the fast tempo of the slam sounds or the immediate attack and high volume of the alien roar sound, suggesting limited conscious awareness of the quantitative sound techniques being employed. Figures 15 and 16 present line graph representations of particular statistical measures of both EEG and EDA, revealing the difference between sound treatment groups and individual sounds.

Figure 15: Line graph representing mean EEG peak values (red = control, blue = DSP treated sound)

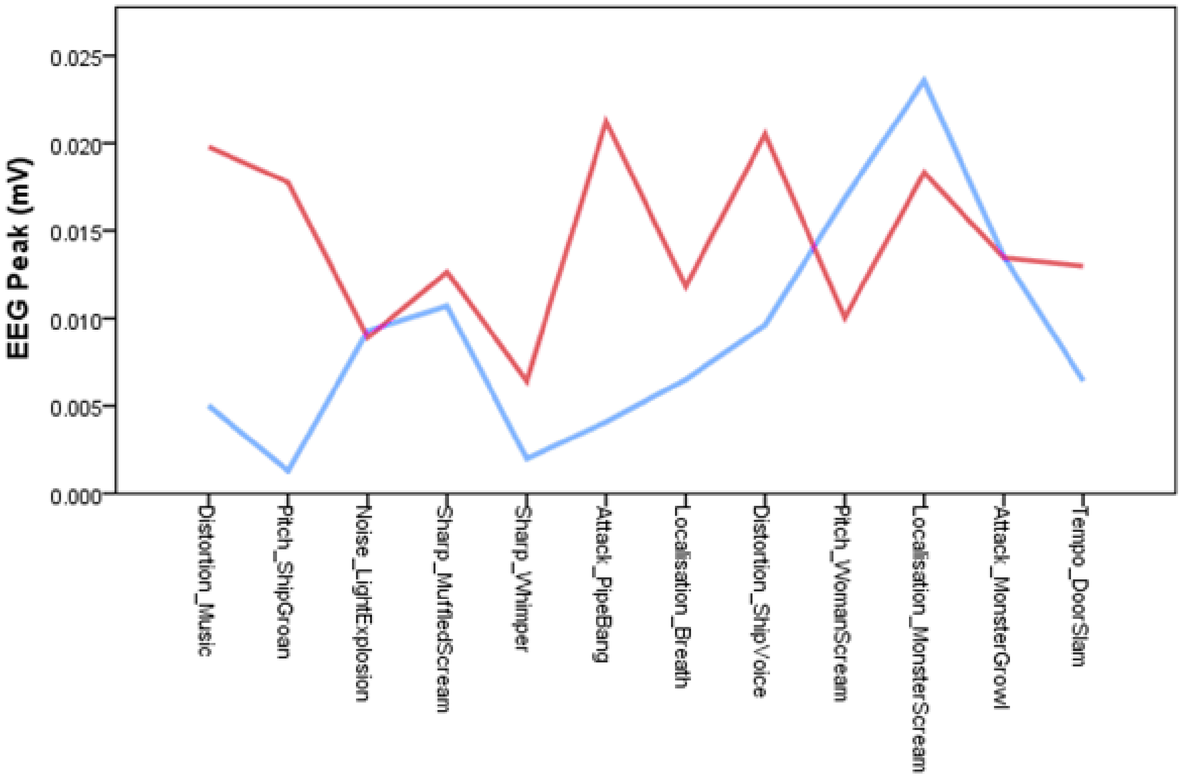
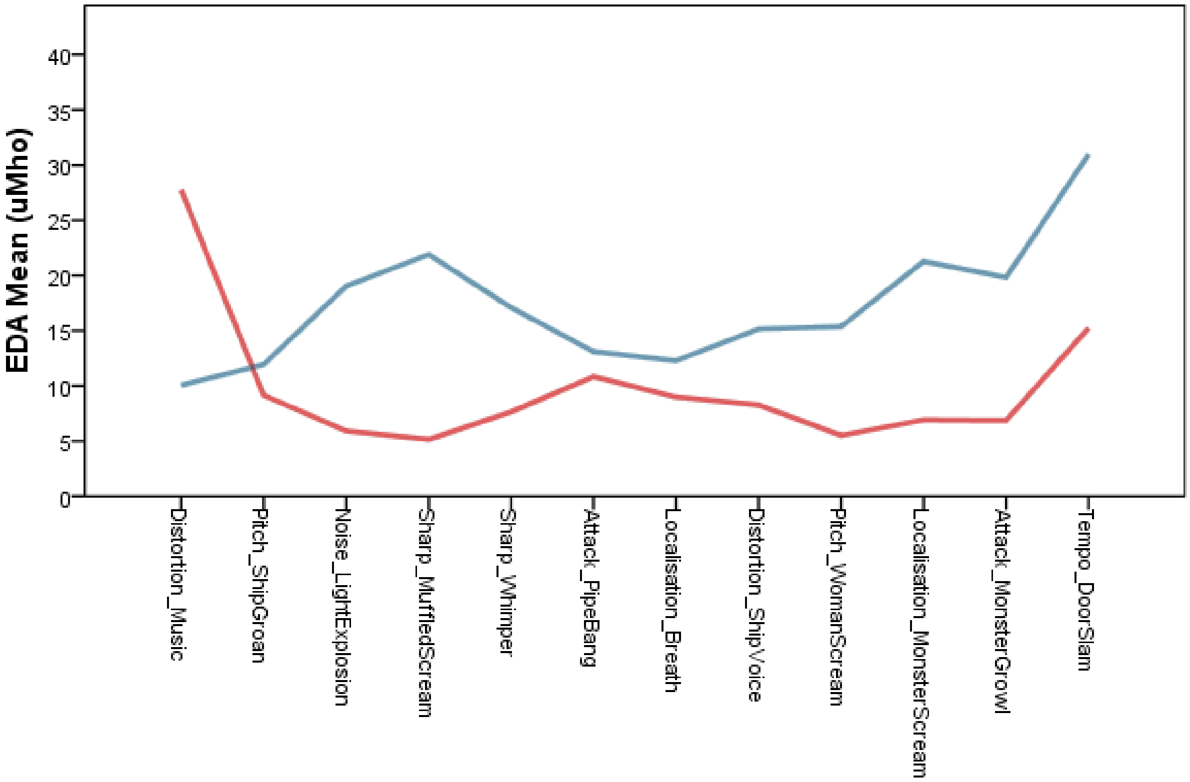


Figure 16: Line graph representing mean EDA values (red = control, blue = DSP treated sound)



3.2 DISCUSSION

As a preliminary experiment, several concerns were foreseeable from the onset whilst others were revealed throughout the course of the study. It is acknowledged that the overarching themes, atmospheres and stylisations of a computer video game are a likely source of variation upon the perception of individual sounds and compound sound events/ambiences, the rationale being that such factors form a contextualising framework against which smaller entities within the game are appraised. To that end it was desirable that two contrasting game levels would be created, providing an opportunity to observe if particular sonic variables had the potential to reliably alter affective states across varied contextual environments. A second game level (*Silence*) was created prior to testing and tasked the player with searching for their missing friend in a foggy woodland environment. A more cinematic feel juxtaposed against a different environment with contrast in the objective, characterisation and colour created a dissimilar experience whilst remaining within the horror theme remit. Unfortunately, its use raised the projected length of testing to 90 minutes per individual and was deemed inappropriate with regards to available resources.

The Biopac EDA/EMG hardware and accompanying software has proven to be a robust and accessible solution. The integrated signal analysis features provide highly usable raw figures upon which statistical analysis can be performed. Connection between players and sensors proved consistent, and the positive reviews from players concerning comfort of use and lack of flow/immersion disruption further advocates both the Biopac system and EDA/EMG biometrics in general as effective data acquisition tools within computer video games research. With regards to the game level design and control interface; observation of the participants' movements, in conjunction with debrief questionnaire responses, revealed a generally high level of usability, with most players able to move effectively throughout the level. The lack of a heads-up display (HUD), text-based instruction and mini-map navigation was regarded by some players as initially confusing, but not a source of frustration. Feedback comments also suggested that the absence of an extra-diegetic HUD improved immersion (via improved realism) and that undetermined player-health feedback increased tension (by way of restricting access to usual game statistics such as hit-points and enemy attack damage, thereby limiting the players' ability to form a defence/coping strategy).

Players also commented that an absence of weapons signified no combat mechanics and after a few minutes of gameplay (in which the player was not attacked or killed) further suggested to players that they could not die, a realisation that quickly reduced fear intensity by way of removing the threat, both within the diegetic narrative (no threat of avatar damage/death) and as an extra-diegetic gameplay tension (no threat of having to repeat part of the level). The limited control interface received mixed reviews with most negative commentary from highly experienced players who felt the lack of *look* freedom (the WASD setup restricted observation movement to the Z-axis) differed too greatly from convention and limited exploration. Players with lower experience ratings however presented a positive report, asserting that the simplified controls increased accessibility. In a search for potential erroneous variables that could have reduced the capacity of the DSP treatment to produce meaningful results, aspects of the testing environment are definite candidates. With reference to electrodermal activity, it could be asserted that ecological validity and laboratory-based bias concerns reduce the capacity to extract meaningful data. It was noted that various aspects of the testing environment (continuous presence of researcher, white-coat syndrome from biometric hardware application and, unfamiliar environment, control hardware, action-button configuration, audio setup and computer monitor / graphics setup) were likely to raise anxiety levels prior to testing and consequently potentially invalidate all subsequent measures in response to game-based stimuli.

The particular durations and placement of data extraction epochs present additional potential for erroneous effects, the most likely problem being the placement of the baseline epoch and the limited time between starting the recording process and starting the game (at which point meaningful measuring begins). EDA trends strongly suggest a reliable peak in activity lasting for (based upon obtained results) up to 90 seconds after beginning the recording and a long decay extending over several minute before a low-level plateau is reached. One potential causal factor could be that the participant was informed when the recording had started, prompting a preparatory state of alertness and focus. As noted within the precious chapter, the exact placement and duration of epochs varies with little agreement as to the ideal. As such it could be appropriate to apply extra resources towards systematic analysis of the biometric signal data from a variety of epoch configurations in search for an ideal arrangement within the specific context of this study.

Whilst that lack of statistically significant difference between the test and control groups could be disheartening, it must be remembered that the primary function of the experiment was to explore new territory, uncover potential methodological problems and present possible solutions for use in future study. Furthermore, the correlation between quantitative biometric data and qualitative debrief responses suggests that data acquisition was notably successful and that the issues are more likely to be associated with the testing environment, equipment and procedure.

3.3 CONCLUSIONS AND EXPERIMENT SUMMARY

Although the results obtained from this study do not support the hypothesis that quantifiable acoustic parameter changes can alter the perceived intensity of fear-related emotional states, they do support the use of biometrics within such experimental scenarios and presents a valuable base from which to build through further study. This chapter strongly advocates a systematic approach to game sound testing, to allow for the plentiful erroneous factors to be addressed. Ecological validity is a substantial concern and future testing will ideally attempt to recreate a comfortable playing environment, comparable to that which a player would experience in their own home. Researcher presence should arguably be minimised and players should not be informed when recording has begun, reducing white-coat effects. Future testing will integrate video tutorials (reducing live researcher presence and adding uniformity to the participant instruction process) and present the player with an interactive tutorial level, allowing them to become familiarised with the interface, control mapping, etc.

and also providing time for stress factors associated with initial exposure to the testing environment to subside. However, recreating such an environment may not be necessary as the developments in biometric technology may soon present us with affordable equipment, suitable for home use and with the robustness and accuracy of research-grade equivalents to source meaningful data acquisition directly from the natural environment. The following chapter discusses the current opportunity for such testing to occur, presenting a selection of consumer-grade biometric headsets that provide affordability and ease of application.

WITH REFERENCE TO THE ACADEMIC REVIEW

The opportunities and concerns raised with regards to the logistics of Experiment 1 certainly resonated with several arguments presented in the relevant review (chapter 6). Comparatively larger numbers of participants were made available (Reips, 2002), physical space and material requirement was minimal (Stanton & Rogelberg, 2001) and the automated data collection/collation process meant that once the tests were live on the internet, there was no additional work required until enough results had been posted (Reips, 1995). Several methodological issues associated with internet-based testing were also reflected during Experiment 1, specifically compatibility issues between browsers and operating systems (see Buchanan & Reips, 2001). In terms of the data collected, the limited difference between online and offline datasets in both HGSD and SOF suggests that the lack of researcher control over participants during online testing (see Krantz, 2001; Nosek & Banaji, 2002; Reips, 2007) may not have been particularly damaging with this methodology and within this specific context.

Direct experience with the psychophysiological measures of electromyography (EMG) and electrodermal activity (EDA) supported many of the assertions referenced within the biometrics chapter (5). EDA proved to be a reliable indicator of arousal (Gilroy et al., 2012; Hedman et al., 2009; Nacke & Mandryk, 2010) and in context, this could be utilised to infer anxiety and stress during gameplay. The EDA equipment was, as expected, easy to apply and operate (Boucsein, 1992; Nacke & Mandryk, 2010) with minimal intrusion for the player (Lorber, 2004). Motor activity (Roy et al., 2008) proved not to be a source of erroneous variation and the temporal resolution, traditionally described as slow (Kivikangas et al., 2010) proved adequate for accurate synchronisation to in-game stimuli. EMG confirmed expectations for high temporal resolution and sensitivity (Bolls, Lang & Potter, 2001) but did not demonstrate as a reliable indicator of negative valence, contradicting much previous research (Harman-Jones & Allen, 2001; Kallinen & Ravaja, 2007). This outcome does, however, support the notion that recreational fear is an ambivalent experience (Perron, 2005; Svendsen, 2008: pp. 75-76). In terms of fear experience, the data obtained from these three experiments strongly supports the concept of a complex, embodied system that is susceptible to reflexive shock, slow-building apprehensive/suspenseful terror and more subtle variations between the two. Despite strong effort to control erroneous variables during testing, between-participant differences remained noteworthy, supporting the notion of interpersonal affective influences such as gender, culture and personality (Mériau et al., 2006; Hamann & Canli, 2004).

The experiments undertaken within this thesis do not confirm or deny many of the auditory processing theories documented within the academic review chapters as this would be beyond the scope of the study. However, with regards to the primary focus of all three experiments (assessing the emotional/affective potential of quantifiable acoustic parameters) the obtained data does reveal both resonance and dissonance when considered alongside some of the previously referenced research. Assertions that parameters such as immediate attack (Moncrieff et al., 2001), slowly increasing intensity (Bach et al., 2009), increasing tempo (Alves & Roque, 2009), low pitch (Parker & Heerema, 2007), and unclear localisation (Breinbjerg, 2005) are supported by the results obtained from these experiments, but not conclusively. The notion that some sounds may have the capacity to universally evoke a particular emotional state by way of underlying evolutionary factors (Parker & Heerema, 2007) remains uncertain due to the presence of contradictory data (for example, participants producing a limited/no clear affective response to sounds specifically designed to evoke evolution-based fear responses). The assertion that sound can be processed pre-attentively (Alho, 1997) is supported by the notably faster response times of EMG (and, in some cases, even EDA) to stimuli than the real-time qualitative responses of players. Indirectly, the lack of clear patterns within the data could be perceived as supportive of the concepts that imply auditory processing as a complex matrix of variables. This includes the discrete modes of listening (Chion, 1994; Gaver, 1993; Grimshaw & Schott, 2008), embodied cognition factors (Wilson, 2002), attention filtering (Ekman, 2009), multi-modal effects (Adams et al., 2002; Ma & McKevitt 2005; Özcan & van Egmond 2009; Väljamäe & Soto-Faraco 2008) and sonification data (Grimshaw, 2007; Schafer, 1994). As a result, data obtained from the three experiments indirectly supports a hypothetical framework of auditory processing that incorporates such concepts.

CHAPTER SUMMARY

The conclusions taken from Experiment 1 weaken the hypothesis that quantitative acoustic parameters can manipulate emotional experience, whilst evidence collected from both Experiments 2 and 3 suggest that context and situational signifiers are essential to evoking fear. Qualitative data taken from these experiments does however suggest that certain DSP effects may cause a context-based response from players without intentional design. Sounds incorporating reverberation, loudness, periodicity/tempo, pitch-shift, sharpness and attack were indirectly described by many participants as significant factors to their emotional states during play. It is acknowledged that the methodologies of these experiments could benefit from further development, but all showed genuine potential, in particular, the capacity of psychophysiological hardware (EMG/EDA) to produce relevant and accurate quantifiable data. The final hypothesis taken from these trials is that context is essential to emotional experience and whilst quantitative sound parameter cannot directly influence affect, they can alter context and therefore influence indirectly. Context/situation is therefore presented as the mediator between sensory input and affective output.

Chapter 8

Hypothetical Frameworks

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Chapter 8: Hypothetical Frameworks

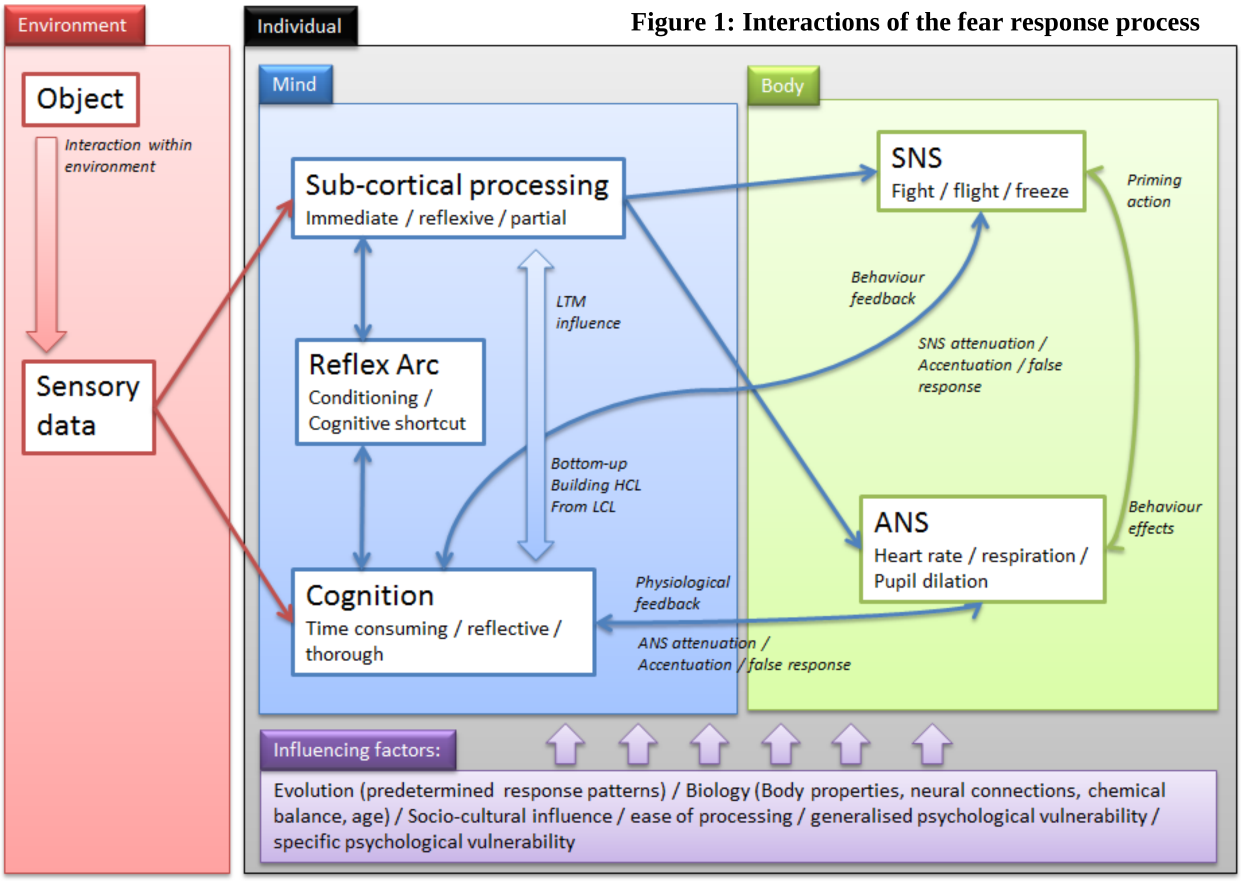
INTRODUCTION

This chapter consolidates the conclusions extracted from both the literature review and experimentation chapters to present several hypothetical frameworks based upon interrelations and processes within audio perception and emotional experience. The purpose of these designs is to provide initial (but nonetheless, well supported) hypotheses of what component entities and interactions exist within the emotion-listening process. The inclusion of evidence sourced from both academic review and primary experimentation supports the assumption that although these frameworks are expected to develop gradually, they are highly unlikely to be rejected completely. Future research is expected to prompt small modifications but, overall, the development of emotion-sensitive game sound will arguably be more efficient if based upon (and building from) these frameworks.

INTERACTIONS AND PROCESSES WITHIN AN ECOLOGY OF FEAR

Figure 1 outlines the interaction of the fear response process within a natural environment and is not contextually specified towards computer game play. Display of the theory associated with human fear response reveals the complex nature of the interactions, with the majority of the causal links bidirectional between framework entities.

Figure 1: Interactions of the fear response process



The process presented here follows the Cannon-Bard theory (1931) of emotions, with sensory data processed via some aspect of the central nervous system (though not necessarily the brain). Although figure 1 does not directly reference sound or computer video gameplay, many of the key entities and processes featured here are also presented in later (more thesis-specific) frameworks. The key assertions within this framework are as follows:

1. Brain processing of sensory data is highly unlikely to be exclusively cognitive or sub-cortical. Instead, there exists a continuum where (depending on the influencing factors) cognition or sub-cortical processes take varying ratio preference.
2. The interactions between the mind (the brain and central nervous system [CNS]) and body are largely bidirectional, meaning that although the process begins with impulses translated via the CNS, the resultant changes in physiology are *felt* by the individual and therefore fed back into the system to influence the future processing. For example, an individual may hear an unfamiliar sound, interpret a threat and feel fear. This response may then trigger increased heart-rate, perspiration and a perceived drop in temperature. The individual has an awareness of these physiological state changes that they interpret as confirmation of threat that, consequently, heightens the fear experience.
3. All elements within the mind/body process are susceptible to embodying influences either directly or indirectly.

Figure 2: Ecology of fear within a virtual environment

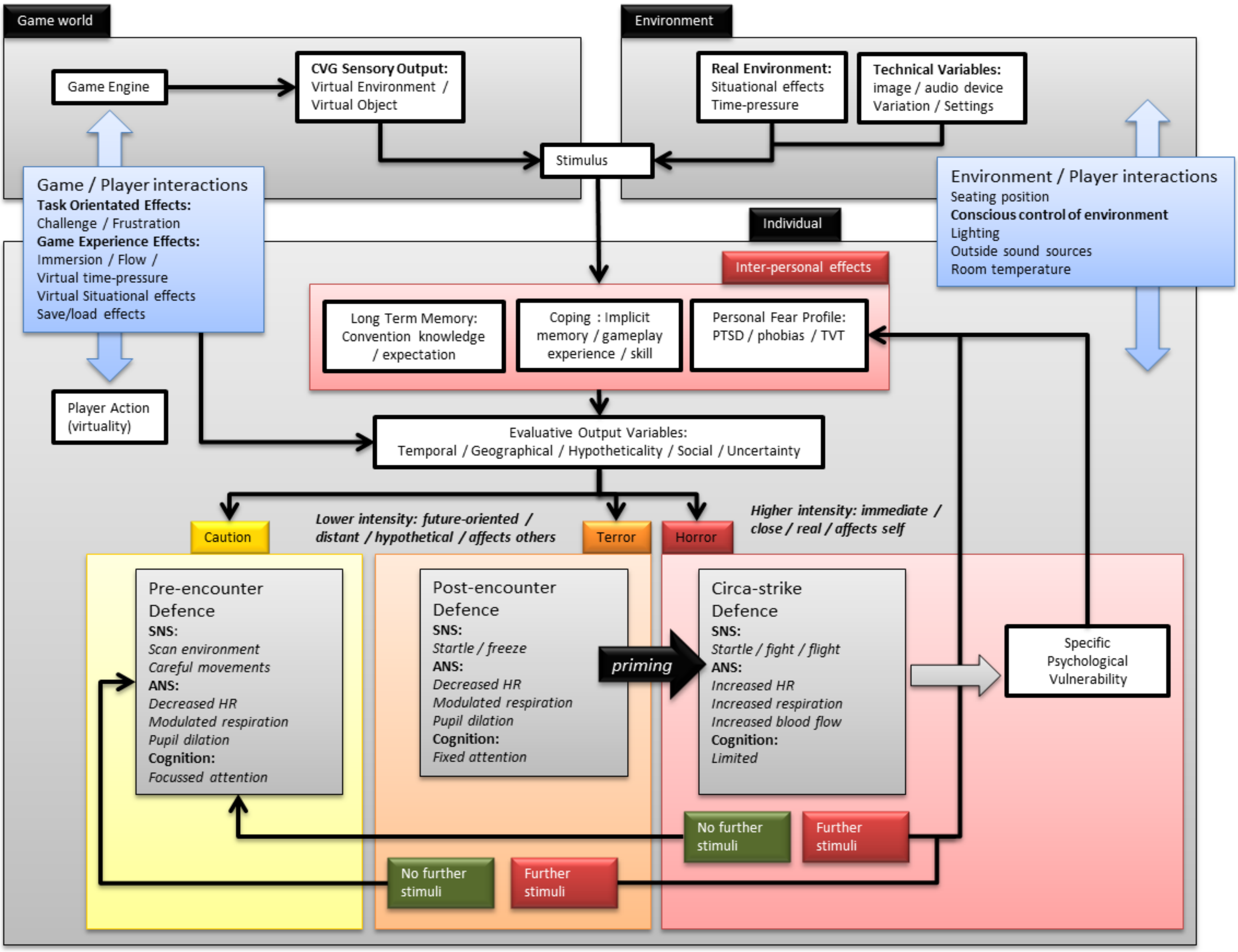


Figure 2 is largely built around the *fear-stage* concepts of pre-encounter, post-encounter and circa-strike defence (Fanselow, 1994). Reaching a particular stage is dependent upon the psychological distance between the individual and the fear-object. Embodied cognition and computer video game theory contextualise this framework, which is intended to reveal the many variables that exist within a fear scenario; both those contained within the individual (personal fear profile, memory, triple vulnerability theory, etc.) and the external variables originating from the natural environment and the virtual game world. This framework elucidates that ways in which almost any element of the system can impact upon any other. This refers to both the macro (environment influences player, player influences game, game influences environment) and micro elements. For example, low background environment sound increases signal to noise ratio. This makes game sound more intense and the player experience circa-strike defence during play. Their dislike of this experience causes the player to turn down the sound within the game system.

INTEGRATING AUDIO CLASSIFICATIONS INTO A FEAR FRAMEWORK

Goodman (2010: p.69) states that ‘cognitive faculties of the auditory cortex do not need to be engaged for fear responses to be engaged’, positing that autonomic processes can evoke a fear response from an audio stimulus as a result of innate processes or operant conditioning. Whilst this suggests that audio signals are capable of inducing a fear sensation by way of biological, psychodynamic and cognitive processes, the question remains as to what properties within an audio stimulus cause a fear response and whether such parameters can be manipulated to attenuate or amplify a fear response. This section discusses various classifications of game sound (reflexive/cognitive responses, listening functions, representative functions) and positions them within a framework of fear.

The power of suggestion has been documented in studies pertaining to experiences of the paranormal (Lange & Houran, 1997) and arguably proposes that it is the preparation of the individual, by establishing a situational context before exposure to explicit fear cues (activation of *pre-encounter defence* [see chapter 3]*)*, that chiefly determines the impact of subsequent fear stimuli. Garner et al. (2010) compared relative pitch, loudness, and localisation changes across several sounds experienced whilst playing a computer game and discovered only limited association between acoustic parameter modulations and emotional impact. Referring back to this thesis, the experiments documented within chapters 6 and 7 did not intentionally characterise the nature or situational context for the sounds employed and it is therefore suggested that not integrating a controlled contextualisation may have attenuated the potential of the parameter modifications. Adding a heavy reverberation without context may have little effect on the impact of a sound, whilst a pre-established gameplay element in which the player is required to identify the position of a sound to avoid the source may have a significant impact as, within this context, the reverberation obscures localisation, reduces coping affordance and increases player-action uncertainty. These notions support the hypothesis that fear, in response to audio stimuli, cannot be significantly augmented by way of universal quantitative acoustic parameter manipulation. The modulating of acoustic parameters must be integrated as part of a situational framework that considers both an established fear experience profile and variation between individuals; creating perceptual audio characteristics that are the key to effective fear manipulation.

Referring back to chapter 3, Fanselow's (1994) three stage structure of fear induction (pre-encounter, post-encounter and circa-strike) provides a contextually relevant method of sound classification in which psychoacoustic/perceptual characteristics can be mapped onto a framework of fear. The nature of pre-encounter defence dictates that stimuli have greater psychological distance (that they are future-orientated, physically distant and hypothetical/suggestive). These sounds are to set the scene and establish mood, tone and atmosphere, consequently denoting that the threat-object is not (yet) present and the audio stimuli available instead signify the immediate environment and entities indirectly relating to the threat. Ainoplast, chronoplast and topoplast functions of sound, first presented in Grimshaw (2007), denote periods within history, the passing of time and the architectural space of the environment respectively. Sounds that possess Schafer's (1994) archetypal sound (historical, symbolic and mysterious sounds), soundmarks (sounds native to a particular location that support identification of place) or keynote (ubiquitous and often ever-present sounds that are not always consciously attended to and, as such, exist in the background of the soundscape) characteristics arguably belong within the pre-encounter stage as their primary functionality to establish scene and present an implicit, rather than explicit threat. Kinediegetic (initiated directly by player action) and proprioceptive (internal bodily) sounds are more complex and likely to transcend Fanselow's stages of fear, depending upon their relative intensity. Whereas low intensity variations (light shaking of player-held lantern, sound of player's slightly elevated heartbeat) suggest initial caution (pre-encounter), high intensity variations (player gasp/scream, dropped lantern hitting floor, etc.) instead reflect increasing terror (post-encounter) or revelatory horror (circa-strike).

Stimulus appraisal in the pre-encounter stage is likely to employ cognitive, high level construal appraisals and anxiety is hypothesised to be present yet relatively low while listening function is expected to be functional, semantic and/or reduced as the listener is afforded more time with which to fully assess the scenario. Within a computer game context, critical listening is also feasible, whereby the player may assess the quality and appropriateness of the sound. To successfully evoke pre-encounter defence, the sonic environment must suggest a locale in which threat exists at a psychological distance. Avatar footsteps treading on disembodied flesh and bone, distant screams of an agonised victim, reverberant acoustic paraspaces (a term coined by Parkes and Thrift [1980] that Grimshaw [2007] refers to as 'a space that, within the acoustic ecology, [that] describes and provides immersory and participatory affordances to do with location, time and cultural and social factors') that obscure localisation, all connote danger at a distance and strongly advise caution without presenting a sound that is directly causally related to the threat-object.

The above classifications of sound possess specific traits that arguably imbue them with high psychological distance (PD) and consequently, within our fear framework, sounds within these classifications retain a pre-encounter *fear function*. Post-encounter defence however, demands decreased PD whilst maintaining a degree of uncertainty. Within this phase there is arguably a great deal of flexibility available as alternative aspects of PD can be manipulated to reach the same affective endeavour. Signal sounds (foreground sounds that are designed to be consciously attended to [Schafer, 1994]) are hypothetically more appropriate within this phase, whereby the player is expected to perceive these sounds as originating directly from the threat source. If we are to accept that the terror stage potentially activates the behavioural inhibition system, freezes movement and potentiates hyper-attentiveness, then an audio stimulus that generates such a response matches the profile of a retainer - a sound that encourages a player to remain in the same location (term originally from McMahan [2003] and adapted for sound by Grimshaw & Schott, [2008]). As noted above, kinediegetic and proprioceptive sounds may also be present; however, the more intense nature of the post-encounter stage suggests that such sounds should reflect this increase (heavier breathing, increased heart-rate, lighter footsteps, etc.). In terms of PD, the hypotheticality and social distance parameters of sounds that fit within the post-encounter phase are reduced as the source is assumed to be actual and attentive towards the player.

Assuming player attention is more acutely focussed; then causal, empathetic, semantic and functional listening is expected within the post-encounter phase as the player may attempt to derive actionable information to support a coping strategy. Here audio designers may decide upon what information they wish to reveal. Sounds that disclose threat intention and emotional state may serve to accentuate fear intensity whilst localisation data may attenuate it. Acoustic properties that signify physical characteristics are deeply subjective in their capacity to modulate a fear response. Clichéd characteristics, including large size, fast movement, unpredictable behaviour, distorted appearance, and great strength, are preferential but their effectiveness remains at the mercy of the player’s individuality.

As discussed previously in chapter 3, the circa-strike defence (revelatory horror event) operates initially by way of an automated behavioural process dependent upon evolutionary and conditioned response routines. As a result, initial appraisal of horror-type audio stimuli is expected to induce reflexive and connotative listening functions to support immediate and decisive response behaviour. An audio stimulus within this context could be described as an attractor – a sound that induces immediate player response (Macmahon [2003] again, adapted for sound by Grimshaw & Schott [2008]). High intensity kinediegetic and proprioceptive sounds can reflect the nature of the horrifying sensation (gasp, scream, player damage).

However, because the complete horror response is not solely an innate, spontaneous reaction, we must continue along the line of fright (Massumi, 2005) where the initial reflexive function is gradually replaced by higher level appraisal as the individual moves out of the circa-strike defence state by increasing the PD between themselves and the threat (e.g. running away from threat to increase physical distance, placing barriers between self and threat to increase temporal distance, etc.). The horrifying stimulus can then be more comprehensively evaluated as the individual reverts to either a terror or caution state (or is relieved from the fear sensation entirely) depending upon the new circumstance. Within this transition between circa-strike and resolution states, sounds within the immediate environment may act as *calmers*, signifying increases in PD (decreased volume of the threat giving chase to signify you are successfully evading, the slam and locking sounds of a heavy door that denote increased safety as a result of an effectively positioned barrier, etc.)

Figure 3 consolidates the above theories to explicate the interactions between audio stimuli and emotional response in a fear context. It is suggested that perceived characteristics of a sound determine the processing pathway and that appraisals of stimuli have the potential to influence the perception of subsequent audio input; in certain cases, conceptually priming the individual for appropriate action in response to possible, high intensity stimuli. In addition to the three states documented by Fanselow (1994) a relief state (referred to as *safe*) is added to create a more complete set of fear states. Comparative analysis of the four alternative fear-arousal states reveals increasing autonomic processing and limited cognitive appraisal in response to greater perceived intensity (relating back to figure 1). Listening function reflects this assumption; aligning critical and evaluative functions to cognitive appraisal whilst immediate and reflexive listening is allied with an autonomic response.

Figure 3: Classification of game sound within a fear scenario

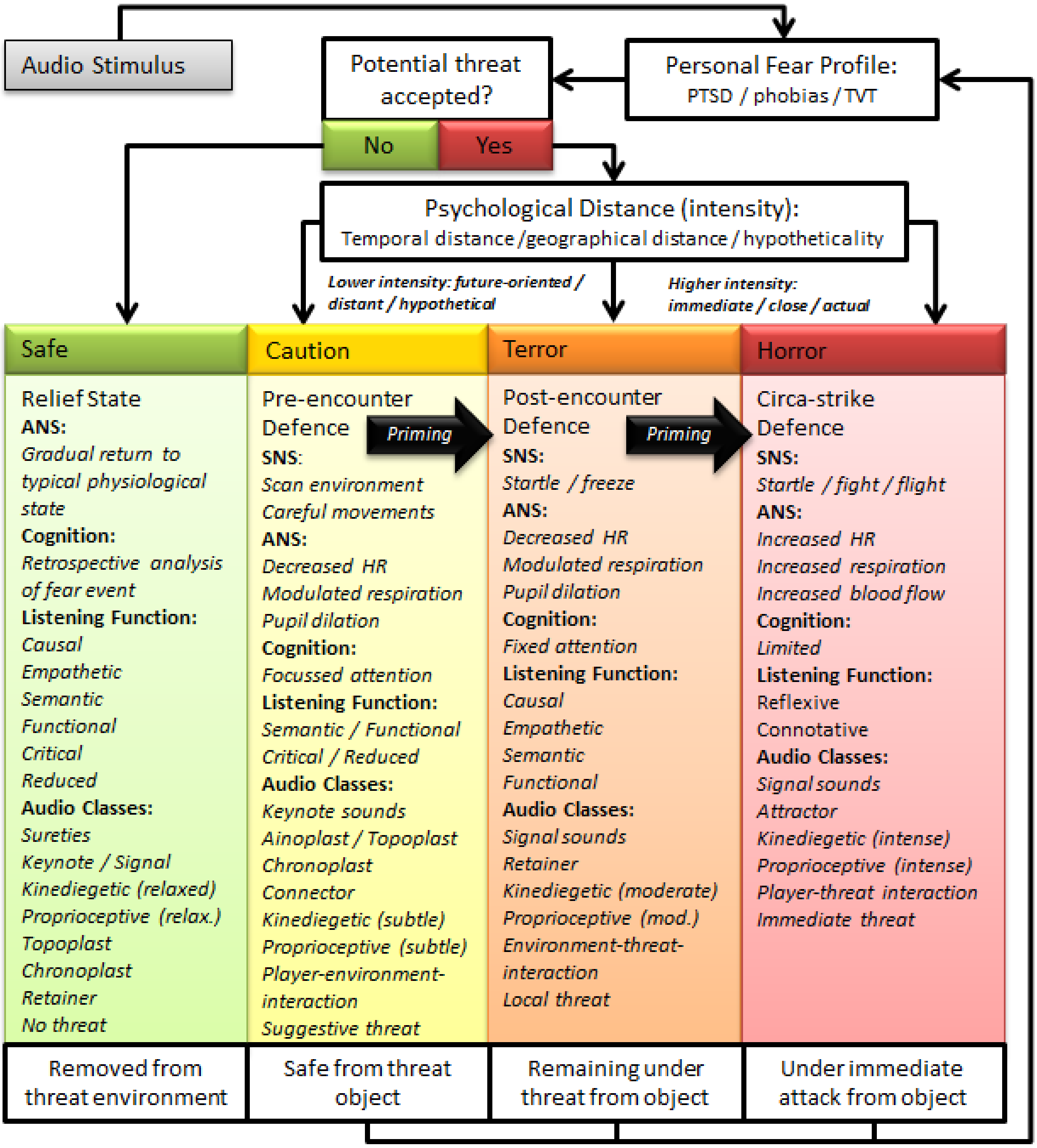
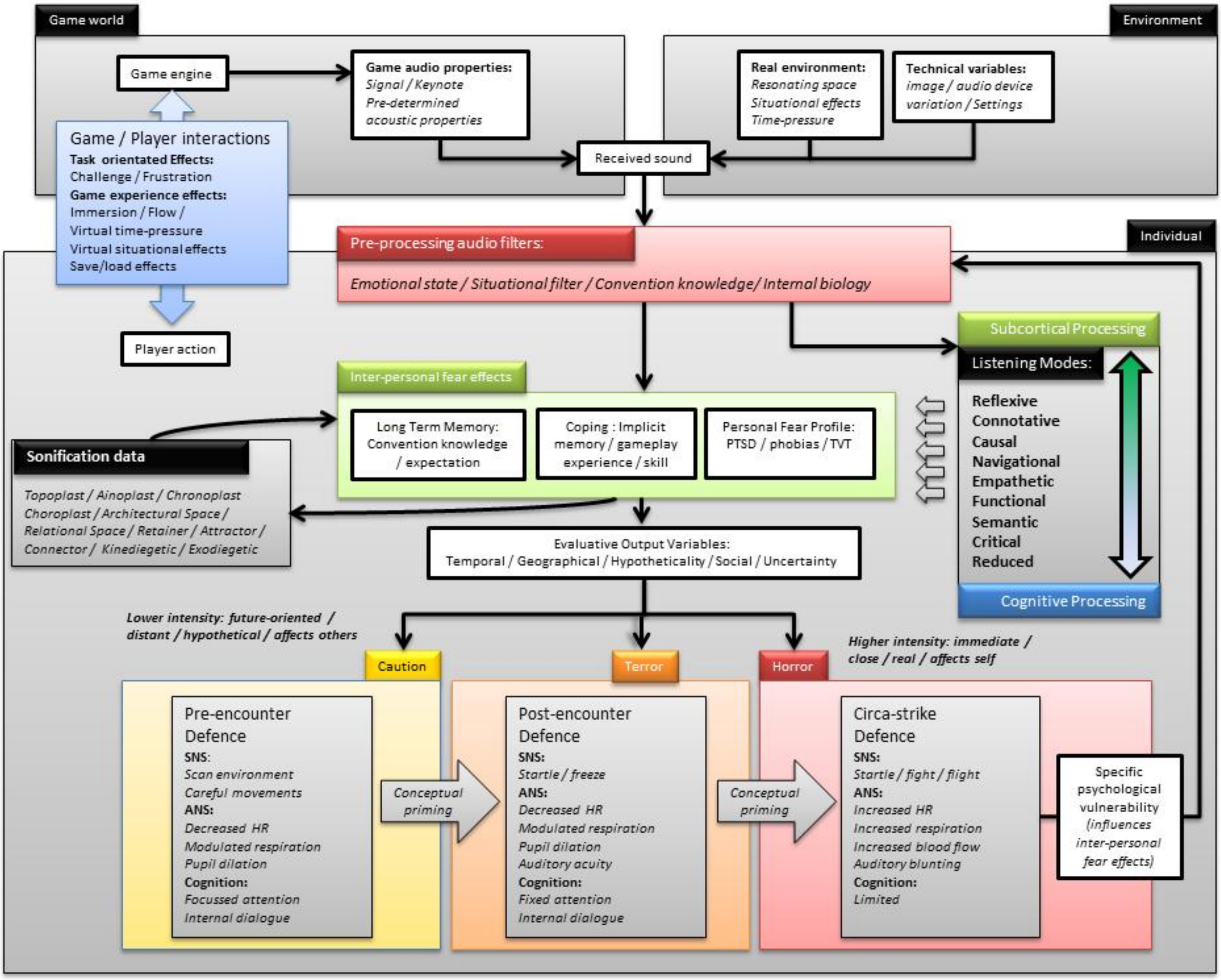


Figure 4 extends the framework documented above to produce a visual representation of a theoretical structure that elucidates the interrelations between individual player, the virtual game world and the environment of reality. The purpose of this framework is to display the complex interactions and processes that occur during gameplay which could then be exploited to manipulate a player's fear response through informed audio design.

Figure 4: Interactions between virtual and real acoustic ecologies in a gameplay context



Ultimately, this framework could potentially act as the foundation for an automated *fear evaluative* audio system, capable of combining data from the game engine (acoustic properties, intended perceptual quality, player action, gameplay contextualisation, etc.) with real-time biometric input to effectively evaluate the fear evoking potential of sound (individual or collective) with relevance to the player. Such a system could potentially generate an understanding of an individual's personal fear profile, which could then alter the properties of audio featuring later in the game, maximising the fear experience.

AN EMBODIED VIRTUAL ACOUSTIC ECOLOGY

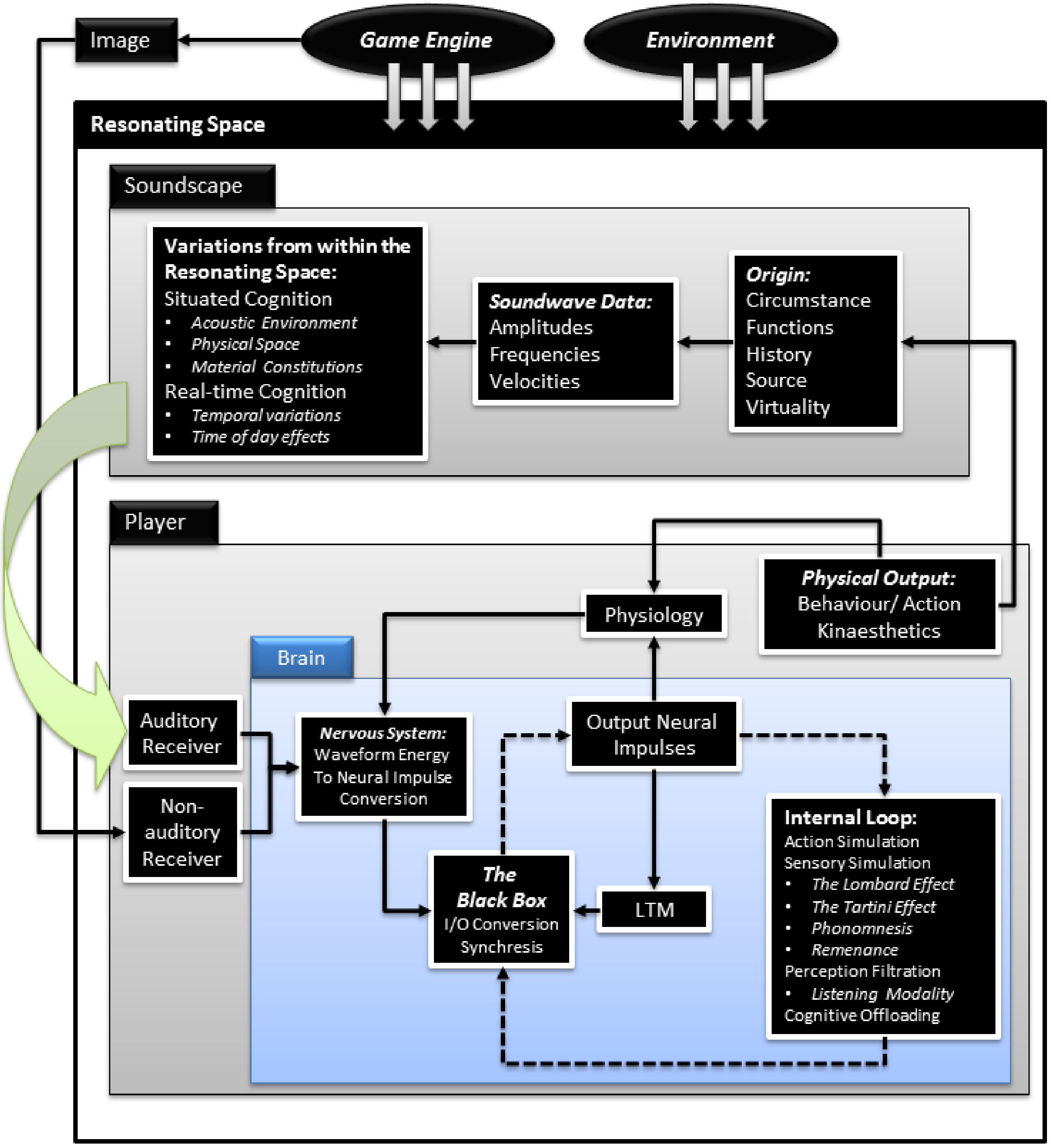
In this section, the advantages of embodied cognition (EC) theory in advancing the understanding of game sound, particularly within an interactive and ecological context are examined. The final framework, visualising an embodied virtual acoustic ecology (eVAE) is also presented to better assert the advantages of EC theory and elucidate the interactions between player, environment and computer video game with a focus upon soundscape variations and brain-processes. Chapter 4 documented several auditory phenomena (largely taken from Augoyard & Torgue [2005]) that included anamnesis, narrowing and the Lombard effect. Within this section it is asserted that if we are to acknowledge the existence of such effects, it is logical to consequently assume that auditory processing is an embodied event, dependent upon the relationship between physical environment, memory and physiology.

Developing from R. Murray Schafer's (1994) notion of acoustic ecology, Grimshaw and Schott (2008) propose that, within a CVG context, there exists a virtual acoustic ecology (VAE) that combines the player, game soundscape (derived from the game's engine) and environment (known as the *resonating space*) as an integrated system. Whilst this framework arguably incorporates EC theory, the VAE construct could be cross-examined with the exploration into EC documented earlier within this chapter in an effort to develop a more fully embodied virtual acoustic ecology framework (eVAE).

Figure 5 visualises a potential procedural chain to better elucidate the looping mechanisms and inter-relating variables that impact upon our perception of game sound within an embodied framework. Critical elements of the VAE construct remain (such as soundscape, resonating space sound functionality and perceptual factors) but specific constructs within the player are now presented that suggest the functionality of EC. At the origin stage, soundwaves are acknowledged to be resultant from a complex matrix of historical and circumstantial factors (asserting that the sound is not only dependent upon the here and now, but also a highly complex chain of past events that have led, by way of causality, to the present) but, irrespective of this stage, the resultant wave can always be reduced to velocity, waveform amplitude and cycle frequency. Resonating spaces are asserted as key determiners of the *here and now* of EC theory, in that the physical makeup of the environment may (through only minor perturbations in signal processing) dramatically alter the perceptual data extracted during cognition.

The dynamic nature of resonating spaces further accommodates the notion of real-time cognition as changes within the physical environment (shifting temperatures, position/density of reflecting surfaces, new materials entering/leaving the resonant space, etc.) have significant potential for signal attenuation/amplification, meaning that no two sonic waveforms should have precisely the same acoustic data outside of a heavily controlled environment. The internal system map displayed here acknowledges the embodiment theory that the central processing unit (CPU) is continuously affected by incoming sensory data, the physiology and the long-term memory of the listener. The term *Black Box* alludes to the limitations of this mapping in that the actual process of converting neural input signals into output impulses (that drive both external action and internal looping systems) remains unknown. One immediate application of this visualisation is derived from its highlighting of key points within the listening process that a designer could focus upon in an attempt to artificially replicate a desired sonic perception. The most apparent eVAE framework element to replicate/synthesise would arguably be the *soundwave data* (the acoustical information that constitutes a complete sound) and this is certainly a common choice within game sound design.

Figure 5: A modified Virtual Acoustic Ecology implementing key Embodied Cognition theory



The line of sound detailed within this framework has interestingly coincided with the developmental approach to game sound design. 8-bit era designers would focus upon manipulation of the origin elements of the sound (plot/circumstance factors or graphics that clearly signified the source of a sound, such as a whirling loop sound presented in tandem with a recognisable UFO sprite, all revealed within an alien-themed game) due to the limitations of waveform synthesis to replicate organic sources. As the game's medium shifted from cartridge to compact disc, designers moved one step forward and attempted to create convincing sonic illusions by focussing upon the soundwaves themselves. These sounds were designed to clearly reflect their origins *and* the current environment, acknowledging the *here and now*. In our current seventh generation of gaming, we are arguably now one step further, experimenting with virtual acoustics as our technology enables us to artificially replicate complex acoustic environments. The key characteristic of these artificial acoustic environments is their capacity to function in real-time, acknowledging the *time-pressured* view of EC theory. To explain, Wilson (2002) described embodied cognition as situated in both space and time. Time-pressured cognition refers to the notion that ‘situated agents must deal with the constraints of [real-time]’. Referring back to the current FPS game engines, audio technology enables sonic landscapes to act (and react) in real-time. For example the sound profile of an approaching monster (splashes, roars, grunts, etc.) in *Amnesia: the Dark Descent* (Frictional, 2010) is augmented, in real-time, in response to interactions between the player’s actions and physics parameters within the game. If the player moves quickly from the monster, overall volume decreases whilst ambient reverberation is increased (although the sounds themselves otherwise continue), signifying to the player that, although the monster is still in pursuit, there is greater distance between them and that they consequently have more time to escape. This progression suggests a general consensus between game sound developers that an embodied approach is highly fruitful in increasing the experience of the *real* during gameplay, as each step of progress has incorporated a key view of EC theory. The embodied virtual acoustic ecology progresses further by considering the interactions between both the virtual and actual resonating spaces and takes artificial manipulation right up to the ear itself.

The amalgamation of circumstances required to facilitate even a simple sound contains a large enough number of elements that, if artificially replicated, would be perceived as real. Take the specific sound wave generated from a gunshot as an example. Even before we consider the environmental impact put upon the wave as it travels from the source to the ear, it is true such an event cannot simply happen without a complex set of requirements met. There needs to be a gun, a bullet, a shooter and a target. There must be a motive, driven by incentive and/or disincentive, which itself requires a complex arrangement of entities, associations and processes. Early game developers lacked the technology to artificially replicate a believable gunshot sound wave, but they could replicate the circumstances leading to that sound, artificially replicating the shooter as a player avatar, the target/weapon as a sprite graphic while the motive was established via plot or simply the player's awareness that “*this is a game and it is my job to shoot things*”. These techniques presented the player with an associative dataset that, when combined with the soundwave data, could manifest a perception of the sound as real.

Currently, most of these methods could be described as non-invasive, in that they only replicate a segment or segments of the data processes that occur externally to the human body. In relation to this, the embodied virtual acoustic ecology diagram reveals the possibility that if we are not to push deeper, into the brain itself, we may have almost reached the limitations of how immersive and believable we can make sonic environments. If it were possible to replicate either input impulses (converted from sensory data) or the output neural impulses (converted from input signals via the Black Box), it could essentially short-circuit the framework, enabling the internal loop to function without actual sensory input. One important question to consider is which neural impulse node (in or out) should be replicated? The answer to this question could be dependent upon the comparative difficulty of distinguishing I/O signals from electrical noise.

CONCLUSIONS AND CHAPTER SUMMARY

The hypothetical frameworks presented within this chapter take influence from all the information already documented earlier within the thesis to ensure that their structure and properties are well-supported, although it is acknowledged that further testing is necessary to confirm absolutely their correctness.

The central hypothesis, relevant to all of these frameworks, is that an awareness of a concrete psychological process that determines user-response to auditory stimuli would provide a great advantage over improvisatory sound design, in computer video game contexts and beyond. Understanding how the various influences of our embodied experiences cause our unique perceptions of sound could ultimately be used to accurately predict perception from controlled sound characteristics. These frameworks deliberately attempt to arrange the complex notions of audio perception and emotion processing as structured blueprints, characteristically similar to computer language. The intention is to create a representation of these processes that is compatible with electronic code in a way that would enable a software program to automatically predict perception outcomes from a programmed artificial awareness of the sound’s properties and contextual information. From this, the software could actively manipulate the emotion outcome by controlling the sound output within the game engine, then evaluate the effectiveness of the sound via biometric feedback, enabling the system to self-customise in response to each unique player.

Chapter 9

Conclusions and Future Work

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Chapter 9: Conclusions and Future Work

INTRODUCTION

This closing chapter revisits the discussions, frameworks and experiments of the thesis to present a final summary of the contributions achieved and concluding arguments that will inform future study. An outline of further research that is expected to continue on from this thesis is also documented as is a brief comparative analysis of two consumer EEG devices that might be used for such research.

SUMMARY OF PhD PROGRAMME

Understanding emotionality is a crucial aspect of human-computer interaction and sound is a critical component to consider when developing emotionality as it is directly associated with a user's experience of emotion (Alves & Roque, 2009). This thesis has documented theoretical research and associated experimentation within the study of acoustics and fear. The work produced was continuously framed within the context of computer video games. The primary aim of the thesis was to collate literature from a range of disciplines to develop a framework of acoustic ecology within the context of fear. The intention being to develop our understanding of the role sounds (excluding musical and speech) play in eliciting fear during gameplay and to provide quantifiable evidence to support the hypothesis that manipulation of acoustic properties could affect the intensity of an individual's fearful experience.

This thesis brought together core concepts of embodied cognition (Wilson, 2002), acoustic ecology (Truax, 1978), virtual acoustic ecology (Grimshaw & Schott, 2008) computer video game experience (Grimshaw, 2007) and fear processing theory (Massumi, 2005) to construct three hypothetical frameworks: an acoustic ecology of fear (both within and outside of a virtuality context), a model of virtual and natural acoustic ecology interactions and an embodied virtual acoustic ecology model. Beginning with an overview of emotions, fear conceptualisation and sound processing; the thesis examined the six main concepts of embodied cognition (Wilson, 2002), thrownness, construal level theory and psychological distance (Heidegger, 1927; Lieberman & Trope; 2008; Winograd & Flores, 1986). These concepts were strongly advocated within the thesis and heavily influence the hypothetical frameworks that could, in turn, provide the basis for a future research programme (outlined below). Existing empirical and conceptual research concerning acoustic parameters, audio classes and modes of listening was also amalgamated and refined within a survival horror game context and additionally includes a consolidation of literature relevant to internet-mediated experimentation.

Empirical investigation included several experiments measuring players' experience of fear by way of both innovative subjective analysis (real-time intensity vocalisation) and quantitative biometrics. Obtained data revealed that changes in acoustic parameters of game sound can have a significant impact upon the player's emotional (fear) experience and both empirical data and secondary research was amalgamated to produce a hypothetical process of fear that was then re-contextualised into a gameplay-relevant acoustic ecology. The intention of these hypothetical designs was primarily to present a transparent, testable framework of audio perception and fear experience that would enable game designers to better understand the emotional responses audiences would have to their sound, enabling them to create a desired impact upon their audience more effectively and efficiently than improvisatory (trial and error) processes.

The experiments presented within this thesis utilised many of the ideas taken from the preceding literature review chapters to begin exploring the emotional qualities of acoustic parameters. This work was preliminary (and also served to test the effectiveness of the methodologies themselves) and future work is expected to provide more highly specified detail. Most specifically, the variances in fear elicitation that can be observed in response to a comprehensive range of parameters within individual acoustic effects. Increased specification could address the impact of particular parameter settings, for example: level of high-pass filtering within reverberation, degree angle within localisation, and individual frequency bands within equalisation. Such detail would enable the development of a comprehensive understanding of the relationships that exist between quantitative acoustic manipulation and subjective emotional experience within a computer video game context. This could eventually lead to the creation of a concrete sound-emotion reference guide, enabling sound designers to immediately discover the expected affective potential of a sound based on its acoustic and contextual characteristics. Such a system would likely evolve over time as social and cultural factors shift our affective perceptions; therefore the original frameworks presented within this thesis would remain valuable as tools to update such a reference.

CONCLUSIONS AND RETROSPECTIVE EVALUATIONS: CHAPTER 2

Chapter 2 discusses the origins, definitions and perspectives concerning human emotions, including an assessment regarding the value of developing a greater understanding of the underlying processes and an evaluative overview of alternative classification techniques. An argument correlating physiology and emotion is presented, followed by an approach to emotions from within a computer video games context and finally, an introductory synopsis of fear (and associated terminology).

A key assertion of Embodied Cognition theories referenced in this thesis is that emotions are an integral part of human thought processing. They are posited as vital to communication, decision-making, survival and reproduction. Consideration of emotions will arguably be of great benefit to human computer interaction development and could significantly improve the power of educational tools/software. Emotions are inherently functional and dysfunction only arises in response to sociocultural clashes where the rapidly changing, geographically bound and contextually specific requirements of behaviour within relationships often demand that we oppose our own natural impulses. Chapter 2 also provides a consolidation of various theories of emotion, enabling efficient access to an array of theoretical standpoints. Theory surrounding emotion study has developed significantly across time, with some past beliefs expunged and replaced with heavily contrasting hypotheses. Currently, there remains an absence of unanimity between both large and small populations with disagreements present between individuals to entire cultures/civilisations. An overview of literature concerning emotions and neuroscience indicates that there is a great deal of information that suggests involvement of various brain structures in emotion processing but the technology and understanding is not yet capable of confirming such assertions or revealing the precise nature of their involvement.

With regards to the development of artificial emotion recognition systems, biometric emotion classification structures utilising dimensional models that differentiate emotional states via trait descriptors (intensity, valence, dominance, etc.) are argued to be more appropriate than a discrete model. Artificial emotion recognition should therefore not attempt to determine a specific emotion (fear, joy, sadness, etc.) from biometrics alone, but instead gather a dimensional profile and contextualise that information from environment/circumstance data to finally infer the emotion. The dimensional model is also preferable because the question will not always be *'what emotion is being experienced?'* but instead *'what is the nature of this emotion and how is it changing within the same discrete experience?'* During survival horror gameplay, an individual may be experiencing fear throughout, but the specifics are dynamic and fluctuate throughout play. In this scenario, parameters such as valence, intensity and dominance are of heightened importance.

Because we no longer live in environments within which we must continually and literally fight for our survival (hunting/gathering food, defending from predators, etc.), our evolution-defined emotional mechanisms are not exerted in the same ways and now fit into different, sociocultural frameworks in which primal emotional experiences can be virtually experienced in a recreational context. With regards to emotional experience within a CVG context, this chapter distinguishes between artefact (A-), fiction (F-), gameplay (G-) and representative (R-) emotions (Perron, 2004; Tan, 1996). Irrespective of whether the player's emotional state is gameplay, fiction, representation or artefact-orientated, game sound designers have to remain aware of the interactive nature of computer video gameplay. Repeated playthroughs (from small sections to replaying the entire game) will undoubtedly evoke differences in emotional response. An additional related conclusion is that a greater consensus of emotion terminology and theory within a CVG context is required to increase the pace of pragmatic development.

With the focus switched towards fear and its subsidiaries, horror is determined to be a more immediate, intense experience and more closely related to shock and disgust; it is revelatory. In contrast, terror is measured and reflects suspense; it is anticipatory. Threat is a necessity for fear elicitation, the significance of which will largely determine the intensity and dominance of the affective response. Fear within a recreational context is positioned as a desirable emotional experience and it is argued within various academic texts (documented within Chapter 2) that the attraction of recreational fear lies in the potential to experience fear and overcome it or relish the relief when the stimulus subsides. The presence of an intrinsic aesthetic appreciation in the dark and macabre, concept of sublime is also asserted and this chapter closes with a model of the interactions between horror and terror within a survival horror gameplay context, elucidating (theoretically) the way in which individual *horror-events* augment the *terror quota* over time.

CHAPTER 3

With an emphasis upon the nature and processes of fear, chapter 3 commences by suggesting that current sound design practice within survival horror games is largely a creative and improvisatory process, with designers instinctively crafting the soundscape from subconscious influences within their own experience. In response to this, a comprehensive understanding of the core processes that underpin a fear-related experience could provide a more grounded, stable foundation of design upon which creative processes can add character, artistry and aesthetic structure. It further states that (as also suggested in chapter 2) understanding emotional experience is highly valuable in human-computer interaction applications, primarily with regards to usability and decreasing user-frustration but also in the development of more fluid and organic operations and workflows and increasing user engagement and productivity levels.

Chapter 3 provides a thesis-contextualised definition of fear subcomponents; differentiating horror, terror, suspense, shock, anxiety and disgust. One significant assertion raised here is that there is a hard-wired core of emotional processing, formed and reinforced over many years by way of evolutionary development that transcends sociocultural and individual differences. Threat is concluded to be a necessity of fear and is determined by the nature of potential loss (the most extreme loss being death of one’s self or loved ones).

With regards to CVG applications, genuine fear is posited as the instinctive response to the perception of a threat as real; therefore, to evoke an authentic fear response, a survival horror game must immerse the player within the game world and make the narrative and virtual environment feel immediate and dominant. It is argued that immersion is intrinsically connected to realism but not simply to the concept defined as an objective set of virtuality characteristics, indistinguishable from reality. Immersion arguably also requires affective realism (Hudlicka, 2009), both in terms of NPC communication reflecting reality and the ways in which the game alters the player’s emotional state. Players need to experience emotional investment in the narrative and feel genuine desire to explore, progress and conquer the game both in a diegetic (rescue the hostages, discover the secret, save the world, etc.) and extra-diegetic (complete all achievements, beat the game before friends, unlock new gameplay modes/levels, etc.) sense.

An overarching assertion within this thesis is that approaches to immersion via affective realism demand a foundational structure in much the same way as physical realism (for example physics engines consist of an established set of mathematical rules to reliably simulate gravity, collision, friction, etc.). Therefore, a structured framework of fear processing could arguably support the creation of a realistic affective ecology that fulfils player expectations without being mechanical or predictable. This system connects study regarding psychophysiology/biometrics to the fear-related research, in that player biometrics and contextualising scenario descriptors can arguably provide the input with which the affective framework interprets player-emotional state and triggers an appropriate output response within the game engine. From both an ethical and commercial perspective, it must be acknowledged that an entirely genuine experience of fear would arguably negate the positive affective potential in *recreational terror* and instead could potentially be disturbing and deeply upsetting for the audience. Therefore, it is crucial that as designers explore new approaches to increasing the fear-elicitation potential of their craft, they remain vigilant to the dangers of making fear too real.

The closing sections of this chapter present a discussion regarding the acoustic and psychoacoustic properties that may connect sound to fear. Within these sections, sound is posited as a crucial element to consider in the designing of computer video games intended to evoke emotional responses, due to the significant potential of sound to alter affective states. Chapter 3 also presents a range of academic texts that support the potential of objective acoustic parameters to effectively evoke emotional responses. Low pitches, rumbling timbres, immediate attack times, gradual volume increases (connoting an approaching source), distortions, dissonances, sharp tones and high contrast volumes are submitted as strong potential candidates for fear elicitation. Localisation techniques are also asserted as providing potential for fear elicitation, specifically exploiting surround sound systems to place sounds behind the player or utilising reverberation and delay DSP to mask localisation, making the source difficult to locate within virtual 3D space. In relation to horrific episodes, sounds that signify disgusting events, if presented in a manner that also evokes shock/surprise, have notable potential to generate an intensely horrific experience. Acoustic parameters associated with disgust include low-pitch rumbling, guttural sounds that connote events such as vomiting and prolonged, high-frequency, sharp tones analogous to fingernails on a blackboard. Unexpected sonic events that break from an established pattern have been associated with negative valence and therefore are suggested as an additional approach to survival horror sound design, both relevant to musical composition and sound effects. Rapid onset/offset of sounds is concomitant to perceived urgency and although not expected to single-handedly evoke a fear response, the potential to influence the intensity of the experience is noteworthy. Sound design in conjunction with ambient soundscapes and with game visuals presents additional opportunity for systematic fear elicitation, specifically utilising acousmatic sound (sound in the absence of a visible source) that conjures feelings of de-familiarisation and the uncanny. Likewise, manipulating the ambient sonic background provides opportunity to mask localisation, create composite dissonance or establish an extended period of silence with which to create a jarring shock. Increasing tempo is connected with the notion of entrainment, specifically gradual escalations of tempo are suggested to increase heart and respiration rates whilst also representative of increasing predator speed and accelerating urgency.

It is advocated that preparation of a player's preceding affective state prior to stimulus is one of the most powerful approaches to generating an intense experience. Essentially, the player's state of mind before the stimulus is vital. This approach strongly reflects the definition of terror outlined within the thesis and suggests that shock-horror events may not necessarily be ineffective (or even cheap and amusing) if they are a component of a well-structured overarching terror scene.

CHAPTER 4

Chapter 4 discusses the concepts and frameworks associated with what it means for a sound to possess virtuality. Also incorporated is a detailed account of embodied cognition (EC) theory that is integrated into concepts of virtuality and acoustic ecology. The term virtuality is differentiated from virtual reality; the former describing a continuum between real and artificial whilst the latter is an electronic emulation of reality. Chapter 4 discusses the notion of perceived truths, suggesting that the inescapable bias intrinsically tied to our view of existence removes the capacity for truly objective perception. We therefore all possess our own unique, *virtual* representation of reality without ever experiencing it completely. It is further suggested that, irrespective of the sonic characteristics that determine a sound to be virtual, all sound is propagated within real acoustic space between speakers and the ear and is therefore susceptible to real acoustic treatment and consequently it is asserted that no sound can be classified as entirely virtual.

Although a typical commercial computer video game can only express its virtual world by way of two (or sometimes three) sensory modalities, this thesis argues that the nature of human perception can be exploited to circumvent this problem. Intense and immediate stimuli can dominate the senses and focus attention; therefore if a computer video game could evoke realistic representations of sonic environments and maintain player attention via sensory dominance, the complete experience could potentially be perceived as real.

The discussion in chapter 4 asserts that immersive and believable game sound is essential to the gaming experience due to this limited number of sensory modalities directly associated with gameplay (sound, vision and sometimes touch). The arguably gross/generalised employment of tactile stimulation alongside an absence of olfactory and gustatory stimuli within mainstream games results in a sparse virtual environment and therefore there is a demand for sound and vision to dominate the gameplay experience and also represent the missing sensory modalities (for example, sounds of coughs and holding of breath in response to disgusting smell, representing olfactory sense; reloading earcon heard when ammunition is collected, reflecting tactile modality).

Later sections within this chapter return to the concept of unique realities between individuals and emotion is positioned as both a governing factor in human attention (which elements of the shared environment are noticed and if/how much information is extracted from them) and in how obtained sensory data are processed. Consequently, if we are to assume that a truly objective perception of existence is impossible then emotions could be, in a sense, our reality.

Chapter 4 also presents in-depth discussions regarding acoustic ecologies (AE) that support the virtual acoustic ecology (VAE) concept and relate to the eVAE construct, an embodied virtual acoustic ecology that visualises the VAE concept within an embodied cognition framework (presented in chapter 8). The assertion that emotional frameworks are essential in development of artificial intelligence systems is maintained, positing that AI should be able to reflect and reflex as well as compute.

Lucid dream states are discussed, raising interesting questions regarding whether truly internalised processing is possible. This section ultimately concludes that, whilst the sensory data experienced within a dream state are internally generated, such stimuli consist of memories whose origins inexorably lead back to the environment and experiences in waking life. In addition, thought processing during dream states nevertheless remains susceptible to particular, immediate environmental and physiological factors that include: environment and internal body temperatures, light penetrating eyelids, current illnesses, various potential tactile inputs and, most notably, sound. Chapter 4 refers to Augoyard and Torgue (2005) in suggesting that various documented auditory phenomena support the concept of an embodied listening process. A complex interrelationship is revealed as sound is shown to influence thought processes (anamnesis, narrowing) whilst the mind appears capable of generating phantom sounds (phonomnesis, remenance), creating a perceptual continuation of sounds that have ceased or even a sound that (within the current space-time) never existed. In result of this, it is concluded that the process of listening cannot ever entirely deconstruct a sound into objective acoustic data and subjective perceptual information.

Such concepts relating to EC theory dictate that human perception frameworks (both relevant to fear and sound processing) must acknowledge time pressure, situation/context, local environment, hypotheticality and relevance as key variables within a thought-processing model. For the purposes of the thesis, such variables are classified under the blanket term *contextualisation,* which here refers to all elements relevant to the sound, beyond the quantitative acoustic properties of the sound itself. This includes EC (all factors associated with the here and now) variables and also past-based factors that include: pre-scene memories (dependent upon recollection filter - memories relevant to current scenario are more likely to be recollected), episodes within overall scenario experienced prior to current event, awareness of prior physiological state (providing reference to compare against new state) and inferred history associated with current stimulus. Chapter 4 presents a table, consolidating several variables that may contribute to a sound being perceived as real or virtual, these comprise: natural (human voice) against artificial (synthetic sine wave) origin, causal (gunshot sound reflects hammer hit on shell casing and gunpowder explosion) against symbolic (human voice shouting *bang!* reflects gunshot) representation, immediate versus delayed temporality (for example, synchrony of voice to mouth movement), natural versus artificial (electric amplification, speakers, etc.) propagation, live against recorded presentation, analogue against digital signal processing, and visible versus hidden (acousmatic) source.

It is also suggested that one notable way in which these numerous variables can potentially alter output thoughts and behaviours in response to audio stimuli is by way of listening modes. It is suggested that the amalgamation of the acoustic nature of a sound and the contextualisation factors of the scenario determines the way in which we hear and, consequently, what information we infer from the sound(s). For example, consider a screeching of car tyres and prolonged horn sounds heard within two scenarios: whilst crossing the road and whilst sitting on a bench nearby. In the first circumstance, the sounds present a high intensity (determined by close proximity) and knowledge of the current situation (awareness of scenario as personally relevant and the source as immediate) implies imminent danger. The consequent response is expected to be reflexive listening, supporting an immediate autonomic response and subsequent evasive behaviour. The second circumstance presents a less intense and less dominant sound and the individual's awareness of their current circumstance and environment does not denote impending danger. As a result, connotative and empathetic listening modes are more probable as the listener appraises the source, assesses the scene and considers the experience for the person who may be in danger.

CHAPTER 5

This chapter consolidates a range of literature to deliberate the applications and limitations of electrodermal activity (EDA), electroencephalography (EEG) and electromyography (EMG) both in general and thesis-specific contexts. The various definitions of psychophysiology and biometrics are addressed and both are discussed within the milieus of emotion, sound and computer video games.

Psychophysiology is the study of observable behaviours in living human organisms to enable a better understanding of the relationships that exist between psychology and physiology. Non-invasive experimental procedures are characteristic of this study. Biometrics as a term is utilised in a way that deviates from tradition; within this thesis it refers to discrete physiological measures that indicate psychological (specifically affective) activity. The original definition bears some similarities, namely that both utilise physiology for identification and classification, but the traditional application of security is replaced with communication and recreation. Chapter 5 also asserts that whilst conception of the origins of emotion is crucial for a complete understanding of the workings of the mind it is arguably less than essential for certain psychophysiological investigations. With an intention to infer affective state changes from physiology, it is arguably immaterial as to the chronology, provided the relationship is accurate. In a more general sense, biometrics provides several distinct advantages over subjective data collection, namely: overcoming participant difficulty in affect-related self-analysis, circumventing false response or intentional repression/accentuation and accurate identification of minute state changes. Biometric approaches to user feedback are posited to be invaluable to usability and user experience testing, chiefly due to the advantages detailed above. The current capabilities regarding eye-tracking technology are also discussed and it is concluded that this biometric may hold much promise as a supportive indicator of the event/entity that has caused a physiological state change.

Establishing a clear definition of electrodermal activity is undertaken within this chapter, positioning EDA as a blanket term under which the hardware configuration, temporal characteristics of the recording and output measurement determine the subtype. Skin conductance response (the type of interest within the thesis) employs a non-invasive, exosomatic hardware configuration, assesses epochs of data synchronised to short-term events and measures electrical conductance (as opposed to impedance, resistance or admittance). The biological connections of the human nervous system reveal associations between various brain structures and EDA. The presented review of relevant literature strongly advocates EDA primarily as an effective measure of arousal, a crucial axis of a dimensional model of affect. Notable advantages of EDA include: affordability and low running costs, ease and non-invasiveness of application, freedom of movement for participants during testing, relatively noise-resistant output signal and accuracy of measurement. A temporal resolution of 1-4 seconds is relatively low compared to other biometrics, however, for the purposes of emotion assessment in response to game events, EDA could be considered more than capable of identifying individual events provided the game utilised adequate pacing. Such scenarios highlight the value of eye-tracking technology, suggesting that the significantly greater temporal resolution (and ability to differentiate multiple events occurring simultaneously) would present a suitable solution.

Within chapter 5, several recent hardware developments (in addition to eye-tracking) are documented that provide usable solutions to several of the typical limitations of EDA measurement. Wireless systems give users freedom from the confines of a testing environment and support ecological validity by way of facilitating use within participants' own homes. Wrist-band and fingerless glove supports for EDA sensors lift the restrictions upon arm, hand and finger movement during testing to reduce distraction and obstruction in tasks that require such movements. Dry sensor technology increases comfort for the user and also diminishes both the risk of allergic reactions and the time required to apply/remove the equipment. Such hardware setups are strongly advocated for use in CVG emotion-related testing, primarily because of the inherent value in maintaining ecological validity (allowing participants to play in their own living environments so data more accurately reflect real scenarios) as it is asserted that player emotions are highly susceptible to lab-based biases (researcher presence, social pressure/expectation, etc.). In addition, sensor setups that allow total freedom of movement allow players to engage with control interfaces naturally, a significant plus when considering the obstructive nature of standard finger-attached, wired setups. It is concluded that the connection between arousal and EDA is established and reliable yet, as a standalone data source, it is arguably inappropriate to infer any additional psychological characteristics without additional biometrics and/or contextualisation information.

The electromyography subtype relevant to the thesis is identified as facial electromyography (fEMG), a further subclass of surface electromyography (sEMG) exists, but fEMG is referred to throughout simply as EMG for clarity and efficiency. Considerable research texts indicate EMG as a reliable measure of hedonic valence that, alongside EDA, facilitates construction of a two-dimensional model of affect measurement. In addition to this, EMG shares many advantages with EDA (non-invasive, affordable, high accuracy levels at minute discrepancies, minimal restriction of movement) and, in addition, provides an extremely high temporal resolution. Noise susceptibility and difficulty of accurate application are acknowledged as potential pitfalls but overall it is stated that, provided necessary care is taken, EMG is arguably an efficient and robust biometric.

Under consideration, and within the context of emotion recognition, biometric measures are largely viewed as effective approaches to differentiating both discrete emotion classifications and emotion characteristics (valence, intensity, dominance) provided two criteria are met. The first is that several complementary biometrics are used simultaneously to address the intrinsic limitations that exist within them (for example, EMG addresses the temporal limitations of EDA, whist EDA solves the noise susceptibility of EMG). The second is that a comprehensive collection of contextual and situational information is collected, both from the participant directly via qualitative assessment and from pre-established descriptors relating to the scene, atmosphere, and motivations, for example, to bridge the gap between concrete observations and abstract concepts.

With relevance to automated identification of fear-related affective states, EMG is positioned as a highly suitable component of such a system, due to activity in the corrugator supercilii (frown muscle) being consistently associated with negative affect throughout the literature. It is also asserted that the temporal characteristics of corrugator activity may also support differentiation of various negative states within the fear spectrum. For example, an immediate and quickly dissipating spike of EMG may indicate shock in response to a horrific event whilst more frequent, and sustained, low-intensity rises in activity could arguably be better attributed to terror. Electrodermal activity has been shown to increase in response to positive stimuli in a comparable manner to that of negative stimuli, with no clear statistical process capable of reliably distinguishing between positive and negative arousal experiences.

This chapter (and indeed the thesis) does not attempt to advocate an ideal model for dimensional affect measurement. Instead the most common approach (the circumplex model) is evaluated and its variations are considered. Whilst ambivalence is assuredly a concern when attempting to assess affective states by way of a dimensional model, it could be suggested that the nature of EMG somewhat limits our capacity to measure positive and negative affect as separable components, primarily due to the absence of an equally reliable facial indicator of positive valence (zygomatic activation has been associated to positive affect but also neutral and negative valence). Whilst it has been claimed that relaxation of the corrugator muscle is itself an indication of positive affect, there does not appear to be a substantial consensus regarding this contention.

Within chapter 5, a range of academic literature is also reviewed to establish the potential of sound stimuli to alter affective states as measurable via biometrics. It is concluded that various psychophysiological measures (EMG, EDA, EEG, heart rate) respond reliably to particular sonic events, most notably: unexpected events, pattern deviations and a range of certain acoustic parameters. The academic literature reviewed within chapter 10 advocates dissonance, and localisation and movement are identified as potential acoustic parameters of which variations are expected to be discernible via biometrics. It is acknowledged that sociocultural factors are likely to influence responses to auditory stimuli, particularly with regards to sounds with significant connotative attributes. However, it is maintained that certain acoustic and psychoacoustic characteristics evoke responses that originate from evolutionary development and consequently transcend sociocultural differences. Furthermore, the primal heritage of fear supports the argument that auditory stimuli that evoke this emotion are more likely to overcome the sociocultural barrier than many other emotions.

This chapter also concludes that biometrics has great potential to support responsive and engaging adaptive gameplay mechanics, particularly those related to emotional experience. Biometrics is beginning to permeate most gaming platforms, from online social network games to serious/educational virtual environments and has furthermore been posited as reliable indicators of game-specific emotional states such as immersion, flow, presence, frustration, challenge and fun. Just as adaptive difficulty can increase or attenuate challenge in response to gameplay parameters (health, shooting accuracy, completion time, etc.), an adaptive fear system may alter the affective intensity in response to biometric parameters. This would not only enable a game to avoid extreme emotional highs (anxiety, genuine upset) and lows (boredom, disengagement), but also increase the replay value by varying the experience to defy expectation and maintain a sense of the unknown in a game that has already been completed by the player. It is acknowledged however, that study concerning biometrics in games applications is in its infancy and there is insufficient agreement between researchers with regards to many of the connections between biometric data and gaming experiences. Computer video games exist in a wide variety of highly discernible genres with distinct game mechanics, motivations, atmospheres, perspectives, interfaces and interactions (and this is certainly not an exhaustive list). Consequently, any associations that prove reliable in one genre cannot be generalised across the multitude of genres or even between individual titles within the same genre (assuming distinct variances in some of the categories documented above are present). The implication for tests of game designs is that they must possess transparent likenesses of the games or genres they represent in order that conclusions can be justifiably extrapolated.

In addition, chapter 5 provides a comprehensive review of electroencephalography (EEG), discussing the relative advantages and limitations of this biometric within a computer video games context. Within this chapter it is asserted that EEG possesses several advantages over many of the alternative biometrics, including: high temporal resolution, portability, affordability and ease of application. Whilst such advantages are also characteristic of EMG and EDA, EEG additionally provides direct access to brain activity, as opposed to indirect measures by way of an intermediate (muscle activity, cardiac activity, sweat secretion, etc.). Whilst other biometric technology shares this benefit (such as functional magnetic resonance imaging and positron emission topography), EEG claims distinct advantages over such equipment, namely: non-invasive hardware, no radiation or magnetic fields and equipment that facilitates freedom of movement and activity during testing.

Limitations are also documented (limited access to lower brain structures, low spatial resolution and signal to noise ratio) however it is advocated that research communities (both in games studies and other disciplines) remain optimistic that EEG will yield significant results in the near future. Recent studies documented within this chapter have revealed EEG to have prolific application and also presented within this chapter are several promising approaches to solving some of electroencephalography's limitations.

With regards to EEG data collection methodological options; laplacian, referential and bipolar sensor montages are considered and it is concluded that referential is the most appropriate setup, primarily in response to the observation that the majority of relevant existing research utilises this montage and that the current generation of consumer-grade EEG headsets all employ the referential montage as standard. A brief overview of EEG feature extraction methods is presented but no in-depth comparison of the various alternatives is offered, neither is there a detailed technical account of these methods. A brief comparative analysis of fast Fourier transforms (FFT) and discrete wavelet transforms (DWT) is documented, highlighting that researchers are arguably required to decide between ease of use and efficiency of the former, and greater control of the latter. DWTs are concluded to be preferable for the purposes of emotion feedback loops within a gameplay context.

Classification options are also discussed in which frontal asymmetry is proposed to be a potential indicator of valence. Other features of EEG have also been connected to an attention/concentration and relaxation continuum, a measure that could be related to arousal, potentially facilitating an effective circumplex model of dimensional affect assessment by way of a single biometric. In addition, a range of mathematical classification algorithms are briefly evaluated to reveal further disagreement between researchers with regards to classification methodologies, with new and updated approaches being published regularly. It is concluded that personal preference holds some influence over which classification tool will be utilised and it is therefore suggested that a new series of research should ideally experiment with several alternatives by way of a preliminary study before committing to a particular scheme.

It is concluded that the above arguments position EEG as a suitable biometric for continuing study in this specific field. This section of chapter 5 is consequently an introductory academic discussion to preface future empirical research that is discussed below, in the closing sections of this conclusions chapter.

Overall, this chapter concludes that biometric data acquisition (particularly EMG, EEG and EDA) has notable worth in game experience and emotion assessment. The multitude of research papers documenting these measures in addition to a gradually increasing consensus level (relating to both theoretical and methodological issues) arguably implies a significant interest in the potential of biometrics within this field but also increasing faith that this approach will yield significant results in the future.

CHAPTER 6

Chapter 6 presents the collective methodologies for the three preliminary experiments undertaken during the course of this study. Whilst each individual experiment differed in data collection and overall design, the purpose remained consistent: to discover the potential of quantifiable acoustic parameters to evoke and/or modulate emotional (fear) experience. As preliminary trials, they were not expected to reveal conclusive evidence but, instead, search for circumstances in which manipulating sounds with digital signal processing effects produced statistically significant differences in emotion measures when compared to untreated controls. This in turn, would reveal if differences in game sound had any discernible effect upon player-emotion as, if not, there would be little value to the forthcoming hypothetical frameworks.

The opening section of chapter 6 establishes the potential value and relative limitations associated with utilising the internet as a medium for academic experimentation. It is asserted that internet-facilitated testing is affordable, efficient, supports multiple simultaneous users, can reach participants across the globe, has potential for very large sample sizes, and supports automation of data collation and filtering. Overall, the generally high level of accessibility and novelty associated with web experiments generates significant participant interest to further increase sample sizes. Utilising the internet also provides greater ecological validity by way of allowing individuals to participate in experiments from their own homes. Carefully crafted web experimentation can remove the need for the researcher's physical presence during testing, reducing researcher-based coercion and white-coat syndrome. As internet-relevant technology develops, so too will the opportunities for web-based experimentation. Progression within virtual reality design may ultimately facilitate highly immersive virtual testing environments, greatly comparable to real equivalents and providing the high levels of control afforded by traditional laboratory setups. Virtual web experiments could support access to participants from around the world and present test environments that would be either difficult or even impossible to obtain in reality.

There arguably remains a stigma against web-based research, placing such approaches immediately on the back foot. Compatibility issues with experimentation materials (graphics, sounds, interactive elements, embedded video, etc.) require careful consideration and the complexities of internet and digital technology present a substantial challenge for researchers. Alternative compression algorithms and connection types/speed in addition to compatibility issues relating to hardware, browsers and third-party plugins (Flash, Java, etc.) inevitably result in difficulty when attempting to create a uniform test environment. In many cases, even the basic layout and colour scheme of a website can vary when viewed in alternative browsers. Researcher absence limits experiment control further, the primary concerns being restricted regulation over intentional participant bias/deception, but there is also concern regarding lack of confirmation that the user understands the task/process and is willing to participate throughout. Additional related problems include risk of multiple or incomplete submissions and several participants completing the same form and submitting responses as an individual. It is also asserted that the nature of web experiments encourages participant samples to be skewed towards a specific demographic and therefore obtained data lack generalizability.

Ethical concerns connected to web experimentation chiefly involve participant anonymity and data protection. This unfortunately creates a conflict between the demands of ethical security and test reliability because the most effective approaches to participant control (automated IP address collection, repeated personal information gathering, required username and password creation, etc.) directly infringe upon security of personal information. Invasive recruitment practices present an additional ethical concern and it is asserted that viral advertising is arguably the most effective compromise solution, enabling interest in a web experiment to spread organically without pressuring potential participants directly. Modern social networking technologies are also advocated as potential approaches to *soft*, viral advertising techniques within which word-of-mouth can spread between virtual networks and links to the test can be shared to provide increased accessibility.

Following from the above discussion, chapter 6 presents the methodologies for the three experiments, beginning with the internet-mediated trials. This experiment consisted of two individual testing environments (*the horror game sound designer* [HGSD] and *the sounds of fear* [SOF]), in which the affective potential of a range of quantitative DPS effects was examined through contrasting approaches. Whilst HGSD utilised a greater degree of interactivity, requiring participants to select sounds they felt most appropriately reflected the accompanying visual material; SOF assessed users' affective responses more directly, requesting that they provide 1-9 scale intensity and valence measures for each sound.

The second experiment utilised a bespoke game level built from the Crysis (Crytek, 2007) game engine, incorporating treated and untreated sound groups into a playable game. Participants provided data through post-questionnaire assessment but the key method of data collection was real-time intensity (RTI) measures, a five-point scale that players would vocalise when prompted during gameplay.

The third and final experiment took its influence from both the previous chapter on biometrics and the prior two preliminary trials. A new test game was presented and electromyography and electrodermal activity data, consolidated alongside subjective player experience reports, allowed an assessment of affective responses to alternative DSP treatments (pitch, periodicity, sharpness, attack time, localisation and signal to noise ratio) comparable to those utilised within the earlier experiments.

CHAPTER 7

Chapter 7 documents the results, evaluative analyses and conclusions relating to the three experiments, beginning with the internet-mediated test. With regards to post-experiment evaluation, the majority of participants for this test noted that the minimalist visual design, accompanied with large interactive icons/buttons and visual plus textual feedback cues created an accessible and transparent experience. Employment of a relatively modern and certainly professional grade web-building tool (Dreamweaver CS4) ensured that all of the embedded material and core programming language utilised within the website was compatible with current web browser applications. Problems did arise with regards to third-party plugins, specifically embedded flash animations that became incompatible with a new version of a major web browser that had been released one month before testing began. This gives an impression of the timeline by which web technology can change, with previous incarnations becoming obsolete very quickly. Tutorial videos demonstrating how the experiment worked proved an effective approach to presenting uniform instructions to participants, although it was noted by several participants that a video recording of a visible instructor speaking to the player (as opposed to a voice-over) would have improved clarity further and increased participant comfort.

In terms of the valence-arousal model (VAM: a classification system mapping intensity and positive/negative measures onto a two-dimensional plane) approach to participant response, it is asserted that, whilst intensity and valence measures do elucidate affective differences (particularly if both terms are clearly defined to the participant during briefing), there are no explicit directions as to the discrete emotions being experienced and, as such, obtained data are arguably limited in specificity. Additional data collection approaches embedded within the test may present a possible solution; for example, requiring the participants to describe their emotional state (either free text entry or multiple choice from a list of predefined descriptors) following audition of each sound.

Overall, the results obtained from the internet-mediated experiments suggest great potential for web experiments as the approach not only provided access to a significantly larger sample size than would have been possible in a local study; but also presented a number of interesting differences in affective potential between untreated and loudness-treated groups and also between various different source sounds. The final proposition raised from this trial is that although the specific nature of sonic characteristics that determine affective response is, as yet, unknown, there is evidence to suggest that such an auditory phenomenon that transcends interpersonal differences really does exist.

The second experiment presented a preliminary assessment of fear-related affective intensity in response to various DSP audio treatments based upon those employed within the web experiments. Although some trends within the data were observable, there was no conclusive evidence to support the hypothesis that loudness, localisation (via 3D positioning) or pitch would have a significant impact upon subjective player affect responses. This is accounted for in a subsequent discussion by a number of potential erroneous variables and an overall lack of differentiation between the treatment groups. Future work is expected to exert greater control over these variables and to experiment systematically with wider extremes of treatment parameters.

The data collection approaches utilised for this experiment did, in contrast, prove to be highly effective. Real-time intensity (RTI) readings, in which participants provided spoken intensity statements (integers 1-5) when cued by an automated scripting program implemented by way of the game engine, enabled subjective user feedback to be more accurately associated with specific in-game events and sounds. Whilst the relatively small 1-5 RTI parameter was employed to increase accessibility for the players, it could be asserted that such a limited range of subjective responses could limit the power of any obtained data. In future testing a 1-9 range (utilised within the relevant, SAM [self-assessment mannequin] scales of valence, intensity and dominance) could be more effective, as players would be presented with more control for differentiating stimuli. Automated event logging also showed notable potential as an efficient approach to data collection and filtering. During testing, the coordinates of the player’s location, sum and duration of *run* function activations, and completion times were all automatically collected and presented within an auto-generated text file. The scripting system (the CryEngine Flow graph) supports additional mathematical functions that would enable basic descriptive statistical analysis to be carried out automatically and in real time (although such features were not used within this experiment). Data logging provides accurate timestamps for any desired event or set of events, supporting simple yet effective correlation against response data, an approach arguably more reliable and precise than manually establishing event times from observation of gameplay videos.

Player experience and confidence (PEC) levels are asserted to be critical variables that should be controlled in order to yield valid results. It is suggested that the primary reason that PEC has such influence over results is connected to coping; specifically that players with high PEC ratings are fluent in FPS controls and avatar coordination whilst also having experience of comparable aesthetic designs, atmospheres and scenarios. As a result, for players with a high PEC rating, test games are unlikely to present surprising or unknown gaming territory, affording them (utilising their knowledge of conventions and playing skill) a coping confidence that negates the fear-evoking stimuli. Finally, completion time is also acknowledged as a potential source of erroneous variation. Longer completion time consistently leads to higher overall intensity responses, suggesting that as players struggle to reach the level exit, increased frustration and anxiety provides a priming effect, accentuating the evocative potential of subsequent audio stimuli.

The third experiment integrated psychophysiological measures, a new game level and several additional DSP treatments. RTI collection was not employed but debrief questions were presented to participants. Despite the suggestion that test games should ideally represent the style/mechanics/interface/etc. of their associated genre (in this case, survival horror) several aspects of the game's design were unique; most notably, the control interface that reduces movement to forward, reverse and left/right rotation via the WASD keys, omitting the characteristic mouse-to-look function. The intention was to limit erroneous gameplay variation (primarily completion time) between participants with differing PEC levels. Ultimately, it is concluded that this was a mistake as, although variations in completion time and player-confidence in exploration and progression were attenuated, there remained distinct variation between some participants. Future associated testing should arguably employ a commonplace control interface and control for PEC through sample screening, the additional logic behind this approach being that participants with very low PEC are not regular game players or have little to no interest in games and therefore do not reflect the target consumer group.

Other design choices that, whilst not necessarily representative of the genre can be observed in existing titles, proved more successful. The omission of a heads up display arguably increased immersion and the absence of weapons/defence (initially) reduced coping ability. Both EDA and EMG equipment met expectations set by the preceding literature review, in terms of ease of application, consistent signal connection, minimal task distraction and user-comfort. Unfortunately, EDA proved considerably susceptible to erroneous laboratory-based effects, supporting the previous chapter's assertion that ecological validity is of prime importance when measuring electrodermal activity.

Consideration of the obtained data generated several logical recommendations for future study. Effort to recreate a generic home-style environment within which to execute testing is expected to reduce erroneous anxiety levels and increase ecological validity. Researcher absence throughout gameplay is advised to reduce social pressure derived from the player's assumptions regarding the expectations of the researcher. The inclusion of an extended period of initial gameplay (comparable to the test section) before biometric recording commences supports the player in acclimatising to the unique features of the game; both diegetic (atmosphere, style, narrative, motivation, etc.) and extra-diegetic (unique controls, navigation, perspective, etc.) Again, this is to reduce erroneous anxiety and reflect comfortable gameplay circumstances to support inferences that any increases in fear-related experience are due to the intentional, crafted elements of the game.

Shifting focus upon the sounds employed within the experiments, the particular digital signal processing (DSP) effects applied within these tests were chosen based upon secondary research into relevant theoretical and experiment-based literature in addition to their presumed ease of application within this context. It is acknowledged that other DSP might potentially have been equally effective and future study should attempt a comprehensive and systematic series of comparable trials to ensure that nothing is overlooked. This is beyond the scale of this thesis. Contextualisation of sound is strongly asserted to be a significant contributor to its affective potential. Due to the absence of an established context or any additional sensory data, participants were likely to embody each sound within their own context (possibly even extending to falsely assuming the source/nature of the sound). Such a variable could potentially have had an erroneous impact upon results and future study should strive to correct this.

Overall, the results from these experiments revealed evidence that not only can different sounds evoke significantly different emotion-related responses but adjustment of individual acoustic parameters can also have a notable effect upon affective experience. This study does not reveal the exact nature of how these interactions work or present a quantifiable *emotion/affect value* for individual sounds/parameters. It does however support the argument that both sound and specific acoustic parameters have the potential to influence emotional response and therefore helps to validate the hypothetical frameworks.

CHAPTER 8

Chapter 8 commences with two models of fear processing. The first begins with a fear object, contained within the environment, that (depending upon the nature of the various variables within the scenario) is processed by way of collaboration between autonomic and cognitive systems. Response to the input is expected to reflect the nature of the processing; meaning an input that is largely processed autonomically will generate a more instinctive response. Conversely a stimulus that is processed primarily via cognition and appraisal is anticipated to engage a more measured and deliberate response. For example, unknown footsteps on a creaking floorboard may generate a momentary automated response (gasp, freeze, increased heart-rate, perspiration) but the most temporally significant response will be cognitive appraisal as the listener consciously hypothesises upon alternative causes for the sound and actively modifies their behaviour to facilitate the gathering of further information (such as maintaining silence to hear more) and confirmation rejection of initial hypotheses.

The second model is contained within a computer video gameplay context; however the input variables include entities from both the game engine and the local environment. Within this model, interpersonal effects (a personal fear profile that includes personal history, phobias and coping ability) plus the nature of the stimulus determines the nature of the fear processing by way of perceived psychological distance. Stimuli appraised as psychologically distant (hypothetical, faraway, future orientated) enable pre-encounter defence: temporary autonomic response with extended cognitive appraisal. Psychologically proximal stimuli (certain, close, immediate) are significantly more likely to trigger circa-strike defence: extended autonomic behavioural response with minimal cognitive appraisal. The model takes influence from continuing ecological models by including a feedback loop in which aspects of the final fear experience (dependent upon its nature) are fed back into the model via the personal fear profile.

The next hypothetical frameworks documented in Chapter 8 include a visualisation of the interactions between real and virtual acoustic ecologies within a survival horror CVG context. The fear model, documented prior to this is extended to incorporate sonification data, listening modalities and environment/player and game/player interactions; the intention being to create a detailed yet transparent model of auditory processing within a survival horror CVG context.

Finally, chapter 8 presents the eVAE model, a framework that places the player and game sound (generated from the game's engine) within a shared resonating space and considers synchresis between audio and visual stimuli, sharing a likeness with the model established by Grimshaw and Schott (2008). The key difference in the eVAE model is the focus upon the brain/mind of the player, which is displayed as internal and external looping mechanisms. The external loop receives sensory data from the local environment and the player's physiological state. The biological body (including the ear and nervous system) translates the auditory data into electrical impulses that are then recoded against the player's individual personality profile (contained in the long-term memory and relating to the personal fear profile documented in chapter 3). The output impulses of this procedure affect physiology (e.g. increased heart-rate, adrenaline secretion, muscular tension) that, in turn, alters physical behaviour (kinaesthetic action: clenching game controller, pressing buttons, etc.) and finally gameplay action (avatar pulls trigger of weapon, sidesteps behind cover, etc.). Each of these elements are themselves, looped directly back into the system whilst gameplay action simultaneously leads to gameplay response dictated by the engine in reply to the gameplay action (NPC enemy is shot, avatar evades enemy fire, etc.). This information is also then integrated back into the system via the sensory inputs and collated to dictate further processing and player response behaviours.

The eVAE model's internal loop acknowledges the possibility that the mind does not simply receive and process input to then generate appraisals and output response behaviour, but also feeds back the appraisal information immediately into the system. For example, inspired by *Dead Space* (Visceral, 2008) a player may receive sensory data during computer video gameplay that is interpreted as: *there is a huge recurring banging sound and intermittent roars heard in the next room and past experience informs me that a boss battle is anticipated beyond this door*. Appraisal of the situation, largely from contextualised auditory data, is then processed to generate a strategy: *stock up on ammunition and switch to contact beam*. The internal loop mechanism denotes that this strategy can be immediately reintroduced into the system for confirmatory reappraisal without new stimuli from the local environment: *but what if the challenge is a swarm of small enemies? Maybe I should equip the pulse rifle instead*. The focus of eVAE is upon cognitive auditory appraisal that processes the data by way of the brain and it does not reference neural shortcuts that bypass the brain in order to enable immediate response behaviour. In the discussion surrounding the eVAE model, a key assertion of the thesis is that, as games technology develops, designers are moving closer to the ear with regards to the focus of their strategies; from initial concentration upon the source and motivation/context of the sound, to crafting of the sound itself, and finally to careful manipulation of the entire virtual soundscape. Modern noise-cancelling surround sound headphones and acoustically treated gameplay environments progress a step further in manipulating the resonating space that the player him/herself inhabits. Whilst currently 'science fiction' in tone, it could be argued that the next logical phase will involve either intentional manipulation of the player's body and/or bypassing the ear completely by way of transmitting synthetic auditory information impulses directly into the brain.

FUTURE STUDY: CONSUMER GRADE ACQUISITION DEVICES

This section refers back to information discussed within chapter 5 (Psychophysiology) and contextualises it within CVG applications and focuses upon consumer grade EEG recording headsets and accompanying software. It commences with an overview of the two currently competing systems, the MindWave from Neurosky and the EPOC from Emotiv.

The MindWave is a highly competitively priced, wireless EEG acquisition headset that requires relatively low computer system resources and utilises a single active electrode that is placed on the forehead and a reference electrode, connected to the left ear lobe (Neurosky, 2011). Although the commercial release of the device is very recent, the proprietary engine and SDK were presented earlier in the MindSet (2009), a comparable Neurosky EEG device that is essentially identical to the MindWave with the exception of integrated Bluetooth headphones. Academic research utilising the Neurosky system (that can be directly applied to the MindWave) dates back to 2008, suggesting that research access predated the commercial release. The MindWave exploits a proprietary algorithm to convert raw EEG data into measurements of cognitive attention and meditation (entitled, *eSense* measurements*)*, rated in integers from 0-100 (Wu, Liu & Tzeng, 2011). These measurements are based upon Alpha and Beta frequency EEG data that are generated via a fast Fourier transform (Peters et al., 2009). The associated marketing publication claims that the algorithm is adaptive, capable of adjusting to individual fluctuation and trends of the user (Myndplay, 2011). Temporal resolution of data collection is high (>1000 samples per second). Included with the hardware, a source development kit is provided (MindWave Development Tools) that supports a moderate range of languages (C/C++, C#, Java) and, for the purposes of game development, is highly suitable for integration into big-budget, commercial/mainstream game engines, mobile game applications and web-based gaming technologies.

The Neurosky system (incorporating both the MindWave and MindSet devices) has been praised for affordability, portability, ease of use and its recognition of attention/meditation levels is mostly agreed to be reliable and accurate (Cowley et al., 2010; Peters et al., 2009; Rebolledo-Mendez & de Freitas, 2008; Vourvopoulos & Liarokapis, 2011). Rebolledo-Mendez and de Freitas (2008) posit that the capacity to reliably measure attention via the Neurosky system could allow researchers to infer further knowledge with regards to motivation and interest. Further research (albeit written by the manufacturing company) asserts a robust EEG signal output, comparable to that of professional grade hardware such as Biopac systems (Neurosky, 2009). The use of a single active electrode presents obvious drawbacks when considering the potential application of the MindWave as an emotion-recognition system. Tammen and Loviscach (2008) assert that the primary functionality of the MindSet is to differentiate attention levels and that such data cannot be further processed to provide reliable insight into the user's emotional state. Spatial resolution is too low to facilitate frontal asymmetry assessments, eliminating the possibility of effective arousal-valence measurement. Rebolledo-Mendez et al. (2009) note that although raw acquisition is of high temporal resolution, the processed attention levels are presented at only 1Hz, reducing temporal sensitivity significantly and presenting a notable delay between state changes and system response. Rebolledo-Mendez et al. also state that whilst the dry electrode improves ease of use and user comfort, connection reliability is affected and a broken connection can take between seven and ten seconds to be re-established. Peters et al. (2009) concur with several of these issues but argue that the MindWave system would prove effective in conjunction with other modalities of EEG acquisition.

The EPOC (Emotiv, 2008) utilises a 14-electrode configuration based upon the international 10-20 arrangement (Campbell et al., 2010) and a referential montage setup that measures difference between the active electrodes and two references placed on opposite sides of the head. Within the class of consumer grade headsets the EPOC currently has the largest number of electrodes than any of its competitors (Seigneur, 2011). The headset operates with a sample rate of 128Hz and 16-bit resolution (Liu et al., 2010), revealing a higher technical specification when compared to the MindWave. In parallel with the MindWave, documented advantages to the EPOC include affordability, portability and ease of use/comfort (Adelson, 2011; Campbell et al., 2010; Lievesley et al., 2011). Flórez et al. (2011) documented a 71% accuracy rating in distinguishing between mental tasks and the capacity of the EPOC to acquire EEG data has also been compared to medical grade products in terms of reliability and accuracy (Stytsenko et al., 2011).

The EPOC can be purchased in various forms from consumer to research grades, the primary difference between the options is the accompanying software (consumer level limits the user to pre-set methods of connecting EEG to software applications and visualisations). The research edition of the software includes the full source development kit that allows full customisation of the processing algorithms and generation of new ones, though, as with the MindWave, API programming knowledge is required before custom setups can be created. The *Emotiv Experimenter* (Adelson, 2011) is an externally developed freeware program that integrates into the EPOC system enabling significantly greater control of EEG processing and classification algorithms. The EPOC system is also compatible with *OpenVibe* (INRIA, 2012) another freeware program that facilitates significant control over every aspect of EEG processing, from signal filters to classification algorithms, providing pre-set parameters whilst permitting high levels of modification (Renard et al., 2010). The brain-computer interface (BCI) research community has revealed an awareness and appreciation of this software application, and *OpenVibe* has been utilised as an EEG interface for gaming development purposes (Congedo et al., 2011) and to support the use of the EPOC itself as a reliable hardware tool (Ekanayake, 2010).

The notion that the EPOC is a match for professional or medical grade EEG is not widely accepted and particular research has argued against such a statement (Campbell et al., 2010). Ismail et al. (2011) argue that the required preparation of the wet-sensors can be time-consuming and that the headset can become uncomfortable after prolonged use. The software algorithms for classification and interpretation of thoughts have been criticised as unreliable and ineffective as a conscious-thought game control interface (Adelson, 2011). Ekanayake (2010) asserts that the electrode arrangement does not cover critical scalp locations and that this fact limits its effectiveness in comparison to higher-grade systems. Adelson (2011) also states that the EPOC suffers from high sensitivity to electromyography (EMG) input that in many circumstances, leads to users controlling a game through physical movements (clenched jaw, strained ocular muscles) rather than genuine EEG mind-control.

Upon consideration of the above discussion it is asserted that the EPOC setup provides the greater advantage over the MindWave. Primarily this is due to the electrode arrangement and external freeware applications and the EPOC has more power to enable effective emotion classification utilising many of the techniques outlined in chapter 5. The Emotiv EPOC shows great potential in providing a solid balance of affordability and robust effectiveness and is expected to feature as the primary hardware peripheral utilised within further study extending from this thesis. Whilst the EPOC headset is arguably less comfortable to wear for extended periods, more difficult to apply and has a lower sample rate than the MindWave, the technology offered by the EPOC is undoubtedly closer to professional/medical grade equipment whilst also accessible and compatible with modern gaming technology.

FUTURE STUDY: OUTLINE

Continuing research will aim to advance the theoretical concepts documented within the PhD thesis, retaining focus upon the emotionality of audio and quantification of subjective experience through psychophysiology. Future study would be anticipated to provide further theoretical advances and also yield a greater volume of empirically sourced data and practical prototyping with real-world application. It is envisioned that, alongside a comprehensive body of secondary inter-disciplinary research and a systematic series of empirical trials, two prototype software systems will be developed with value to both academic and commercial spheres. Produced work is expected to generate meaningful results, actionable conclusions and prototype systems of significant interest to usability, quality assurance, acoustics/psychoacoustics, computer video game development, artificial intelligence, audio therapy and cognitive neuroscience research fields.

Future research should strive to further consolidate and further substantiate the concepts documented within this thesis through the provision of additional data and demonstration of clear value of the results via successful prototyping. The primary focus of continuing research should encompass fear-associated emotional experience and acoustics, extending beyond: ‘what is the potential of quantifiable acoustic parameters to modulate affective response’ to: ‘what is the potential of individual variables (within acoustic parameters of sound) to both intensify or attenuate a person’s sensation of fear’. This will incorporates more detail to, hopefully, inform sound designers not only which acoustic characteristics are likely to create a desired emotional response, but also state the specific levels/measures of these parameters (beyond the scope of the thesis, that was limited to comparative analysis of 2-3 variations).

Theoretical and empirical work will advance from the more general concepts detailed within this PhD thesis to explore the full potential of a range of acoustic parameters in greater depth, elucidating not only the emotioneering (Freeman, 2003) potential of an individual acoustic parameter, but also the comparative potential of a range of variations within the same parameter. Combinations of parameter settings will also be addressed, facilitating the expansion (and hopefully the completion) of the thesis' framework for audio design within emotion-manipulation applications.

It is expected that future study expanding beyond this thesis will include a substantial quantity of pragmatic effort. Practical applications of the theoretical developments (documented above) are to include the development of a prototype software tool. The initial prototype system (Prototype 1) is an observation tool intended to aid researchers. It enables real-time two-way interaction between a computer video game program and biometric software, *viz.*, biofeedback. It will essentially be a data gathering and display system that would allow the recording of physiology to be synchronised to game events and for physiology measurements to affect game events. Much of the acquisition and initial processing of biometric data would be automated and synchronised to the key events within the user's experience, reducing the risk of human error and significantly improving the efficiency of data collection during empirical trials. This system would also enable the data to be presented visually in real-time to the user. The researcher would be able to observe the same readings synchronised to both a video recording of the user's in-game activity and the user's audio commentary (should real-time subjective data collection be required). All the information would be recorded as a video file, facilitating easy revisiting of each test and the automated production of valuable presentation materials. Such a system can be implemented within a traditional desktop computer/console system or may utilise mobile technology to create an iOS or Android compatible program enabling the system to work effectively on a range of alternative formats and capitalise upon the current trends of mobile application development and portable computing technology.

The second prototype (2) will utilise the theoretical framework and empirical data gathered using the initial prototype for a specific purpose; to create a biometric feedback loop system in which the user is able to manipulate the audio landscape of the virtual reality by way of psychophysiological measures (specifically their brainwaves via EEG). The intention is to support two contrasting applications. The first, to aid individuals who suffer from phobias by presenting them with an audio landscape that is representative of their fear and provide them with real-time biofeedback measures that they aim to attenuate. The audio framework is used here to increase/decrease difficulty, allowing users an adaptive difficulty that makes the program accessible at first and increasingly challenging to aid their coping development. The second application utilises the same system with the opposing objective of intensifying a fearful experience for recreational purposes. In this scenario, the system creates a 'living' acoustic virtual reality that reacts in real-time to the player's emotional state as they progress through the game. The core gameplay mechanic requires players to control their emotional state to move between game levels as the soundscape attempts to undermine their efforts. For example, a player may be required to achieve a relaxed and calm state in order to progress but is pitted against a soundscape designed to elicit fear and discomfort. The hardware used within these systems is open to several variations. Electroencephalography, galvanic skin response and heart rate are preferred methods of measurements of physiology as, at present, they are the more difficult to manipulate via conscious thought and therefore are more representative of our emotional subconscious.

Continuing study within this field has wide-ranging potential merit for both industrial and academic application. Biometric feedback systems and psychophysiology advances have specific value in user-experience (UX) and quality assurance (QA) testing; an avenue of research that is of critical importance to manufacturers of any consumer product from automotive to PC tablet design. Fear and anxiety can produce significant barriers between product and user, therefore a thorough understanding of attenuating these emotional states may allow designers to greatly improve accessibility of their products, allowing them to expand their customer base and to enable those who would normally be excluded by fear/anxiety to experience and enjoy the benefits of modern technology. In addition to these benefits, a biometric feedback system capable of varying the intensity of phobia-related audio soundscapes could have a great potential in attenuating a range of phobias by allowing the user to develop their coping ability through repeat practice and real-time progress feedback.

Significant practical application is also asserted within the field of recreational computer video gameplay. Within a recreational context, fear can be a gateway to joy and excitement (Perron, 2005; Svendsen, 2008) and emotions are often a prerequisite to immersive gameplay experiences (Shilling, 2002). Consequently, systems capable of accurately interpreting a player’s emotional state might not only support innovative gameplay mechanics (e.g. players must master their emotional output to progress) and real-time adaptive gameplay (ex. emotional output affects artificial intelligence director, making the game experience unique between both individual players and repeat plays), they could also facilitate a deeper level of communication with non-player characters which may result in more meaningful relationships between the player and the characters of the game. As a body of theoretical work, such study would consolidate a wide range of research from various disciplines to provide a succinct analysis of fear/anxiety theory and could also further advocate sound as a powerful tool in the manipulation of human emotion. A more detailed understanding of the affective power of audio could enable sound designers to better incite and convey emotional characteristics across a wide variety of sonic applications from fire alarms to cinematic foley (reproduction of everyday sounds, developed in film/TV post-production) design. A conceptual framework of fear amplification/attenuation could be further expanded upon to better understand additional emotional traits such as joy or anger.

CHAPTER SUMMARY AND FINAL STATEMENT

Referring back to the introduction chapter and the primary hypothesis stated within; the evidence gathered and literature reviewed supports the assumption that game sound, biometric data and qualitative game experience descriptors have the potential to operate as a psychophysiological feedback loop system.

The first foundational assumption, that human emotion can be understood as arrangements of quantitative variables that exist within the brain and body, cannot be conclusively acknowledged or rejected, but could be extended to include environment as an additional source of variables. Whilst the evidence gathered via the academic review and empirical studies support this hypothesis (and the hypothetical frameworks embody it), proof that such systems can be employed to accurately predict emotional outcomes from specific sound characteristics is needed to support this hypothesis conclusively. With regards to the second foundational assumption of the introduction (that quantitative acoustic parameters have the potential to modulate the affective value of a sound without contextual support), this study suggests that this could be true. Evidence reveals certain acoustic parameter changes having statistically significant impact upon player-emotion measures. However, the circumstances in which these parameters work are not consistent between experiments and more extensive testing is required to reach a definite conclusion. The possibility of a game sound/biometric feedback loop system is ultimately supported by the evidence within this thesis, as the potential for both game sounds to evoke emotion and the psychophysiological equipment to analyse it is promising.

With regards to the empirical study undertaken as part of this thesis, the web-mediated experiment reveals some strong associations between user-rated emotional valence and effect and particular sounds (and digital sound treatments). Whilst evidence does not provide a comprehensive account regarding the potential of digital signal processing to accentuate/attenuate an emotional response, this trial arguably elucidates several methodological difficulties lying within this test, thereby presenting a valuable guide for future research to better refine testing of this kind. The real-time intensity (RTI) experiment presents a novel yet effective approach to qualitative data collection and also reveals several propositions as to how affect testing within this context might be enhanced. The psychophysiology/biometrics experiment presents a strong argument for the employment of electro-dermal activity and electromyography as measures of human affect within a CVG context, revealing some reliable correlations between such physiological measures and fear-related game experiences. This collective research is anticipated to greatly support future research into biometric feedback applications within gaming and has also presented enough data to further support sound as a valid form of stimuli for modulating fear during computer video gameplay.

This thesis has also presented a range of theoretical explorations, comprising: emotionality, psychoacoustics, psychophysiology and game studies. The principal theoretical contributions put forward within the thesis are: an ecological framework of fear within a CVG context, a new perspective regarding the virtuality of sound, a new structure of gameplay experience that amalgamates fear processing and embodied listening during play, and an embodied virtual acoustic ecology (eVAE) model. It is anticipated that sound designers and researchers concerned with manipulating fear-related affect in response to sound will find this thesis of interest and value. By presenting research-supported frameworks of both how we listen and how we experience fear in a CVG context, it is hoped that the improvisatory or trial-and-error approach to sound design within this field will be more regularly rejected in favour of a methodical approach, centred around the audience as they exist within their environments. Ultimately the intention is to support the development of future games capable of transcending social, cultural, age and gender barriers to ensure that everyone is equally, and deeply, scared – but in the most positive sense.

This thesis has significantly contributed to the understanding of the affective potential of game sound. The hypothetical frameworks take existing knowledge (regarding sound perception, embodied cognition, and emotions) and apply them in a unique way to a CVG context. Modern approaches to measuring player experience are implemented for the unique purpose of assessing fear responses to sound during computer video gameplay, providing original data to support new conclusions. It is hoped that, in addition to driving forward future research, this thesis will encourage more structured and logical game sound design practices that denote an appreciation for the complex embodied world we listeners live in, ultimately supporting the development of game sound systems that can respond to the natural acoustic environment and the physiological characteristics of the player, as well as the traditional input from the controller.

Chapter 10

Appendix: Future Work, References & Complete Datasets

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Chapter 10: Future Work, References and Complete Datasets

INTRODUCTION

This closing chapter presents a design document for a bespoke software application, intended to begin development in the immediate future. Commencing with an outline of the circumstances from which the Xpresence development began, an initial blueprint of the software is presented alongside a statement of potential value, relevant to the themes and ideas raised within this thesis. The chapter concludes with a complete reference list and set of raw data figures obtained from the three experimental trials.

XPRESENCE: PURPOSE AND FUNCTIONALITY

The functionality of the software arose from observable limitations with currently available software to perform certain biofeedback tasks with a high degree of user-control. The overarching function of Xpresence is to facilitate a two-way communication between the Emotiv Epoc headset and the majority of computer video game engines, with which electroencephalographic response to game events can cause elements within the game to change. To specify, the primary component functions of Xpresence are to: acquire data from the Emotiv Epoc headset, process the raw EEG and gyroscope data to support extraction of custom features, provide an automated but fully editable classification tool, facilitate various real-time visualisation methods and, enable any data derived from the headset to be mapped to computer keystrokes.

Whilst various comparable software titles do currently exist, the specific requirements of the future research documented above reveal certain limitations. The research edition of the Emotiv system incorporates a source development kit with an array of implementations that includes a key mapping tool and real-time 2D graph generation. The chief concern with the former is the distinct restriction in terms of specifiable independent variables. Users can select from a small range of predetermined, subjective descriptors (relaxation, excitement, engagement, frustration and meditation) however the particular processing and classification algorithms utilised by the Emotiv system cannot be customised and therefore the connection between quantitative statistical EEG features (frequency analysis, signal spikes, mean activity, etc.) and qualitative descriptors is beyond user control. One feature of the Emotiv system that is potentially beneficial is the ability to record brief epochs of EEG activity and then map that output to a keystroke; meaning if a characteristically similar signal is received, the system will recognise it and consequently activate the set keystroke. However, limitations are present also with this tool in that the exact method by which the system compares activity is undetermined and, in practice, using this tool for conscious control (such as moving an avatar forward) lacks reliability. Therefore the facility to customise the recognition method by way of specifying specific statistical features would be a notably useful feature of Xpresence.

The visualisation toolset within the Emotiv system shares similar advantages and limitations. Raw and frequency-domain (generated via a standard FFT) measures are generated in real-time to enable live observation of EEG data. The restrictions of this system again relate to a lack of user control over the mathematical processes that lie between the acquired raw EEG and the Emotiv-defined qualitative descriptors. Although the recorded signal can be exported, there are no native tools within the software that allow statistical analysis of the data.

Alternative software packages present a resolution to the control limitations associated with the Emotiv system yet remain an incomplete solution, primarily due to communication restrictions between both the Emotiv headset and games engines. The *BSL Pro* (Biopac, 2012) currently at version 3.7.7, presents an array of analytical tools, including: FFT, histogram generation, smoothing, difference, peak detection and waveform mathematics, alongside a suite of digital filters for comprehensive initial signal processing. Parameter control of these tools is a mixture of low and high-level, with user access to a selection of parameter pre-sets with some low-level control afforded in several of the more basic functions (e.g. filter cut off frequency and number of coefficients settings in the low-pass digital filter and sample number defining within the smoothing tool). This presents a balanced compromise between control and accessibility, allowing users access to a range of advanced functions without alienating them with highly complex interfaces.

The clear limitation with the BSL software is that it communicates only with associated Biopac hardware that will far exceed low budgets. *Mind Workstation* (Transparent Corp., 2012) presents a potential solution. This software exists as a midpoint between the Emotiv and BSL systems in terms of user control and statistical toolset range. Analysis is largely limited to measuring frequency bands, raw data and the qualitative descriptors (frustration, excitement, etc.) set by the Emotiv hardware. However, there is greater control over these features when compared to the Emotiv system and, unlike BSL, it supports connectivity to both the Emotiv Epoc and Neurosky Mindwave headsets. Visualisation options are of a high standard and can also be generated in real-time. In addition, the Mind Workstation (MW) presents a native biofeedback toolset, enabling users to loop EEG data back into the system to manipulate stimuli in real-time. The principal limitation with this system is that the stimuli are self-contained within the software. Users are able to import custom sounds and visuals but there is no clear means to incorporate a third party system (such as a game engine) into the MW biofeedback routine.

The MW system is a commercial software title (currently priced at $490 for the most advanced version) that, while considerably more cost effective against an equivalent BSL system, lacks research-grade control (in certain areas) and, when combined with the Epoc headset costs, may be an overly expensive solution for some budgets. The final software presented here provides an effective solution to the budgetary and control limitations of the previous packages. *OpenVibe* (Inria, 2012) is a free to use, open-source software package that provides comprehensive user control over signal processing, feature extraction, classification and acquisition setup. OpenVibe utilises a flow-graph interface style with user-generated patches built up of connectable nodes (similar to *MaxMSP* [Cycling '74] and *Reaktor* [Native Instruments]). Control within the toolset is largely similar to that of the BSL system and provides a solid level of freedom for designing custom biofeedback routines. The single notable concern with the OpenVibe software is the lack of accessibility (particularly to those without programming knowledge/experience) when attempting to establish communication between OpenVibe and a third party program. The system employs a VRPN (virtual reality peripheral network) to enable effective communication between any programs that are written in C++ programming language. The difficulty is that setup of the VRPN requires significant programming ability and there is currently little regulated support available due to the open-source nature of the product. In response to the information documented above, Xpresence is intended to be a cost-effective graphics-based solution, requiring no low-level programming ability and only minor occurrences of text-based commands (fully supported by way of a comprehensive in-built help system) for the most advanced tools. Connectivity is initially to be limited to the Emotiv Epoc headset. The primary functional intention of Xpresence is to develop a software package capable of the following:

1) Professional and research-grade signal processing and statistical analysis tools
2) Comprehensive classification integrating both biometric and stimulation (game data) input
3) Keystroke mapping to connect classification outputs to peripheral systems (game engines)
4) Visualising biometrics and game data with a range of customisable presentation styles

XPRESENCE: DESIGN DOCUMENT

The aesthetic design for Xpresence takes influence from modern audio/music plugins for digital audio workstations that emulate physical equipment, such as the Solid State Logic 4000 (Waves, 2008), a collection of software programs that replicate the processing of the renowned SSL4000 and 9000 physical mixing desks. Although Xpresence does not employ graphical buttons, knobs and faders for all functions, such entities are integrated where possible to increase user-accessibility and engagement. Standard drop-down menu options are available but in most cases, the functions presented within these menus can also be accessed directly within the graphic user interface (GUI) window. EEG record and playback is controlled via a selection of animated buttons that colourise in response to user-action to provide immediate and clear feedback. All primary subsections of the program are presented within the main screen (figure 1) as clearly distinguishable nodes and the vertical tool window incorporates standardised icons for general functionality (new, save, cut, copy, paste, etc.). All icons/symbols reveal a text descriptor if the mouse pointer is positioned over them. Font and size of text is designed to balance between clarity and individual aesthetic with the colour scheme/background also intended to support this by way of a minimalist design with high contrast to clearly distinguish between sections of the GUI, supporting faster user-familiarisation. The superscript integers presented below point to corresponding numbers within the screenshot images to aid visual interpretation.

The functionality of the primary window centres on the flow graph window and incorporates a headset connectivity window, a play/record control panel and timer, a standard drop-down menu array and two quick-access toolbars, one containing the interactive icons representing the main Xpresence nodes/modules and the other providing easy access to generic tools. The headset connectivity window[1] is very similar in design to the equivalent tool provided with the Emotiv system as a visual representation of headset connection is essential and the Emotiv window is transparent and easily interpretable. Like the Emotiv tool, the connectivity window updates in real-time in response to connectivity changes, registering black for no connection, red for limited, orange for poor, yellow for good and green for excellent. The play/record control[2] is a moveable and hideable panel allowing immediate recording and playback function of EEG data without requiring the user to open the acquisition server.

The standard drop-down menu[3] allows alternative access to all of the functionality available via the quick-access menus plus links to the help/tutorial menu, view controls and structural nodes. The help/tutorial menu is presented in a standard Microsoft Windows format, with content split into chapters and keyword search functionality for fast reference. The view menu enables limited control over the general appearance/colour schemes and allows the quick access menus and play/record panel to be hidden (creating space that is automatically filled by expansion of the flow-graph window. Structural modules (accessed by way of the modules menu) allow more complex patches to be built by enabling any function module to have multiple (between 2 and 5) inputs or outputs. For example, the game engine and acquisition modules could both be connected to the classification module to enable headset EEG data to be cross-referenced against real-time game event data via a 2 to 1 structural node.

The generic quick-access toolbar[4] presents immediate access to common functions (new project, save, load, cut, copy and paste) in addition to a comments tool (selecting the tool opens a moveable text box to enable labelling of individual modules or sections of a complete patch to aid navigation around complex patches or remind the user of specific settings) and a help icon (when selected, hovering the mouse pointer over certain areas reveals a concise description of that element). The function module toolbar[5] provides immediate access to the primary modules used within Xpresence. Each icon within the toolbar represents one of the key Xpresence tools and can be easily dragged and dropped onto the flow-graph window. The flow-graph window[6] itself is relatively basic in design. Modules can be added, removed and duplicated using the quick-access tools, via a small drop-down menu that appears in response to right clicking the module and in response to keystrokes/short-cuts (e.g. ctrl+X for cut, ctrl+D for duplicate, etc.). Single and sustained left clicks towards the base or top of the function modules activate the connection wire. With this selected, the wire can be extended to connect with the input/output of any other node (although not all connections will create a valid function). Double left clicking of the function modules opens up new windows in which the settings and parameters particular to that tool are presented.

Figure 1: Xpresence main screen and primary module arrangement window

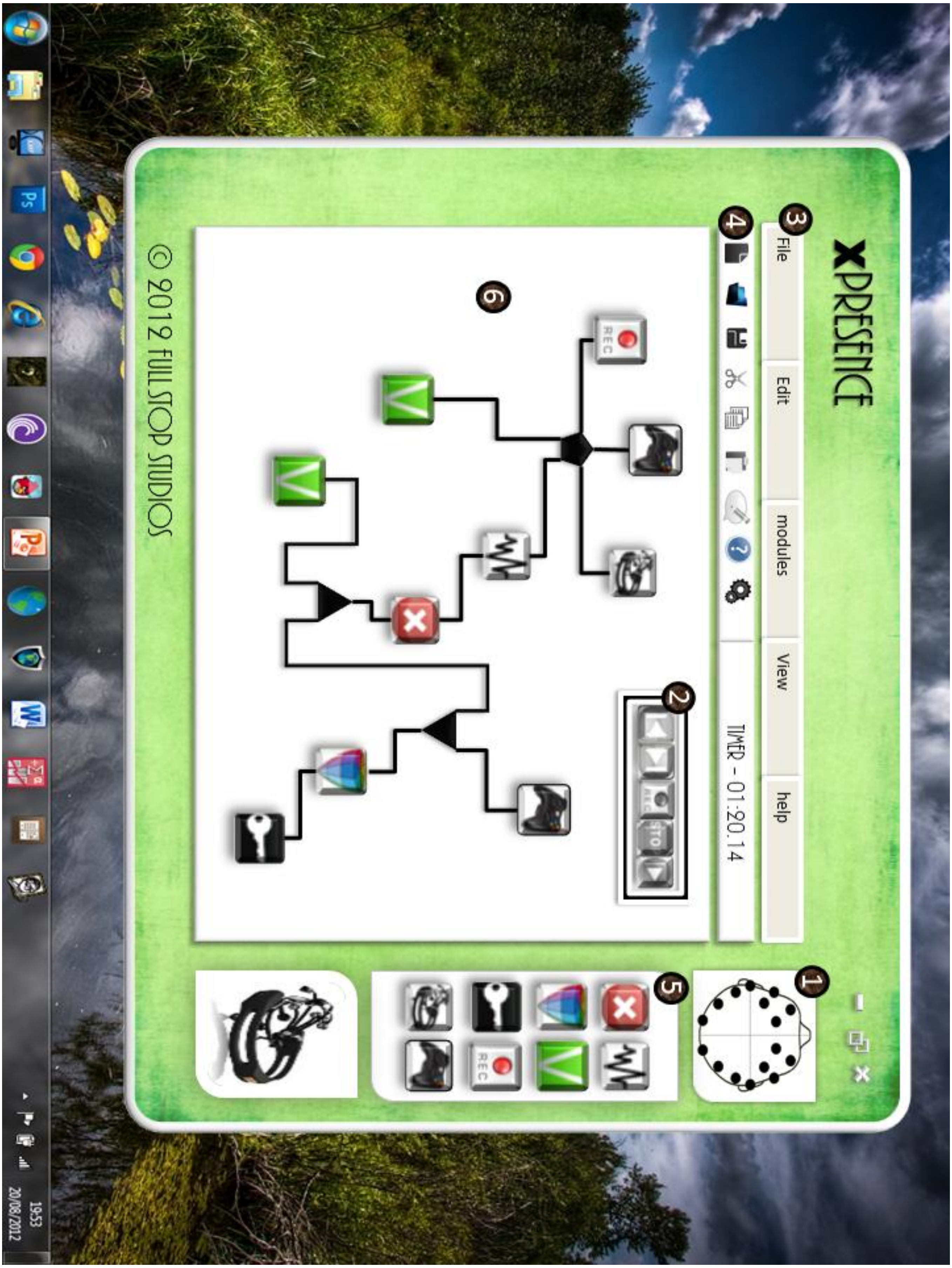
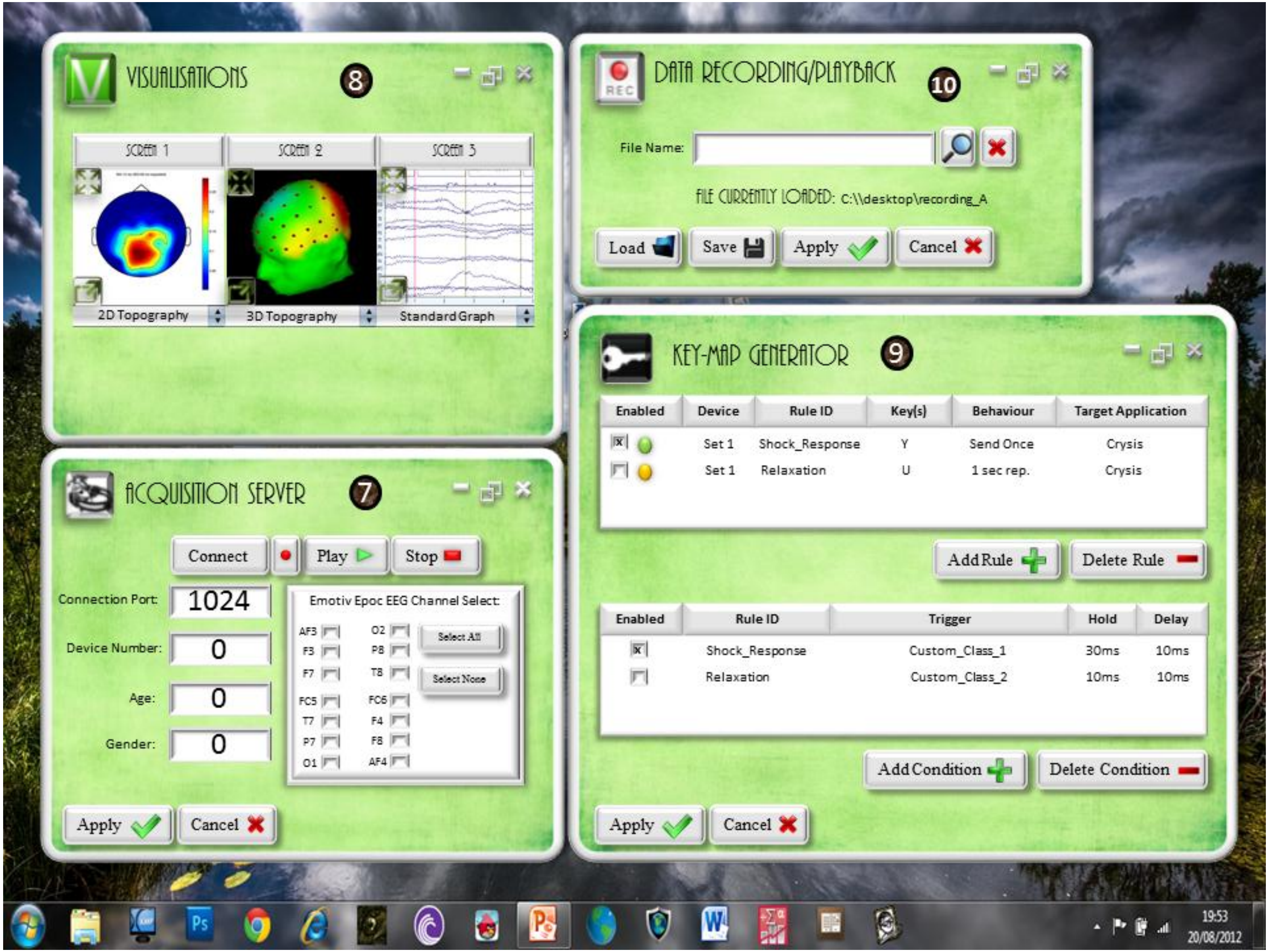


Figure 2 presents the acquisition server, visualisation tool, keymap generator and record/playback setting window. The acquisition server[7] takes its influence largely from OpenVibe (Inria, 2012) in terms of the adjustable settings offered, namely: alternative connection ports, age/gender adjustment and device identification (ultimately supporting simultaneous multiplayer functionality). A second play/record panel is presented alongside the option to collect data from any arrangement of the 14 electrodes, enabling researchers to examine specific spatial locations and economise on computing power. The visualisation tool[8] enables researchers to present graphs and topographical imagery in real-time, both in response to live data acquisition and playback of pre-recorded signal streams. Within a single visualisation window, three viewing ports are presented that enable data to be viewed in up to three alternative formats that include standard graphs and topography in both 2D and 3D versions. Each viewport can be detached from the main visualisation window and then size-adjusted or set to full-screen in much the same way as with a typical computer media player. The keymap generator[9] takes influence from the Emotiv tool, primarily because the research edition SDK being utilised to build Xpresence will facilitate easy access to the coding behind this tool. Within this tool, researchers can select from multiple connected headsets and establish a rule that connects a *trigger* with a *behaviour* and identify the application they would like this rule to apply to. The functionality of the trigger is the primary bespoke addition when comparing the Emotiv keymap generator to the one within Xpresence. Whereas the trigger within the Emotiv tool was limited to facial expressions and pre-established (non-editable) features, Xpresence provides a communication between the keymap generator and the classification module (discussed below) that allows the user to create a range of custom triggers from the raw data. The behaviour settings allow the connection between trigger and keystroke some basic customisation, enabling researchers to determine how long the keystroke is held for, set a delay between trigger onset and keystroke activation and configure repetition/periodicity. The record/playback window[10] incorporates a basic toolbar that opens a generic browser window, enabling users to load pre-recorded headset data files (instead of using live data) and save recordings to employ later.

Figure 3 provides a screenshot of the signal processing and feature extraction tool. The BSL pro software (Biopac, 2012) inspires several elements of both design and function, with the main signal display, timescale bar and feature analysis windows positioned in a comparable arrangement. With regards to functionality: customisable timescales, marker tools, viewer settings and analysis windows all take cues from the BSL software. The most notable differences presented in the Xpresence tool are the custom feature configuration and the simplified, streamlined aesthetic design. The main signal display[11] presents raw EEG data from all (or selected) Epoc headset channels. Within this window, both live and pre-recorded signal data can be visualised. To the lower left position of the main display window, the display control panel[12] is placed, incorporating (from left to right) a marker generator (that positions a marker upon the display window wherever to timeline indicator is currently placed) the settings tool (that opens a small drop-down window, allowing users to choose between mouse pointer function) and the timescale tool (enabling users to set the chronological scale and time measurement).

Figure 2: Module windows (Visualisation, Read/write, Keymap Generator & Acquisition Server)



File Name:

FILE CURRENTLY LOADED: C:\\desktop\recording_A

Enabled	Device	Rule ID	Key(s)	Behaviour	Target Application
☒ ●	Set 1	Shock_Response	Y	Send Once	Crysis
☐ ●	Set 1	Relaxation	U	1 sec rep.	Crysis

Enabled	Rule ID	Trigger	Hold	Delay
☒	Shock_Response	Custom_Class_1	30ms	10ms
☐	Relaxation	Custom_Class_2	10ms	10ms

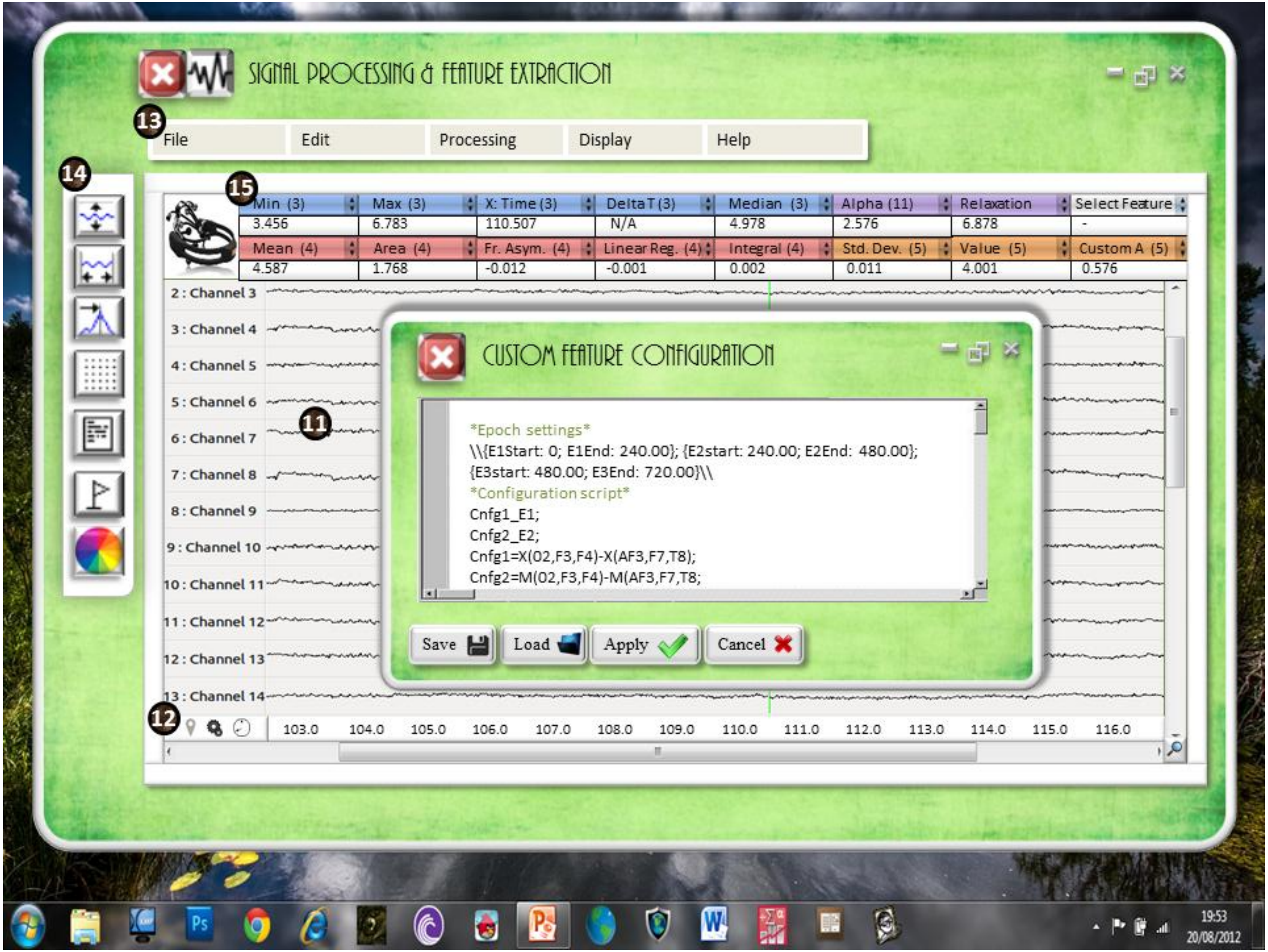
Connection Port: 1024
Device Number: 0
Age: 0
Gender: 0

The main drop-down menu[13] follows a similar functionality (chiefly with regards to the file, edit and help options) to the one presented in the initial Xpresence window. Processing is a pivotal menu however, as it provides the only route to signal processing tools. Although expected to incorporate various digital filters (hi-pass, low-pass, band stop, etc.) it is expected that this element of the overall software will include only essential processing initially, and integrate additional processes as plugins later in development. The display menu enables the user to set the number of feature analysis rows (up to three can be used) and adjust several visual parameters. This includes: the thickness and resolution of the signal streams, the colour coding of each channel and each feature analysis box, automated vertical and horizontal signal scaling and marker reveal/hiding. It is also possible to select any combination of the fourteen EEG channels for visualisation in the 2D graph.

The quick-access menu[14] provides the user with an accessible alternative to navigating the drop-down menus for some of the most common tasks that includes icons for (from top to bottom): automatic vertical scaling, automatic horizontal scaling, move to peak/next peak, display grid, add comments, place marker and visual display settings.

The feature analysis toolbar[15] initially presents the user with a single row of eight boxes, each of which reveals a drop-down menu that, when selected, displays a feature and an EEG channel (including *select all*) to attribute that feature too (e.g. mean (4) = the mean measure for channel 4). Features can be established statistical calculations (mean, min, max, integral, etc.), pre-established affective measures (meditation, excitement, engagement, etc.) or custom equations built by the user. It is the custom feature configuration tool that distinguishes the feature extraction module from Biopac BSL pro or the Emotiv control panel supporting the user with a relatively simple script-based system for building bespoke features. The custom feature configuration (CFC) window can be accessed via the *feature extraction* option in the main drop-down menu and also by a quick-access icon found in the top right of the screen. The CFC tool itself is a simple code-editing window with a compliment of standard buttons (save, load, apply, cancel). The exact nature of the code is not fully determined, however the intention is to allow the user to build equations based around mathematical functions, qualitative descriptors and raw EEG data. The code window can also automate epoch recording, allowing a user to select specific points in time for the automated analysis to be executed. For example, if a user wished to define a custom feature as *within a 30 second epoch between 1m15s and 1m45, when the mean signal from channels 1-7 is 25%(or more) greater than the mean signal from channels 8-14*, they would first establish the epoch times (E1start=1:15, E1end=1:45) then state the feature as an equation (*f*=m[c1:c7]>m[c8:c14]) and finally, state the value of the greater than symbol (>=25%+). This equation is then saved and given a user-defined name. The use of specific symbols and the syntax of the script is not yet established and the above equations are presented merely to elucidate the system.

Figure 3: Signal Processing and Feature Extraction windows



Min (3)	Max (3)	X: Time (3)	Delta T (3)	Median (3)	Alpha (11)	Relaxation	Select Feature
3.456	6.783	110.507	N/A	4.978	2.576	6.878	-
Mean (4)	**Area (4)**	**Fr. Asym. (4)**	**Linear Reg. (4)**	**Integral (4)**	**Std. Dev. (5)**	**Value (5)**	**Custom A (5)**
4.587	1.768	-0.012	-0.001	0.002	0.011	4.001	0.576

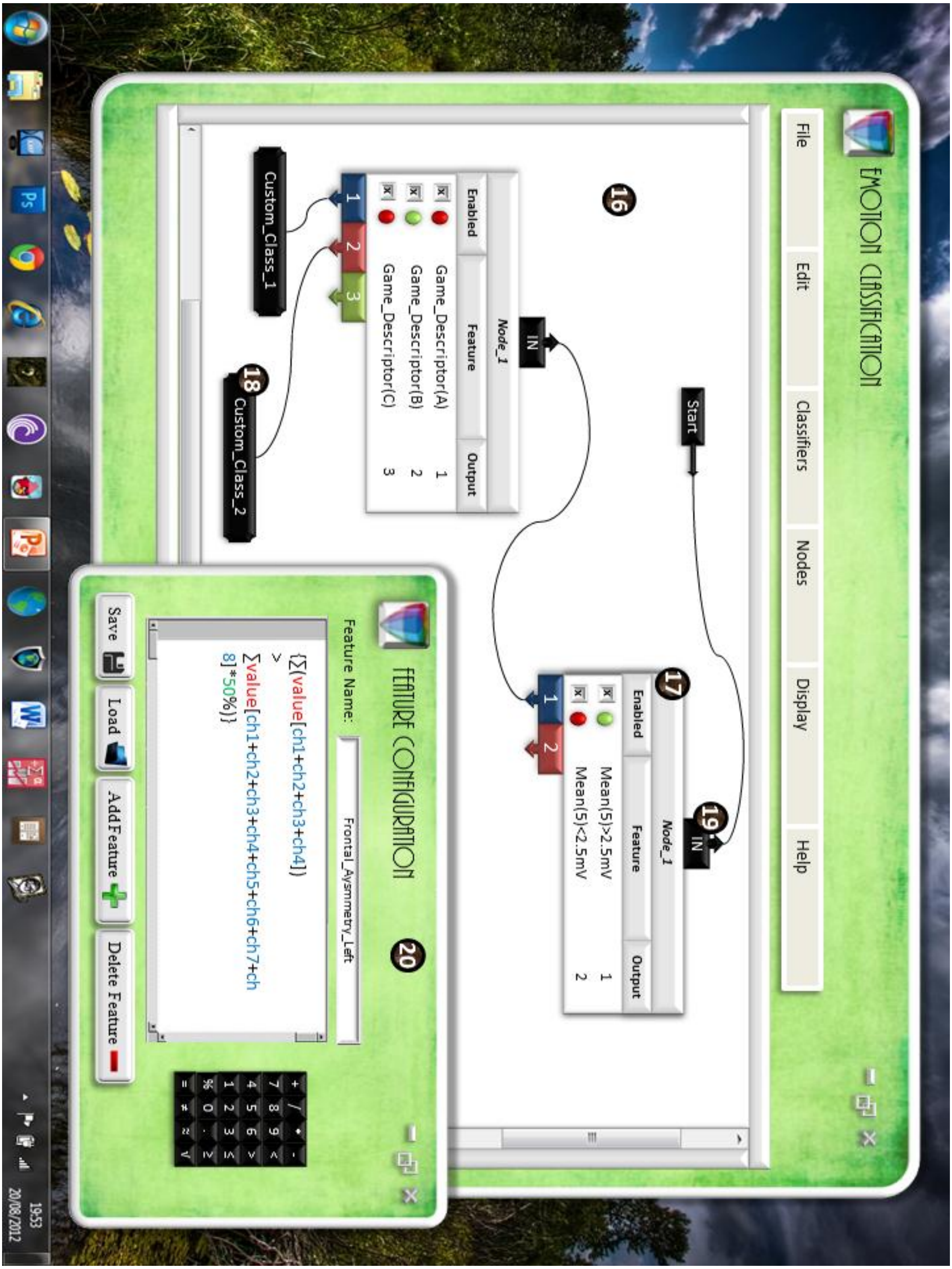
```
*Epoch settings*
\\{E1Start: 0; E1End: 240.00}; {E2start: 240.00; E2End: 480.00};
{E3start: 480.00; E3End: 720.00}\\
*Configuration script*
Cnfg1_E1;
Cnfg2_E2;
Cnfg1=X(O2,F3,F4)-X(AF3,F7,T8);
Cnfg2=M(O2,F3,F4)-M(AF3,F7,T8;
```

Figure 4 is represents a typical view of the classification tool, another flow-graph based system designed to support the implementation of complex class algorithms with relative ease. The classification tool primarily takes its influence from the GUI scripting engines utilised within modern FPS source development kits such as the *Unreal SDK* (2012) and the *CryEngine* 3 *SDK* (Crytek, 2012) that replace conventional, text-based coding with graphics nodes that present all relevant parameters as visible controls. The structure of the classification tool also takes influence from the *classification trees* presented in SPSS (IBM, 2012). This approach allows users to create complex interconnecting patches, capable of controlling intricate systems such as artificial intelligence or game physics, without requiring the user to navigate bulky text files or learn difficult syntax and commands. The main flow-graph arrangement window[16] is positioned in the centre of the screen and is initially blank. Nodes can be added via right-clicking anywhere in the blank space, revealing a drop-down menu containing all available nodes. The primary node is the *feature node*[17], a condition-based matrix with a user-specified number of outputs, each of which is activated based upon the rules set by the user. For example, in the first node the user could specify the feature as *raw EEG signal at channel 5* (electrode FC5) then connect one output to *S<25µV* (signal is below 25µV) another to *S=25:75µV* signal is between 25 and 75 µV), and a third to *S>75µV* (signal is greater than 75µV).

Each output could be coupled directly to the keymap generator by way of connecting them to a *send* node[18] or instead link to a second feature node via the *in* port[19] to create a more complex classification network. Double-left clicking upon a feature node reveals another custom feature configuration tool[20] with comparable functionality to the CFC presented in the processing and feature extraction tool and consequently means that there is some overlap between the two toolsets. This is primarily due to a need for usability feedback, to determine whether the CFC would be more appropriate within the feature extraction or classification tool. Small differences do exist between the two, with the classification CFC integrating a graphical keypad display, presenting the user with the most common mathematical functions. As with other aspects of the Xpresence program, hovering the mouse pointer over the keypad buttons will reveal a text description to further aid accessibility by way of reducing the number of mathematical elements a user may have to learn before proficient use. Colour coding is also different, though it is anticipated that the script colour schemes are to be fully customisable.

In addition to the function and send nodes, the classification tool will incorporate various logic (AND, OR, NOT, gate, XOR, etc.) and mathematical nodes (abs, add, sin, counter, etc.) to support the construction of large, complex patches. In addition to the *classification tree*-style documented above, the Xpresence classification tool will enable users to implement classification algorithms common to established academic literature, such as support vector machines and linear discriminant analysis, enabling researchers to use (and customise) advanced and current classification processes.

Figure 4: Emotion Classification flowgraph tool and Feature Editor programming window



Node_1

Enabled	Feature	Output
☒ ●	Game_Descriptor(A)	1
☒ ●	Game_Descriptor(B)	2
☒ ●	Game_Descriptor(C)	3

Node_1

Enabled	Feature	Output
☒ ●	Mean(5)>2.5mV	1
☒ ●	Mean(5)<2.5mV	2

Feature Name: Frontal_Aysmmetry_Left

```
{∑(value[ch1+ch2+ch3+ch4])
>
∑value[ch1+ch2+ch3+ch4+ch5+ch6+ch7+ch
8]*50%)}
```

BUILD AND IMPLEMENTATION STRATEGY

The Emotiv API provides the core functionality around which Xpresence will be built. As a proof of concept the C++ programming language dictated by the API is expected to enable control over any Windows PC-based games title. There are limits to some testing applications; most notably Apple Mac products (XCODE) and Microsoft XBOX live Arcade (C#) which would facilitate prototype testing upon what are arguably the most globally popular mobile and console-based independent gaming platforms respectively. Provided the initial development was successful, a port between platforms could yield further value as a future endeavour. It is also a distinct possibility that the Xpresence program could be extended to communicate with internet applications, particularly web-based/flash and social games, ultimately meaning the technology could permeate all forms of popular modern gaming.

The majority of graphics have already been developed, primarily using *PowerPoint* (Microsoft, 2010) and *Illustrator CS5* (Adobe, 2010) and all functionality programming is expected to be achieved via *Visual Studio C++* (Microsoft, 2010). The initial games engine Xpresence will attempt to communicate with will be the *CryEngine 3 SDK* (currently v3.4, Crytek, 2012). This is chiefly due to the accessibility of the engine’s flow graph system (enabling quick setup of links between keystrokes and game parameters) and the capacity to manipulate the game sound with a high degree of control. In addition, the CryEngine showcases some of the most advanced graphics and AI features currently within modern gaming, enabling many of the game responses to EEG input to both look and sound particularly impressive.

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i) Real-time Biometric Fear Assessment of Audio during Video Gameplay

ii) Game Completion Time

	Game Completion time (seconds)		Game Completion time (seconds)
Player 1	1400.47	Player 6	592.49
Player 2	703.139	Player 7	532.62
Player 3	471.14	Player 8	529.59
Player 4	779.18	Player 9	501.36
Player 5	385.45	Player 10	816.97

ii) Average (mean) Biometric Output

Game Events	**EMG (5 seconds)**				
	Min	**Max**	**Mean**	**Area**	**Slope**
Player 1	-0.1932	0.1817	-0.0019	8.6128	0.0000
Player 2	-0.1895	0.1371	-0.0019	2.1599	0.0000
Player 3	-0.0782	0.0703	-0.0019	1.1637	-0.0000
Player 4	-0.0591	0.1224	-0.0019	3.6823	0.0000
Player 5	-0.0733	0.0920	-0.0020	2.2600	0.0000
Player 6	-0.1652	0.1339	-0.0019	38.9178	0.0002
Player 7	-0.1788	0.1317	-0.0019	2.4383	-0.0000
Player 8	-0.3123	0.2554	-0.0019	8.8096	0.0000
Player 9	-0.2573	0.2706	-0.0019	1.7986	0.0000
Player 10	-0.2201	0.1938	-0.0019	42.0299	-0.0001

EDA (5 seconds)				
Min	**Max**	**Mean**	**Area**	**Slope**
48.1212	61.6455	55.1202	2620.0685	0.0008
76.2100	111.6257	86.0977	10582.1693	0.0094
71.4417	104.2252	80.4326	6209.4030	-0.0415
87.9822	115.9794	96.6648	10385.2933	-0.0116
89.3097	172.3251	109.5869	12474.0917	-0.1267
70.3964	87.3718	75.7320	4990.1912	0.0014
151.1002	186.0275	166.1906	3842.0477	-0.0034
70.9839	118.4464	87.8569	9217.1232	0.0287
81.3141	131.0043	95.5596	3826.1672	-0.0267
6.1697	136.1389	104.1216	7623.4559	0.0497

Game Events [Player 1]	Raw EMG (5 second sample following sound onset)				
	Min	Max	Mean	Area	Slope
Base	-0.0366	0.0382	-0.0019	0.0353	-0.0009
Music	-0.0145	0.0098	-0.0020	0.0182	-0.0012
Ship Groan	-0.0450	0.0388	-0.0020	0.0417	0.0036
light explosion	-0.0531	0.0426	-0.0019	0.0570	0.0060
Muffled Scream	-0.0303	0.0413	-0.0019	0.0323	-0.0007
Man Whimper	-0.0349	0.0441	-0.0018	0.0506	-0.0018
Pipe Banging	-0.0320	0.0391	-0.0019	0.0454	0.0030
Breath	-0.0429	0.0365	-0.0019	0.0654	0.0077
Ship Voice	-0.0386	0.0373	-0.0019	0.0424	0.0017
Scream	-0.0392	0.0340	-0.0019	0.0611	0.0039
Animal Scream	-0.0342	0.0289	-0.0020	0.0386	-0.0025
Monster Roar	-0.0452	0.0504	-0.0020	0.0578	-0.0013
Door Slams	-0.0695	0.0797	-0.0020	0.0695	-0.0073

Raw EDA (5 second sample following sound onset)				
Min	Max	Mean	Area	Slope
50.5842	51.2231	50.9041	0.5804	0.0097
52.4826	53.8559	52.9507	2.2208	-0.1876
52.9404	54.2374	53.9851	0.6806	-0.0915
56.2744	58.9218	57.6651	2.1224	0.2852
56.2363	59.1736	57.7736	2.0850	0.3859
55.9311	57.7698	56.6076	3.2259	0.1800
57.2662	58.1360	57.7072	0.7651	0.1312
57.6706	59.9518	58.9169	2.9419	0.1495
57.6706	58.7845	58.2172	1.2556	0.1190
57.2052	61.2717	58.9945	2.2485	0.7946
59.4177	61.6608	60.6169	3.9727	-0.1052
59.5779	61.0504	60.2048	2.7418	-0.0229
61.1420	62.5229	61.7185	2.6656	0.0656

Game Events [Player 1]	Differential EMG (Raw data minus base reading)				
	Min	Max	Mean	Area	Slope
Music	0.0221	-0.0284	-0.0001	-0.0171	-0.0003
Ship Groan	-0.0084	0.0006	-0.0001	0.0064	0.0045
light explosion	-0.0165	0.0044	0	0.0217	0.0069
Muffled Scream	0.0063	0.0031	0	-0.003	0.0002
Man Whimper	0.0017	0.0059	0.0001	0.0153	-0.0009
Pipe Banging	0.0046	0.0009	0	0.0101	0.0039
Breath	-0.0063	-0.0017	0	0.0301	0.0086
Ship Voice	-0.002	-0.0009	0	0.0071	0.0026
Scream	-0.0026	-0.0042	0	0.0258	0.0048
Animal Scream	0.0024	-0.0093	-0.0001	0.0033	-0.0016
Monster Roar	-0.0086	0.0122	-0.0001	0.0225	-0.0004
Door Slams	-0.0329	0.0415	-0.0001	0.0342	-0.0064

Differential EDA (Raw data minus base reading)				
Min	Max	Mean	Area	Slope
1.8984	2.6328	2.0466	1.6404	-0.1973
2.3562	3.0143	3.081	0.1002	-0.1012
5.6902	7.6987	6.761	1.542	0.2755
5.6521	7.9505	6.8695	1.5046	0.3762
5.3469	6.5467	5.7035	2.6455	0.1703
6.682	6.9129	6.8031	0.1847	0.1215
7.0864	8.7287	8.0128	2.3615	0.1398
7.0864	7.5614	7.3131	0.6752	0.1093
6.621	10.0486	8.0904	1.6681	0.7849
8.8335	10.4377	9.7128	3.3923	-0.1149
8.9937	9.8273	9.3007	2.1614	-0.0326
10.5578	11.2998	10.8144	2.0852	0.0559

Game Events [Player 2]	Raw EMG				
	Min	Max	Mean	Area	Slope
Base	-0.0224	0.0174	-0.0018	0.0158	-0.0005
Music	-0.0265	0.0179	-0.0019	0.0336	0.0015
Ship Groan	-0.0141	0.0095	-0.0020	0.0126	0.0012
light explosion	-0.0274	0.0241	-0.0023	0.0218	-0.0009
Muffled Scream	-0.0163	0.0123	-0.0016	0.0149	-0.0015
Man Whimper	-0.0125	0.0100	-0.0019	0.0122	0.0004
Pipe Banging	-0.0201	0.0147	-0.0019	0.0123	0.0000
Breath	-0.0190	0.0203	-0.0019	0.0172	0.0004
Ship Voice	-0.0193	0.0176	-0.0019	0.0233	0.0023
Scream	-0.0168	0.0201	-0.0019	0.0124	0.0002
Animal Scream	-0.0157	0.0124	-0.0020	0.0130	0.0003
Monster Roar	-0.0367	0.0164	-0.0022	0.0173	0.0013
Door Slams	-0.0162	0.0152	-0.0022	0.0254	0.0007

Raw EDA				
Min	Max	Mean	Area	Slope
76.2100	77.1027	76.6353	1.2526	-0.0817
87.7991	90.4007	88.7199	2.5934	-0.3356
78.8193	80.5588	79.5282	1.6981	-0.1952
80.9250	99.8306	88.7233	8.9310	3.6362
93.0176	103.1647	97.4664	7.6145	1.7663
91.9724	94.3985	93.2508	1.2360	-0.3783
81.1768	84.5337	82.8489	2.9092	0.4439
80.8029	83.3588	81.7038	3.8640	0.2559
82.2678	86.0443	84.1516	2.9711	0.6132
82.8018	87.5473	84.5889	4.7252	0.8114
88.6612	98.3658	94.6106	9.2617	1.5405
88.0280	106.0791	95.6387	10.0439	3.5035
101.8600	111.6257	107.7458	8.0343	1.5237

Game Events [Player 2]	**Differential EMG**				
	Min	Max	Mean	Area	Slope
Music	-0.0041	0.0005	-0.0001	0.0178	0.002
Ship Groan	0.0083	-0.0079	-0.0002	-0.0032	0.0017
light explosion	-0.005	0.0067	-0.0005	0.006	-0.0004
Muffled Scream	0.0061	-0.0051	0.0002	-0.0009	-0.001
Man Whimper	0.0099	-0.0074	-0.0001	-0.0036	0.0009
Pipe Banging	0.0023	-0.0027	-0.0001	-0.0035	0.0005
Breath	0.0034	0.0029	-0.0001	0.0014	0.0009
Ship Voice	0.0031	0.0002	-0.0001	0.0075	0.0028
Scream	0.0056	0.0027	-0.0001	-0.0034	0.0007
Animal Scream	0.0067	-0.005	-0.0002	-0.0028	0.0008
Monster Roar	-0.0143	-0.001	-0.0004	0.0015	0.0018
Door Slams	0.0062	-0.0022	-0.0004	0.0096	0.0012

Differential EDA				
Min	Max	Mean	Area	Slope
11.5891	13.298	12.0846	1.3408	-0.2539
2.6093	3.4561	2.8929	0.4455	-0.1135
4.715	22.7279	12.088	7.6784	3.7179
16.8076	26.062	20.8311	6.3619	1.848
15.7624	17.2958	16.6155	-0.0166	-0.2966
4.9668	7.431	6.2136	1.6566	0.5256
4.5929	6.2561	5.0685	2.6114	0.3376
6.0578	8.9416	7.5163	1.7185	0.6949
6.5918	10.4446	7.9536	3.4726	0.8931
12.4512	21.2631	17.9753	8.0091	1.6222
11.818	28.9764	19.0034	8.7913	3.5852
25.65	34.523	31.1105	6.7817	1.6054

Game Events [Player 3]	Raw EMG				
	Min	Max	Mean	Area	Slope
Base	-0.0123	0.0074	-0.0019	0.0094	0.0001
Music	-0.0107	0.0067	-0.0020	0.0266	-0.0004
Ship Groan	-0.0131	0.0054	-0.0019	0.0100	-0.0009
light explosion	-0.0362	0.0347	-0.0019	0.0140	-0.0006
Muffled Scream	-0.0515	0.0526	-0.0019	0.0167	-0.0006
Man Whimper	-0.0161	0.0096	-0.0019	0.0097	0.0004
Pipe Banging	-0.0139	0.0117	-0.0020	0.0079	-0.0005
Breath	0.0195	0.0157	-0.0019	0.0236	0.0007
Ship Voice	-0.0666	0.0703	-0.0018	0.0157	-0.0002
Scream	-0.0127	0.0069	-0.0019	0.0069	-0.0000
Animal Scream	-0.0478	0.0486	-0.0018	0.0262	-0.0001
Monster Roar	-0.0285	0.0281	-0.0019	0.0106	-0.0003
Door Slams	-0.0219	0.0112	-0.0019	0.0105	0.0003

Raw EDA				
Min	Max	Mean	Area	Slope
71.8613	72.7463	72.3981	0.6572	-0.1357
86.9217	88.8977	87.5987	3.7967	0.2242
77.3468	78.4760	78.0117	0.6915	-0.1617
71.4417	81.5125	74.7715	9.8683	1.8850
77.5681	81.6803	78.4347	6.9274	0.7443
80.6503	83.2443	82.3562	3.2633	0.2928
77.9724	79.0405	78.6306	1.0736	-0.0381
76.9959	77.6291	77.3368	0.5336	-0.0473
76.0269	79.2313	77.1938	3.3532	0.3920
73.2574	75.5692	73.9776	2.0789	0.2593
74.8062	77.8427	75.7080	4.2708	0.5155
75.2792	78.5294	76.4297	2.9391	0.5689
76.4008	77.6062	77.1548	1.4275	-0.0793

Game Events [Player 3]	Differential EMG				
	Min	Max	Mean	Area	Slope
Music	0.0016	-0.0007	-0.0001	0.0172	-0.0005
Ship Groan	-0.0008	-0.002	0	0.0006	-0.001
light explosion	-0.0239	0.0273	0	0.0046	-0.0007
Muffled Scream	-0.0392	0.0452	0	0.0073	-0.0007
Man Whimper	-0.0038	0.0022	0	0.0003	0.0003
Pipe Banging	-0.0016	0.0043	-0.0001	-0.0015	-0.0006
Breath	0.0318	0.0083	0	0.0142	0.0006
Ship Voice	-0.0543	0.0629	0.0001	0.0063	-0.0003
Scream	-0.0004	-0.0005	0	-0.0025	-0.0001
Animal Scream	-0.0355	0.0412	0.0001	0.0168	-0.0002
Monster Roar	-0.0162	0.0207	0	0.0012	-0.0004
Door Slams	-0.0096	0.0038	0	0.0011	0.0002

Differential EDA				
Min	Max	Mean	Area	Slope
15.0604	16.1514	15.2006	3.1395	0.3599
5.4855	5.7297	5.6136	0.0343	-0.026
-0.4196	8.7662	2.3734	9.2111	2.0207
5.7068	8.934	6.0366	6.2702	0.88
8.789	10.498	9.9581	2.6061	0.4285
6.1111	6.2942	6.2325	0.4164	0.0976
5.1346	4.8828	4.9387	-0.1236	0.0884
4.1656	6.485	4.7957	2.696	0.5277
1.3961	2.8229	1.5795	1.4217	0.395
2.9449	5.0964	3.3099	3.6136	0.6512
3.4179	5.7831	4.0316	2.2819	0.7046
4.5395	4.8599	4.7567	0.7703	0.0564

Game Events [Player 4]	**EMG (5 seconds)**				
	Min	Max	Mean	Area	Slope
Base	-0.0311	0.0200	-0.0019	0.0374	0.0012
Music	-0.0201	0.0130	-0.0020	0.0108	0.0001
Ship Groan	-0.0229	0.0159	-0.0019	0.0345	-0.0016
light explosion	-0.0222	0.0192	-0.0020	0.0246	-0.0018
Muffled Scream	-0.0232	0.0166	-0.0019	0.0236	0.0014
Man Whimper	-0.0347	0.0235	-0.0019	0.0303	-0.0020
Pipe Banging	-0.0317	0.0266	-0.0020	0.0315	0.0004
Breath	-0.0253	0.0319	-0.0019	0.0410	0.0017
Ship Voice	-0.0273	0.0222	-0.0019	0.0464	0.0025
Scream	-0.0539	0.0597	-0.0018	0.0390	-0.0005
Animal Scream	-0.0637	0.1238	-0.0019	0.0314	-0.0022
Monster Roar	-0.0250	0.0197	-0.0019	0.0215	0.0011
Door Slams	-0.0366	0.0224	-0.0019	0.0334	-0.0008

EDA (5 seconds)				
Min	Max	Mean	Area	Slope
87.9822	88.6230	88.2087	0.8693	-0.0756
88.2339	89.2410	88.6671	0.4459	-0.0482
97.7707	99.0448	98.2892	0.7698	-0.0961
96.2753	97.2824	96.7542	0.5601	0.1388
97.7707	98.4497	98.3555	0.4747	-0.0610
94.2841	95.2835	94.8273	0.8876	-0.1998
94.5663	95.3674	94.8035	0.9285	-0.1525
93.9255	94.9860	94.4250	0.7892	-0.0839
100.4791	103.8208	101.6025	3.8544	0.6161
96.8323	97.6410	97.1980	1.5182	0.0564
99.7696	106.2164	104.6560	11.7090	1.0188
103.9505	110.2600	108.7247	11.2863	0.9684
106.4835	107.4142	106.8779	0.6411	0.0031

Game Events [Player 4]	**EMG**				
	Min	Max	Mean	Area	Slope
Music	0.011	-0.007	-0.0001	-0.0266	-0.0011
Ship Groan	0.0082	-0.0041	0	-0.0029	-0.0028
light explosion	0.0089	-0.0008	-0.0001	-0.0128	-0.003
Muffled Scream	0.0079	-0.0034	0	-0.0138	0.0002
Man Whimper	-0.0036	0.0035	0	-0.0071	-0.0032
Pipe Banging	-0.0006	0.0066	-0.0001	-0.0059	-0.0008
Breath	0.0058	0.0119	0	0.0036	0.0005
Ship Voice	0.0038	0.0022	0	0.009	0.0013
Scream	-0.0228	0.0397	0.0001	0.0016	-0.0017
Animal Scream	-0.0326	0.1038	0	-0.006	-0.0034
Monster Roar	0.0061	-0.0003	0	-0.0159	-0.0001
Door Slams	-0.0055	0.0024	0	-0.004	-0.002

EDA				
Min	Max	Mean	Area	Slope
0.2517	0.618	0.4584	-0.4234	0.0274
9.7885	10.4218	10.0805	-0.0995	-0.0205
8.2931	8.6594	8.5455	-0.3092	0.2144
9.7885	9.8267	10.1468	-0.3946	0.0146
6.3019	6.6605	6.6186	0.0183	-0.1242
6.5841	6.7444	6.5948	0.0592	-0.0769
5.9433	6.363	6.2163	-0.0801	-0.0083
12.4969	15.1978	13.3938	2.9851	0.6917
8.8501	9.018	8.9893	0.6489	0.132
11.7874	17.5934	16.4473	10.8397	1.0944
15.9683	21.637	20.516	10.417	1.044
18.5013	18.7912	18.6692	-0.2282	0.0787

Game Events [Player 5]	**Raw EMG**				
	Min	Max	Mean	Area	Slope
Base	-0.0326	0.0208	-0.0017	0.0090	0.0000
Music	-0.0245	0.0101	-0.0020	0.0128	0.0001
Ship Groan	-0.0180	0.0125	-0.0020	0.0203	-0.0017
light explosion	-0.0217	0.0211	-0.0020	0.0225	-0.0010
Muffled Scream	-0.0226	0.0190	-0.0020	0.0410	-0.0006
Man Whimper	-0.0310	0.0240	-0.0019	0.0281	-0.0012
Pipe Banging	-0.0323	0.0243	-0.0019	0.0351	0.0011
Breath	-0.0410	0.0429	-0.0020	0.0439	-0.0024
Ship Voice	-0.0455	0.0370	-0.0021	0.0363	0.0009
Scream	-0.0439	0.0389	-0.0019	0.0740	0.0005
Animal Scream	-0.0470	0.0327	-0.0020	0.0493	0.0017
Monster Roar	-0.0403	0.0436	-0.0019	0.0533	-0.0012
Door Slams	-0.0254	0.0215	-0.0017	0.0474	-0.0003

Raw EDA				
Min	Max	Mean	Area	Slope
89.3097	90.2634	89.6986	1.7971	-0.0529
141.1285	149.7879	145.3598	0.9853	-1.7312
109.7565	112.2284	111.1564	0.7380	-0.4683
103.8513	105.2933	104.4535	3.0377	0.0930
99.2279	100.0366	99.7385	1.1454	-0.0915
100.8911	102.2949	101.6353	0.9453	-0.1922
100.8301	102.1957	101.4239	1.3128	-0.1693
97.5494	98.8083	98.1875	0.6098	-0.2318
96.3593	97.4731	96.9964	1.2046	0.0320
93.8644	94.9631	94.3241	0.8360	-0.0305
94.1772	95.6573	94.8259	0.8636	-0.0793
99.7696	101.4175	100.3142	1.6661	0.2471
121.2387	126.1139	123.5397	0.9860	-0.9746

Game Events [Player 5]	**Differential EMG**				
	Min	Max	Mean	Area	Slope
Music	-0.0571	-0.0107	-0.0003	0.0038	0.0001
Ship Groan	-0.0506	-0.0083	-0.0003	0.0113	-0.0017
light explosion	-0.0543	0.0003	-0.0003	0.0135	-0.001
Muffled Scream	-0.0552	-0.0018	-0.0003	0.032	-0.0006
Man Whimper	-0.0636	0.0032	-0.0002	0.0191	-0.0012
Pipe Banging	-0.0649	0.0035	-0.0002	0.0261	0.0011
Breath	-0.0736	0.0221	-0.0003	0.0349	-0.0024
Ship Voice	-0.0781	0.0162	-0.0004	0.0273	0.0009
Scream	-0.0765	0.0181	-0.0002	0.065	0.0005
Animal Scream	-0.0796	0.0119	-0.0003	0.0403	0.0017
Monster Roar	-0.0729	0.0228	-0.0002	0.0443	-0.0012
Door Slams	-0.058	0.0007	0	0.0384	-0.0003

Differential EDA				
Min	Max	Mean	Area	Slope
51.8188	59.5245	55.6612	-0.8118	-1.6783
20.4468	21.965	21.4578	-1.0591	-0.4154
14.5416	15.0299	14.7549	1.2406	0.1459
9.9182	9.7732	10.0399	-0.6517	-0.0386
11.5814	12.0315	11.9367	-0.8518	-0.1393
11.5204	11.9323	11.7253	-0.4843	-0.1164
8.2397	8.5449	8.4889	-1.1873	-0.1789
7.0496	7.2097	7.2978	-0.5925	0.0849
4.5547	4.6997	4.6255	-0.9611	0.0224
4.8675	5.3939	5.1273	-0.9335	-0.0264
10.4599	11.1541	10.6156	-0.131	0.3
31.929	35.8505	33.8411	-0.8111	-0.9217

Game Events [Player 6]	Raw EMG				
	Min	Max	Mean	Area	Slope
Base	-0.0189	0.0214	-0.0020	0.0196	-0.0003
Music	-0.0237	0.0172	-0.0020	0.0170	0.0001
Ship Groan	-0.0178	0.0172	-0.0019	0.0166	0.0009
light explosion	-0.0427	0.0435	-0.0018	0.0166	-0.0007
Muffled Scream	-0.0139	0.0117	-0.0019	0.0115	-0.0005
Man Whimper	-0.0155	0.0151	-0.0019	0.0141	0.0005
Pipe Banging	-0.0164	0.0133	-0.0019	0.0156	-0.0016
Breath	-0.0207	0.0144	-0.0019	0.0174	0.0003
Ship Voice	-0.0253	0.0183	-0.0019	0.0228	0.0007
Scream	-0.0182	0.0114	-0.0019	0.0133	-0.0001
Animal Scream	-0.0214	0.0125	-0.0020	0.0182	0.0019
Monster Roar	-0.0298	0.0254	-0.0018	0.0222	0.0009
Door Slams	-0.0265	0.0144	-0.0019	0.0161	-0.0003

Raw EDA				
Min	Max	Mean	Area	Slope
70.3964	71.9833	71.4716	0.7335	-0.0371
75.4547	76.8509	76.2118	0.7173	-0.2744
72.6929	73.3414	73.0249	0.4000	0.0030
73.6160	78.6667	75.3225	4.9132	0.8963
79.4830	80.6122	79.7991	1.3698	-0.1921
77.5299	77.9953	77.9112	0.6303	-0.0793
76.2405	76.4465	76.3076	0.2577	0.0320
73.8144	75.7370	75.1703	0.6398	0.0046
74.4171	75.4852	75.0807	0.5971	0.1433
72.7310	73.4177	73.0817	0.6270	0.0244
72.8531	74.0814	73.3754	1.2888	0.1113
70.3975	76.9730	73.1911	5.6054	0.9481
83.3664	85.0449	84.2279	0.8060	-0.2226

Game Events [Player 6]	Differential EDA				
	Min	Max	Mean	Area	Slope
Music	-0.0048	-0.0042	0	-0.0026	0.0004
Ship Groan	0.0011	-0.0042	0.0001	-0.003	0.0012
light explosion	-0.0238	0.0221	0.0002	-0.003	-0.0004
Muffled Scream	0.005	-0.0097	0.0001	-0.0081	-0.0002
Man Whimper	0.0034	-0.0063	0.0001	-0.0055	0.0008
Pipe Banging	0.0025	-0.0081	0.0001	-0.004	-0.0013
Breath	-0.0018	-0.007	0.0001	-0.0022	0.0006
Ship Voice	-0.0064	-0.0031	0.0001	0.0032	0.001
Scream	0.0007	-0.01	0.0001	-0.0063	0.0002
Animal Scream	-0.0025	-0.0089	0	-0.0014	0.0022
Monster Roar	-0.0109	0.004	0.0002	0.0026	0.0012
Door Slams	-0.0076	-0.007	0.0001	-0.0035	0

Differential EDA				
Min	Max	Mean	Area	Slope
5.0583	4.8676	4.7402	-0.0162	-0.2373
2.2965	1.3581	1.5533	-0.3335	0.0401
3.2196	6.6834	3.8509	4.1797	0.9334
9.0866	8.6289	8.3275	0.6363	-0.155
7.1335	6.012	6.4396	-0.1032	-0.0422
5.8441	4.4632	4.836	-0.4758	0.0691
3.418	3.7537	3.6987	-0.0937	0.0417
4.0207	3.5019	3.6091	-0.1364	0.1804
2.3346	1.4344	1.6101	-0.1065	0.0615
2.4567	2.0981	1.9038	0.5553	0.1484
0.0011	4.9897	1.7195	4.8719	0.9852
12.97	13.0616	12.7563	0.0725	-0.1855

Game Events [Player 7]	Raw EMG				
	Min	Max	Mean	Area	Slope
Base	-0.0121	0.0070	-0.0016	0.0128	-0.0007
Music	-0.0219	0.0210	-0.0019	0.0116	-0.0003
Ship Groan	-0.0265	0.0238	-0.0020	0.0388	-0.0015
light explosion	-0.0250	0.0189	-0.0019	0.0300	0.0035
Muffled Scream	-0.0225	0.0188	-0.0020	0.0165	-0.0010
Man Whimper	-0.0332	0.0257	-0.0020	0.0291	-0.0007
Pipe Banging	-0.0365	0.0267	-0.0019	0.0357	-0.0041
Breath	-0.0330	0.0328	-0.0019	0.0251	0.0007
Ship Voice	-0.0362	0.0259	-0.0018	0.0454	-0.0011
Scream	-0.0383	0.0336	-0.0020	0.0364	-0.0027
Animal Scream	-0.0269	0.0341	-0.0019	0.0224	-0.0007
Monster Roar	-0.0287	0.0191	-0.0020	0.0243	0.0013
Door Slams	-0.0235	0.0246	-0.0019	0.0254	0.0007

Raw EDA				
Min	Max	Mean	Area	Slope
156.7383	157.7606	157.2321	1.7053	-0.0587
173.7518	182.1747	178.2915	2.1824	-1.5091
159.2789	160.3012	159.7822	0.4737	-0.1556
159.0576	161.4380	160.2746	2.0963	0.2196
156.7764	163.8260	159.9262	5.6077	1.2294
163.1775	168.3197	165.6311	4.9348	0.6650
163.1317	164.3143	163.7133	0.6453	-0.1724
160.3775	166.4658	162.9351	4.6649	1.1058
163.5513	164.7110	164.0633	0.5381	-0.2059
162.5137	167.0380	164.6206	3.7726	0.7215
164.7034	167.0380	165.7209	2.8791	0.1205
160.2631	167.7628	163.4242	5.4854	1.4673
171.5164	173.5153	172.5912	0.5099	-0.3447

Game Events [Player 7]	Differential EMG				
	Min	Max	Mean	Area	Slope
Music	-0.0098	0.014	-0.0003	-0.0012	0.0004
Ship Groan	-0.0144	0.0168	-0.0004	0.026	-0.0008
light explosion	-0.0129	0.0119	-0.0003	0.0172	0.0042
Muffled Scream	-0.0104	0.0118	-0.0004	0.0037	-0.0003
Man Whimper	-0.0211	0.0187	-0.0004	0.0163	0
Pipe Banging	-0.0244	0.0197	-0.0003	0.0229	-0.0034
Breath	-0.0209	0.0258	-0.0003	0.0123	0.0014
Ship Voice	-0.0241	0.0189	-0.0002	0.0326	-0.0004
Scream	-0.0262	0.0266	-0.0004	0.0236	-0.002
Animal Scream	-0.0148	0.0271	-0.0003	0.0096	0
Monster Roar	-0.0166	0.0121	-0.0004	0.0115	0.002
Door Slams	-0.0114	0.0176	-0.0003	0.0126	0.0014

Differential EDA				
Min	Max	Mean	Area	Slope
17.0135	24.4141	21.0594	0.4771	-1.4504
2.5406	2.5406	2.5501	-1.2316	-0.0969
2.3193	3.6774	3.0425	0.391	0.2783
0.0381	6.0654	2.6941	3.9024	1.2881
6.4392	10.5591	8.399	3.2295	0.7237
6.3934	6.5537	6.4812	-1.06	-0.1137
3.6392	8.7052	5.703	2.9596	1.1645
6.813	6.9504	6.8312	-1.1672	-0.1472
5.7754	9.2774	7.3885	2.0673	0.7802
7.9651	9.2774	8.4888	1.1738	0.1792
3.5248	10.0022	6.1921	3.7801	1.526
14.7781	15.7547	15.3591	-1.1954	-0.286

Game Events [Player 8]	**Raw EMG**				
	Min	Max	Mean	Area	Slope
Base	-0.0167	0.0138	-0.0019	0.0203	-0.0007
Music	-0.0186	0.0113	-0.0019	0.0120	-0.0003
Ship Groan	-0.0088	0.0074	-0.0019	0.0092	-0.0006
light explosion	-0.0121	0.0079	-0.0018	0.0109	0.0009
Muffled Scream	-0.0094	0.0069	-0.0019	0.0125	0.0001
Man Whimper	-0.0129	0.0061	-0.0019	0.0240	0.0002
Pipe Banging	-0.0290	0.0095	-0.0019	0.0202	-0.0014
Breath	-0.0135	0.0125	-0.0019	0.0175	0.0000
Ship Voice	-0.0150	0.0101	-0.0019	0.0226	0.0008
Scream	-0.0139	0.0142	-0.0019	0.0239	-0.0025
Animal Scream	-0.0180	0.0170	-0.0019	0.0145	0.0002
Monster Roar	-0.0196	0.0184	-0.0018	0.0178	-0.0003
Door Slams	-0.0176	0.0110	-0.0019	0.0155	0.0004

Raw EDA				
Min	Max	Mean	Area	Slope
70.9839	71.7087	71.2348	1.5503	-0.0696
87.3261	95.2988	89.8498	17.0222	0.8191
87.7304	90.2786	88.9035	0.9116	-0.4942
90.1184	97.3358	94.3570	4.6298	1.3702
93.6203	96.5729	94.9007	3.6814	0.1571
86.8988	87.9593	87.4219	0.6638	-0.1739
77.5604	78.2928	77.9985	0.6499	-0.0717
75.5234	76.4771	76.0337	1.4902	0.0214
75.0427	84.7626	78.0504	10.0379	1.8860
78.5980	85.0678	80.6701	7.3231	1.1256
82.9468	91.9800	86.2465	10.6474	1.3498
70.9845	96.9238	81.2454	21.5723	5.1829
109.0698	111.9461	109.8741	4.2236	-0.4909

Game Events [Player 8]	**Differential EMG**				
	Min	Max	Mean	Area	Slope
Music	-0.0019	-0.0025	0	-0.0083	0.0004
Ship Groan	0.0079	-0.0064	0	-0.0111	0.0001
light explosion	0.0046	-0.0059	0.0001	-0.0094	0.0016
Muffled Scream	0.0073	-0.0069	0	-0.0078	0.0008
Man Whimper	0.0038	-0.0077	0	0.0037	0.0009
Pipe Banging	-0.0123	-0.0043	0	-0.0001	-0.0007
Breath	0.0032	-0.0013	0	-0.0028	0.0007
Ship Voice	0.0017	-0.0037	0	0.0023	0.0015
Scream	0.0028	0.0004	0	0.0036	-0.0018
Animal Scream	-0.0013	0.0032	0	-0.0058	0.0009
Monster Roar	-0.0029	0.0046	0.0001	-0.0025	0.0004
Door Slams	-0.0009	-0.0028	0	-0.0048	0.0011

Differential EDA				
Min	Max	Mean	Area	Slope
16.3422	23.5901	18.615	15.4719	0.8887
16.7465	18.5699	17.6687	-0.6387	-0.4246
19.1345	25.6271	23.1222	3.0795	1.4398
22.6364	24.8642	23.6659	2.1311	0.2267
15.9149	16.2506	16.1871	-0.8865	-0.1043
6.5765	6.5841	6.7637	-0.9004	-0.0021
4.5395	4.7684	4.7989	-0.0601	0.091
4.0588	13.0539	6.8156	8.4876	1.9556
7.6141	13.3591	9.4353	5.7728	1.1952
11.9629	20.2713	15.0117	9.0971	1.4194
0.0006	25.2151	10.0106	20.022	5.2525
38.0859	40.2374	38.6393	2.6733	-0.4213

Game Events [Player 9]	**Raw EMG**				
	Min	Max	Mean	Area	Slope
Base	-0.0133	0.0103	-0.0018	0.0127	0.0006
Music	-0.0594	0.0560	-0.0020	0.0208	0.0005
Ship Groan	-0.0835	0.0720	-0.0019	0.0340	0.0012
light explosion	-0.0150	0.0118	-0.0019	0.0136	0.0009
Muffled Scream	-0.0125	0.0084	-0.0019	0.0107	-0.0004
Man Whimper	-0.0146	0.0130	-0.0019	0.0195	-0.0013
Pipe Banging	-0.0939	0.0886	-0.0018	0.0382	-0.0003
Breath	-0.0153	0.0121	-0.0019	0.0177	0.0021
Ship Voice	-0.0170	0.0145	-0.0019	0.0113	-0.0001
Scream	-0.0161	0.0089	-0.0019	0.0163	-0.0013
Animal Scream	-0.0155	0.0130	-0.0019	0.0140	0.0011
Monster Roar	-0.0122	0.0102	-0.0019	0.0100	0.0007
Door Slams	-0.0179	0.0122	-0.0019	0.0131	-0.0010

Raw EDA				
Min	Max	Mean	Area	Slope
81.3141	81.9016	81.5234	1.1290	-0.0015
122.2382	131.0043	126.2175	13.8884	0.0702
93.5898	95.4590	94.5100	1.0352	-0.3458
83.5342	85.0143	84.2018	1.6124	-0.0503
81.3144	82.0160	81.6223	0.7460	-0.0351
83.1985	84.5490	83.7858	1.8435	-0.1434
102.6611	106.9717	104.4599	2.4823	-0.8145
98.3810	100.1358	99.2540	0.7428	-0.3160
96.2448	97.2748	96.6125	0.7688	0.0213
86.7844	88.4476	87.4236	1.0698	-0.2569
86.8835	90.8585	89.4672	5.1539	0.7102
85.0449	86.6013	85.7147	1.6582	0.0504
92.0105	93.8187	92.9309	1.0532	-0.1939

Game Events [Player 9]	**Differential EMG**				
	Min	Max	Mean	Area	Slope
Music	-0.0461	0.0457	-0.0002	0.0081	-0.0001
Ship Groan	-0.0702	0.0617	-0.0001	0.0213	0.0006
light explosion	-0.0017	0.0015	-0.0001	0.0009	0.0003
Muffled Scream	0.0008	-0.0019	-0.0001	-0.002	-0.001
Man Whimper	-0.0013	0.0027	-0.0001	0.0068	-0.0019
Pipe Banging	-0.0806	0.0783	0	0.0255	-0.0009
Breath	-0.002	0.0018	-0.0001	0.005	0.0015
Ship Voice	-0.0037	0.0042	-0.0001	-0.0014	-0.0007
Scream	-0.0028	-0.0014	-0.0001	0.0036	-0.0019
Animal Scream	-0.0022	0.0027	-0.0001	0.0013	0.0005
Monster Roar	0.0011	-0.0001	-0.0001	-0.0027	0.0001
Door Slams	-0.0046	0.0019	-0.0001	0.0004	-0.0016

Differential EDA				
Min	Max	Mean	Area	Slope
40.9241	49.1027	44.6941	12.7594	0.0717
12.2757	13.5574	12.9866	-0.0938	-0.3443
2.2201	3.1127	2.6784	0.4834	-0.0488
0.0003	0.1144	0.0989	-0.383	-0.0336
1.8844	2.6474	2.2624	0.7145	-0.1419
21.347	25.0701	22.9365	1.3533	-0.813
17.0669	18.2342	17.7306	-0.3862	-0.3145
14.9307	15.3732	15.0891	-0.3602	0.0228
5.4703	6.546	5.9002	-0.0592	-0.2554
5.5694	8.9569	7.9438	4.0249	0.7117
3.7308	4.6997	4.1913	0.5292	0.0519
10.6964	11.9171	11.4075	-0.0758	-0.1924

Game Events [Player 10]	Raw EMG				
	Min	Max	Mean	Area	Slope
Base	-0.0265	0.0290	-0.0013	0.0270	-0.0006
Music	-0.0332	0.0176	-0.0019	0.0190	0.0003
Ship Groan	-0.0340	0.0288	-0.0020	0.0339	0.0014
light explosion	-0.0490	0.0405	-0.0019	0.0328	0.0017
Muffled Scream	-0.0708	0.0682	-0.0019	0.0289	-0.0019
Man Whimper	-0.0336	0.0286	-0.0019	0.0312	0.0004
Pipe Banging	-0.0410	0.0337	-0.0019	0.0387	0.0008
Breath	-0.0414	0.0390	-0.0019	0.0439	-0.0022
Ship Voice	-0.0968	0.0685	-0.0020	0.0456	0.0019
Scream	-0.0438	0.0611	-0.0019	0.0484	-0.0017
Animal Scream	-0.0474	0.0365	-0.0019	0.0420	0.0003
Monster Roar	-0.1329	0.0893	-0.0020	0.0765	0.0067
Door Slams	-0.0505	0.0518	-0.0019	0.0541	0.0031

Raw EDA				
Min	Max	Mean	Area	Slope
70.5032	74.2340	71.9034	6.9073	-0.3848
84.0683	87.5015	86.2899	4.3308	0.5587
98.1140	100.5859	99.4435	4.9044	0.1250
87.4939	124.6490	119.4763	18.4357	1.1709
113.7848	120.2011	118.4553	5.6154	0.7327
110.7407	112.6480	111.4705	3.8608	-0.0061
103.7674	116.5695	112.9415	8.4552	0.6312
80.8029	121.9788	113.5548	29.4184	0.9262
98.2819	126.5030	116.3370	35.5495	1.2227
117.5156	126.7014	120.7566	7.1936	1.8357
124.9084	129.4174	126.9136	6.1829	0.5251
83.4503	134.4223	119.7767	46.4461	7.7467
123.2834	126.4648	125.5346	3.1489	-0.0991

Game Events [Player 10]	Differential EMG				
	Min	Max	Mean	Area	Slope
Music	-0.0067	-0.0114	-0.0006	-0.008	0.0009
Ship Groan	-0.0075	-0.0002	-0.0007	0.0069	0.002
light explosion	-0.0225	0.0115	-0.0006	0.0058	0.0023
Muffled Scream	-0.0443	0.0392	-0.0006	0.0019	-0.0013
Man Whimper	-0.0071	-0.0004	-0.0006	0.0042	0.001
Pipe Banging	-0.0145	0.0047	-0.0006	0.0117	0.0014
Breath	-0.0149	0.01	-0.0006	0.0169	-0.0016
Ship Voice	-0.0703	0.0395	-0.0007	0.0186	0.0025
Scream	-0.0173	0.0321	-0.0006	0.0214	-0.0011
Animal Scream	-0.0209	0.0075	-0.0006	0.015	0.0009
Monster Roar	-0.1064	0.0603	-0.0007	0.0495	0.0073
Door Slams	-0.024	0.0228	-0.0006	0.0271	0.0037

Differential EDA				
Min	Max	Mean	Area	Slope
13.5651	13.2675	14.3865	-2.5765	0.9435
27.6108	26.3519	27.5401	-2.0029	0.5098
16.9907	50.415	47.5729	11.5284	1.5557
43.2816	45.9671	46.5519	-1.2919	1.1175
40.2375	38.414	39.5671	-3.0465	0.3787
33.2642	42.3355	41.0381	1.5479	1.016
10.2997	47.7448	41.6514	22.5111	1.311
27.7787	52.269	44.4336	28.6422	1.6075
47.0124	52.4674	48.8532	0.2863	2.2205
54.4052	55.1834	55.0102	-0.7244	0.9099
12.9471	60.1883	47.8733	39.5388	8.1315
52.7802	52.2308	53.6312	-3.7584	0.2857

1.2 Average (Mean) Statistics: Raw Data Set

Group A Mean	**EMG**					**EDA**				
	Min	Max	Mean	Area	Slope	**Min**	Max	Mean	Area	Slope
Base	-0.02138	0.01674	-0.00178	0.01584	-0.00018	**89.96152**	90.779	90.35126	1.1738	-0.04782
Music	-0.0262	0.02072	-0.00198	0.018	-0.00026	**115.30456**	121.1441	118.08364	4.61472	-0.6267
Ship Groan	-0.03722	0.0305	-0.00196	0.02896	0.00014	**98.58248**	100.1404	99.48908	0.7238	-0.24458
light explosion	-0.0302	0.02576	-0.00192	0.02742	0.00176	**94.83184**	98.43598	96.2733	3.74742	0.4865
Muffled Scream	-0.02788	0.02802	-0.00194	0.02344	-0.00066	**94.22456**	97.3465	95.49906	3.3023	0.4466
Man Whimper	-0.02596	0.02328	-0.0019	0.0274	-0.00092	**96.7697**	99.23554	98.0032	2.84256	0.16044
Pipe Banging	-0.04172	0.03808	-0.0019	0.03246	-0.00016	**100.3723**	102.13164	101.18698	1.25582	-0.21262
Breath	-0.02254	0.028	-0.00192	0.03514	0.00176	**98.19488**	100.59816	99.32606	1.8986	0.13204
Ship Voice	-0.04078	0.037	-0.0019	0.03022	0.00024	**97.97058**	99.49494	98.61664	1.42406	0.07168
Scream	-0.03004	0.02446	-0.00192	0.03894	0.00008	**94.72502**	97.45792	95.86808	2.00116	0.2976
Animal Scream	-0.03428	0.03146	-0.00192	0.0301	-0.0001	**95.9976**	98.61146	97.26778	3.42802	0.23234
Monster Roar	-0.03098	0.03028	-0.00194	0.0312	-0.00016	**95.98694**	99.07228	97.21752	2.89812	0.46216
Door Slams	-0.03164	0.02984	-0.00188	0.03318	-0.00152	**104.46168**	106.7154	105.58702	1.32844	-0.30538

Group B Mean	**EMG**					**EDA**				
	Min	Max	Mean	Area	Slope	**Min**	Max	Mean	Area	Slope
Base	-0.02312	0.02032	-0.00178	0.02402	-0.00018	**75.21514**	76.73034	75.89076	2.2626	-0.12976
Music	-0.02442	0.0154	-0.00194	0.01848	0.00034	**84.57642**	87.85858	85.9477	5.02192	0.14392
Ship Groan	-0.01952	0.01576	-0.00194	0.02136	0.00026	**87.02546**	88.7619	87.83786	1.73678	-0.1315
light explosion	-0.03068	0.02704	-0.00196	0.02134	-0.00016	**85.68572**	99.5529	94.92666	7.49396	1.44248
Muffled Scream	-0.02672	0.02314	-0.00184	0.01828	-0.00048	**95.53528**	99.80012	97.7954	3.75116	0.4806
Man Whimper	-0.02184	0.01666	-0.0019	0.02236	-0.0001	**92.28518**	93.65692	92.97634	1.4557	-0.16748
Pipe Banging	-0.02764	0.01956	-0.00192	0.02366	-0.00036	**86.66228**	90.24198	88.98	2.6401	0.17658
Breath	-0.02398	0.02362	-0.0019	0.0274	0.00004	**80.97382**	90.50754	88.17752	7.24032	0.22484
Ship Voice	-0.03674	0.0273	-0.00192	0.03214	0.00164	**86.09772**	95.32318	91.04444	10.602	0.89626
Scream	-0.02932	0.0333	-0.00188	0.0274	-0.00092	**89.69574**	94.07504	91.25906	4.27742	0.7707
Animal Scream	-0.03324	0.04044	-0.00194	0.02382	0.0001	**93.82782**	100.0122	97.16042	7.81796	0.9091
Monster Roar	-0.0488	0.03384	-0.00194	0.03106	0.00194	**83.36182**	104.93164	95.71532	18.9908	3.66992
Door Slams	-0.02948	0.02296	-0.00196	0.0289	0.00062	**104.81262**	108.49914	106.85206	3.37078	0.14284

1.3 Average (Mean) Statistics: Differential Data Set

Group A Mean	**EMG**				
	Min	Max	Mean	Area	Slope
Music	-0.01786	0.00398	-0.0002	0.00216	-0.00008
Ship Groan	-0.02888	0.01376	-0.00018	0.01312	0.00032
light explosion	-0.02186	0.00902	-0.00014	0.01158	0.00194
Muffled Scream	-0.01954	0.01128	-0.00016	0.0076	-0.00048
Man Whimper	-0.01762	0.00654	-0.00012	0.01156	-0.00074
Pipe Banging	-0.03338	0.02134	-0.00012	0.01662	0.00002
Breath	-0.0142	0.01126	-0.00014	0.0193	0.00194
Ship Voice	-0.03244	0.02026	-0.00012	0.01438	0.00042
Scream	-0.0217	0.00772	-0.00014	0.0231	0.00026
Animal Scream	-0.02594	0.01472	-0.00014	0.01426	0.00008
Monster Roar	-0.02264	0.01354	-0.00016	0.01536	0.00002
Door Slams	-0.0233	0.0131	-0.0001	0.01734	-0.00134

EDA				
Min	Max	Mean	Area	Slope
25.34304	30.3651	27.73238	3.44092	-0.57888
8.62096	9.3614	9.13782	-0.45	-0.19676
4.87032	7.65698	5.92204	2.57362	0.53432
4.26304	6.5675	5.1478	2.1285	0.49442
6.80818	8.45654	7.65194	1.66876	0.20826
10.41078	11.35264	10.83572	0.08202	-0.1648
8.23336	9.81916	8.9748	0.7248	0.17986
8.00906	8.71594	8.26538	0.25026	0.1195
4.7635	6.67892	5.51682	0.82736	0.34542
6.03608	7.83246	6.91652	2.25422	0.28016
6.02542	8.29328	6.86626	1.72432	0.50998
14.50016	15.9364	15.23576	0.15464	-0.25756

Group B	**EMG**				
	Min	Max	Mean	Area	Slope
Music	-0.0013	-0.00492	-0.00016	-0.00554	0.00052
Ship Groan	0.0036	-0.00456	-0.00016	-0.00266	0.00044
light explosion	-0.00756	0.00672	-0.00018	-0.00268	0.00002
Muffled Scream	-0.0036	0.00282	-0.00006	-0.00574	-0.0003
Man Whimper	0.00128	-0.00366	-0.00012	-0.00166	0.00008
Pipe Banging	-0.00452	-0.00076	-0.00014	-0.00036	-0.00018
Breath	-0.00086	0.0033	-0.00012	0.00338	0.00022
Ship Voice	-0.01362	0.00702	-0.00014	0.00812	0.00182
Scream	-0.0062	0.01298	-0.0001	0.00338	-0.00074
Animal Scream	-0.01012	0.02012	-0.00016	-0.0002	0.00028
Monster Roar	-0.02568	0.01352	-0.00016	0.00704	0.00212
Door Slams	-0.00636	0.00264	-0.00018	0.00488	0.0008

EDA				
Min	Max	Mean	Area	Slope
9.36128	11.12824	10.05694	2.75932	0.27368
11.81032	12.03156	11.9471	-0.52582	-0.00174
10.47058	22.82256	19.0359	5.23136	1.57224
20.32014	23.06978	21.90464	1.48856	0.61036
17.07004	16.92658	17.08558	-0.8069	-0.03772
11.44714	13.51164	13.08924	0.3775	0.30634
5.75868	13.7772	12.28676	4.97772	0.3546
10.88258	18.59284	15.15368	8.3394	1.02602
14.4806	17.3447	15.3683	2.01482	0.90046
18.61268	23.28186	21.26966	5.55536	1.03886
8.14702	28.2013	19.82456	16.7282	3.79968
29.59748	31.7688	30.9613	1.10818	0.2726

1.4 Questionnaire Data

Group A (control)	Player 1	Player 3	Player 5	Player 7	Player 9
Overall intensity (1-10)	5	8	8	4	7
Significant emotion	Anticipation	Anticipation	Anticipation	Anticipation	Anticipation
Description of most memorable & intense section of game	Final countdown bangs	Alien in corridor and black screen	Alien in corridor and black screen	Female scream in control room	Following NPC into unknown
Game Difficulty (1-10)	3	5	3	3	3
Average hrs spent playing games (0-20)	8	18	13	8	20
Preferred platform	Console	PC	Console	PC	PC
FPS experience (1-10)	5	7	10	9	10
Horror game experience (1-10)	2	4	6	6	10
Gender	Male	Male	Male	Male	Male
Age	25	19	21	26	26
Interruption of flow/immersion	3	4	2	2	4
Comfort of sensors	8	8	7	6	7

Group B (test group)	Player 2	Player 4	Player 6	Player 8	Player 10
Overall intensity (1-10)	8	6	7	7	7
Significant emotion	Excitement	Anticipation	Anticipation	Surprise	Anticipation
Description of most memorable & intense section of game	Alien in corridor and black screen	Alien rushing past open door	Walk up to alien and Lights explode	Final countdown bangs	Bodies in control room
Game Difficulty (1-10)	3	4	3	3	3
Average hrs spent playing games (0-20)	13	4	4	8	8
Preferred platform	Console	PC	Console	PC	Console
FPS experience (1-10)	8	9	8	10	5
Horror game experience (1-10)	2	5	7	4	1
Gender	Male	Male	Male	Male	Female
Age	19	27	23	27	27
Interruption of flow/immersion	3	2	2	2	3
Comfort of sensors	6	7	7	8	7

ii) Preliminary Web-based Assessment of Affective Computer Game Audio

2.1 *The Sounds of Fear*: Raw data comparing untreated audio against DSP effects (🔊) and online datasets (A1-10) against offline (B1-10) for user-defined measures of emotional *activation* on a nine point scale

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
Footsteps	3	4	1	2	3	4	5	1	7	3	4	2	1	1	6	7	5	7	4	1
🔊	3	4	1	3	5	5	2	3	7	4	1	3	5	1	2	8	2	5	7	2
Music Radio	3	7	1	7	1	5	1	5	3	2	6	6	8	5	5	7	4	2	3	6
🔊	5	4	1	6	4	5	1	4	6	3	4	6	9	5	5	4	6	3	4	9
Window	5	5	7	3	3	9	1	5	1	2	2	1	7	5	8	6	2	4	7	7
🔊	3	5	1	6	1	5	3	5	1	4	3	1	2	5	7	4	4	5	5	6
Zombie	7	7	6	6	6	7	1	9	5	4	6	6	7	4	7	2	1	7	4	2
🔊	7	9	5	3	1	8	4	9	1	8	2	4	3	1	2	5	1	5	8	1
Voice Radio	7	8	7	5	1	8	7	9	1	7	8	9	9	8	8	7	9	2	4	9
🔊	1	2	4	2	2	5	7	8	5	2	6	7	8	3	8	8	5	4	9	8
Tree fall	7	6	1	8	4	6	4	6	4	2	3	6	9	6	5	9	3	6	4	7
🔊	7	8	4	8	5	7	2	8	6	3	3	5	9	6	7	8	6	6	9	5
Church	8	7	3	6	5	7	5	1	8	3	6	8	8	7	6	8	7	3	4	3
🔊	6	8	8	3	5	8	1	3	1	4	3	3	4	3	5	2	3	3	9	4
Monster	6	3	6	7	1	6	5	9	3	3	4	5	7	5	3	3	2	7	5	6
🔊	7	7	2	8	5	6	6	5	4	3	4	2	7	2	4	4	3	6	9	3
Scream	8	6	3	8	4	6	2	9	5	4	7	7	9	2	7	7	7	5	9	9
🔊	7	3	2	6	8	3	8	9	4	4	7	6	9	7	8	8	8	4	8	9
Manhole	8	4	2	6	4	5	2	1	6	5	4	7	6	2	2	7	6	4	5	6
🔊	7	6	6	7	5	6	8	6	7	2	7	7	7	5	7	9	6	4	3	6
Roar	7	6	2	9	4	6	1	7	4	4	2	5	6	6	7	6	6	5	3	1
🔊	7	3	5	7	1	4	3	9	1	4	8	8	6	8	7	9	7	5	9	5
Water	6	9	7	3	3	8	1	1	2	6	7	8	9	1	8	8	9	7	9	9
🔊	6	8	3	2	5	5	1	7	7	2	8	8	9	8	9	9	8	7	9	8

2.2 *The Sounds of Fear*: Raw data comparing untreated audio against DSP effects (🔊) and offline datasets (A1-10) against online (B1-10) for user-defined measures of emotional *valence* on a nine point scale

	A1	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**	**A8**	**A9**	**A10**	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	**B9**	**B10**
Footsteps	5	6	5	5	5	5	4	3	5	3	2	5	1	1	4	7	5	5	4	5
🔊	5	4	5	3	5	4	4	3	2	4	7	5	4	1	5	7	5	5	7	4
Music Radio	5	3	5	3	4	5	5	7	3	5	4	3	8	4	5	3	5	4	9	1
🔊	5	3	5	4	5	4	5	6	2	3	3	3	9	4	4	4	3	2	4	1
Window	5	4	4	5	4	3	5	5	1	3	8	5	7	4	2	4	5	4	5	3
🔊	5	4	5	4	3	4	5	6	1	5	7	5	2	3	3	4	5	4	3	3
Zombie	3	4	3	5	7	3	5	1	3	5	6	2	5	4	2	6	5	7	4	4
🔊	3	1	3	5	1	2	3	1	5	1	7	2	3	5	2	3	5	3	2	4
Voice Radio	3	2	2	4	5	2	3	1	5	1	4	1	9	2	1	6	1	3	4	1
🔊	5	5	5	5	7	5	2	1	1	3	4	2	8	5	1	3	3	3	1	3
Tree fall	2	3	2	3	3	3	7	3	2	4	7	3	7	3	5	8	5	5	4	3
🔊	3	2	2	2	5	3	3	3	1	3	3	4	7	3	2	8	4	5	1	3
Church	5	5	1	4	7	5	3	1	2	5	6	1	8	2	3	7	2	5	6	4
🔊	4	4	4	3	4	3	6	4	5	5	7	3	4	5	4	3	5	3	7	3
Monster	3	5	3	7	7	4	3	2	2	3	6	4	5	4	5	4	5	6	4	4
🔊	2	5	5	2	5	4	2	5	3	4	6	4	7	5	5	2	4	5	2	5
Scream	5	3	4	3	5	4	5	1	2	3	6	2	9	5	2	7	2	6	1	1
🔊	1	5	5	3	9	5	1	1	4	3	2	3	9	2	2	9	2	3	2	1
Manhole	1	5	5	3	4	5	3	4	2	2	7	2	7	4	3	6	3	4	5	4
🔊	6	3	2	5	6	4	2	4	2	5	5	2	4	4	3	8	3	4	5	3
Roar	3	3	5	2	6	4	5	1	2	3	6	3	7	2	2	6	2	7	4	4
🔊	3	5	3	8	7	3	4	9	5	3	3	2	7	2	2	9	2	5	1	3
Water	4	3	2	2	5	3	5	5	3	2	6	2	9	5	3	6	1	7	2	1
🔊	6	2	1	5	6	5	5	7	3	5	3	2	9	2	2	8	1	7	2	1

2.3 *The Horror Sound Designer*: Raw data comparing user input and online datasets (A1-10) against offline (B1-10)

	Pref. Sound	Attack 1	*d*	Attack 2	*d*	Pitch 1	*d*	Pitch 2	*d*	Delay 1	*d*	Delay 2	*d*	Position 1	*d*	Position 2	*d*
A1	Slam	15	1	5	2	+7	3	-10	2	2	2	2	3	Centre	2	Centre	2
A2	Slam	15	3	15	3	+7	1	0	1	2	1	14	2	Centre	1	Centre	1
A3	Slam	5	3	15	4	+7	1	-10	2	14	4	14	3	L2R	2	L2R	2
A4	Thunder	15	1	15	4	-10	1	-10	1	2	1	14	1	R2L	1	Centre	1
A5	Thunder	15	3	15	2	-10	3	-10	3	14	4	8	3	R2L	3	R2L	3
A6	Thunder	5	6	15	5	+7	4	-10	3	2	2	2	2	L2R	3	L2R	3
A7	Thunder	5	3	15	1	-10	1	+7	2	8	2	8	2	L2R	3	Right	1
A8	Thunder	15	3	15	4	-10	5	-10	2	14	4	2	3	Left	3	R2L	3
A9	Thunder	15	1	5	1	+7	6	0	3	8	1	8	1	L2R	1	Right	1
A10	Thunder	15	2	15	1	-10	1	-10	1	2	1	2	1	R2L	1	R2L	1
B1	Thunder	5	4	0	4	0	4	+7	3	2	4	14	3	Centre	3	R2L	4
B2	Thunder	0	6	5	6	+7	5	+7	5	2	5	14	5	Centre	5	Centre	5
B3	Thunder	5	4	15	3	+7	3	-10	2	14	2	8	2	Left	2	Right	2
B4	Insect	5	6	15	6	+7	6	0	6	2	5	8	5	L2R	5	R2L	5
B5	Thunder	5	4	15	3	0	2	-10	1	8	1	2	1	Centre	1	Right	1
B6	SMG	0	4	15	3	+7	6	-10	4	14	4	14	4	Centre	4	Left	3
B7	Slam	5	2	5	1	0	4	+7	4	2	4	2	3	R2L	1	Centre	1
B8	Insect	0	4	15	3	0	1	-10	1	2	1	14	1	L2R	2	Centre	2
B9	Train	5	4	5	6	+7	5	+7	3	8	3	2	4	Centre	1	L2R	3
B10	Thunder	15	4	15	5	-10	5	0	1	8	4	2	2	L2R	3	R2L	3

2.4 *The Horror Sound Designer*: Complete online dataset (users 1-19)

	Pref. Sound	Attack 1	*d*	Attack 2	*d*	Pitch 1	*d*	Pitch 2	*d*	Delay 1	*d*	Delay 2	*d*	Position 1	*d*	Position 2	*d*
1	Thunder	5	4	0	4	0	4	+7	3	2	4	14	3	Centre	3	R2L	4
2	Thunder	0	6	5	6	+7	5	+7	5	2	5	14	5	Centre	5	Centre	5
3	Thunder	5	4	15	3	+7	3	-10	2	14	2	8	2	Left	2	Right	2
4	Insect	5	6	15	6	+7	6	0	6	2	5	8	5	L2R	5	R2L	5
5	Thunder	5	4	15	3	0	2	-10	1	8	1	2	1	Centre	1	Right	1
6	SMG	0	4	15	3	+7	6	-10	4	14	4	14	4	Centre	4	Left	3
7	Slam	5	2	5	1	0	4	+7	4	2	4	2	3	R2L	1	Centre	1
8	Insect	0	4	15	3	0	1	-10	1	2	1	14	1	L2R	2	Centre	2
9	Train	5	4	5	6	+7	5	+7	3	8	3	2	4	Centre	1	L2R	3
10	Thunder	15	4	15	5	-10	5	0	1	8	4	2	2	L2R	3	R2L	3
11	Thunder	0	4	15	4	-10	4	-10	3	14	3	2	2	Left	1	L2R	1
12	Slam	15	4	15	4	-10	4	-10	3	8	2	14	2	Left	3	L2R	3
13	Thunder	5	3	15	1	-10	1	+7	2	8	2	8	2	L2R	3	Right	1
14	Thunder	15	3	15	4	0	3	0	1	14	4	8	3	L2R	1	Right	1
15	Slam	15	4	15	3	+7	3	0	3	8	3	8	3	L2R	2	L2R	2
16	Slam	15	3	15	4	0	3	-10	1	8	2	8	2	Centre	1	Left	4
17	Thunder	15	3	15	3	+7	4	0	3	14	3	8	3	R2L	1	Right	1
18	Insect	0	5	15	3	-10	1	-10	1	8	1	14	1	R2L	1	Right	1
19	Thunder	15	3	15	3	0	2	0	2	14	4	8	3	L2R	6	Left	5

2.5 *The Horror Sound Designer*: Complete online dataset (users 20-38)

	Pref. Sound	Attack 1	*d*	Attack 2	*d*	Pitch 1	*d*	Pitch 2	*d*	Delay 1	*d*	Delay 2	*d*	Position 1	*d*	Position 2	*d*
20	Slam	0	3	15	2	+7	2	-10	3	8	3	8	2	Left	3	Centre	3
21	Slam	15	4	15	3	0	3	+7	2	2	2	2	2	Centre	1	Centre	2
22	Insect	0	4	0	5	0	3	0	3	14	2	8	2	R2L	2	Centre	2
23	Thunder	15	3	15	4	-10	5	-10	2	14	4	2	3	Left	3	R2L	3
24	Slam	5	3	15	4	0	5	0	3	2	3	2	3	Left	5	L2R	5
25	Slam	15	4	15	5	-10	3	0	2	2	5	14	4	L2R	2	L2R	3
26	Slam	5	4	0	4	-10	5	+7	4	14	3	2	4	L2R	3	Left	4
27	Slam	15	2	15	4	-10	4	+7	2	8	4	2	3	Centre	6	Centre	4
28	Thunder	15	3	0	5	+7	5	-10	2	8	6	2	4	L2R	4	L2R	4
29	Slam	15	5	0	4	-10	6	+7	1	2	4	14	5	Centre	2	Centre	3
30	Thunder	5	4	5	4	-10	5	0	4	14	6	2	3	Centre	4	Centre	4
31	Thunder	15	1	5	1	+7	6	0	3	8	1	8	1	L2R	1	Right	1
32	Thunder	15	2	15	1	-10	1	-10	1	2	1	2	1	R2L	1	R2L	1
33	Slam	15	1	5	2	+7	3	-10	2	2	2	2	3	Centre	2	Centre	2
34	Slam	15	3	15	3	+7	1	0	1	2	1	14	2	Centre	1	Centre	1
35	Slam	5	3	15	4	+7	1	-10	2	14	4	14	3	L2R	2	L2R	2
36	Thunder	15	1	15	4	-10	1	-10	1	2	1	14	1	R2L	1	Centre	1
37	Thunder	15	3	15	2	-10	3	-10	3	14	4	8	3	R2L	3	R2L	3
38	Thunder	5	6	15	5	+7	4	-10	3	2	2	2	2	L2R	3	L2R	3

2.6 *The Sounds of Fear*: Complete activation online dataset (users 1-14)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Footsteps	4	2	1	1	6	7	5	7	4	1	2	4	3	5
🔊	1	3	5	1	2	8	2	5	7	2	3	3	1	5
Music Radio	6	6	8	5	5	7	4	2	3	6	6	1	1	2
🔊	4	6	9	5	5	4	6	3	4	9	6	3	2	5
Window	2	1	7	5	8	6	2	4	7	7	2	5	2	1
🔊	3	1	2	5	7	4	4	5	5	6	3	4	1	6
Zombie	6	6	7	4	7	2	1	7	4	2	4	2	7	8
🔊	2	4	3	1	2	5	1	5	8	1	3	1	8	6
Voice Radio	8	9	9	8	8	7	9	2	4	9	7	7	6	3
🔊	6	7	8	3	8	8	5	4	9	8	7	3	6	6
Tree fall	3	6	9	6	5	9	3	6	4	7	5	4	5	7
🔊	3	5	9	6	7	8	6	6	9	5	7	1	8	6
Church	6	8	8	7	6	8	7	3	4	3	7	5	2	6
🔊	3	3	4	3	5	2	3	3	9	4	4	2	2	7
Monster	4	5	7	5	3	3	2	7	5	6	4	7	7	7
🔊	4	2	7	2	4	4	3	6	9	3	3	8	3	5
Scream	7	7	9	2	7	7	7	5	9	9	5	9	2	6
🔊	7	6	9	7	8	8	8	4	8	9	6	8	7	3
Manhole	4	7	6	2	2	7	6	4	5	6	5	4	2	6
🔊	7	7	7	5	7	9	6	4	3	6	5	2	6	4
Roar	2	5	6	6	7	6	6	5	3	1	6	3	2	2
🔊	8	8	6	8	7	9	7	5	9	5	7	5	4	6
Water	7	8	9	1	8	8	9	7	9	9	8	5	8	9
🔊	8	8	9	8	9	9	8	7	9	8	8	7	8	6

2.7 *The Sounds of Fear*: Complete activation online dataset (users 15-28)

	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Footsteps	3	3	2	2	5	1	7	3	3	4	1	2	3	4
🔊	3	2	1	3	2	3	7	4	3	4	1	3	5	5
Music Radio	5	6	4	6	1	5	3	2	3	7	1	7	1	5
🔊	3	3	4	5	1	4	6	3	5	4	1	6	4	5
Window	2	3	3	3	1	5	1	2	5	5	7	3	3	9
🔊	2	4	2	5	3	5	1	4	3	5	1	6	1	5
Zombie	4	4	3	3	1	9	5	4	7	7	6	6	6	7
🔊	4	1	2	3	4	9	1	8	7	9	5	3	1	8
Voice Radio	8	6	8	8	7	9	1	7	7	8	7	5	1	8
🔊	3	1	7	6	7	8	5	2	1	2	4	2	2	5
Tree fall	2	5	3	7	4	6	4	2	7	6	1	8	4	6
🔊	2	6	3	4	2	8	6	3	7	8	4	8	5	7
Church	5	7	3	7	5	1	8	3	8	7	3	6	5	7
🔊	3	3	2	3	1	3	1	4	6	8	8	3	5	8
Monster	6	3	4	4	5	9	3	3	6	3	6	7	1	6
🔊	3	4	5	3	6	5	4	3	7	7	2	8	5	6
Scream	7	4	7	7	2	9	5	4	8	6	3	8	4	6
🔊	7	8	6	7	8	9	4	4	7	3	2	6	8	3
Manhole	3	7	5	8	2	1	6	5	8	4	2	6	4	5
🔊	5	7	5	6	8	6	7	2	7	6	6	7	5	6
Roar	2	3	3	4	1	7	4	4	7	6	2	9	4	6
🔊	7	3	4	6	3	9	1	4	7	3	5	7	1	4
Water	7	8	6	8	1	1	2	6	6	9	7	3	3	8
🔊	8	9	7	4	1	7	7	2	6	8	3	2	5	5

2.8 *The Sounds of Fear*: Complete valence online dataset (users 1-14)

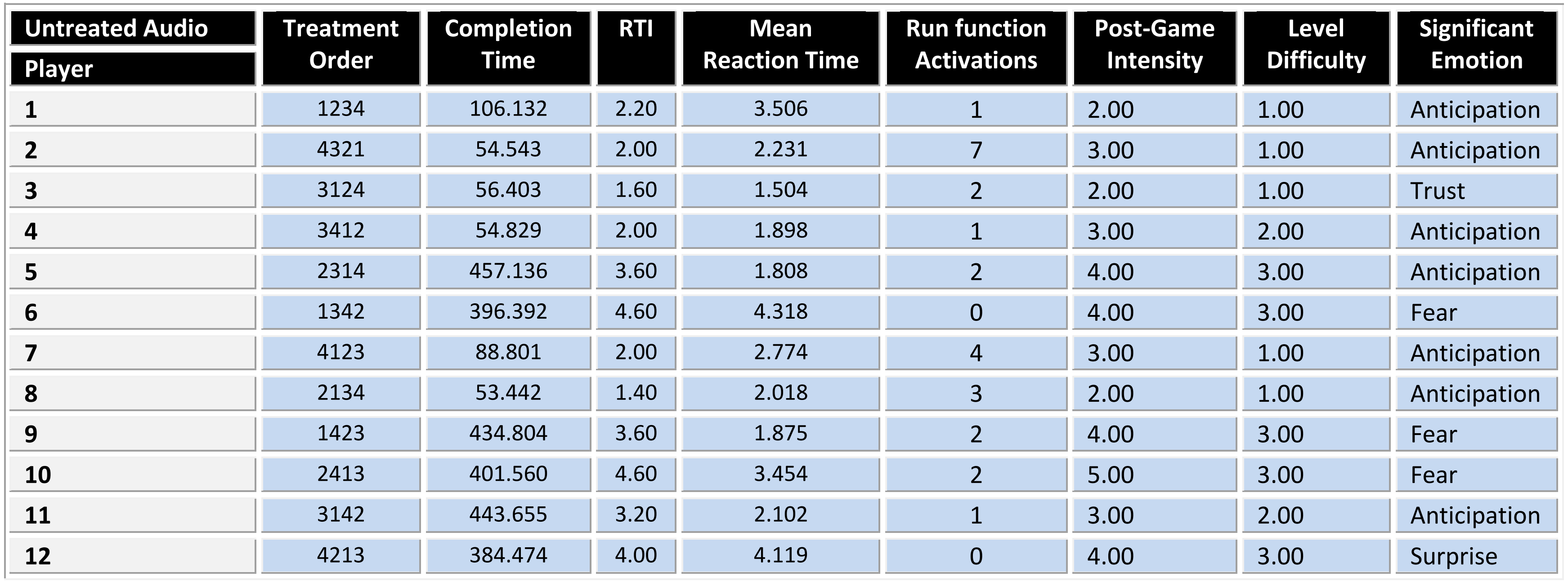
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Footsteps	2	5	1	1	4	7	5	5	4	5	5	4	5	3
🔊	7	5	4	1	5	7	5	5	7	4	5	7	5	3
Music Radio	4	3	8	4	5	3	5	4	9	1	4	5	5	5
🔊	3	3	9	4	4	4	3	2	4	1	4	6	5	4
Window	8	5	7	4	2	4	5	4	5	3	5	3	5	5
🔊	7	5	2	3	3	4	5	4	3	3	5	2	5	2
Zombie	6	2	5	4	2	6	5	7	4	4	4	5	2	1
🔊	7	2	3	5	2	3	5	3	2	4	5	7	1	2
Voice Radio	4	1	9	2	1	6	1	3	4	1	4	3	4	6
🔊	4	2	8	5	1	3	3	3	1	3	2	5	3	2
Tree fall	7	3	7	3	5	8	5	5	4	3	4	4	3	3
🔊	3	4	7	3	2	8	4	5	1	3	3	6	2	3
Church	6	1	8	2	3	7	2	5	6	4	4	3	4	3
🔊	7	3	4	5	4	3	5	3	7	3	4	6	5	4
Monster	6	4	5	4	5	4	5	6	4	4	5	1	2	1
🔊	6	4	7	5	5	2	4	5	2	5	5	2	4	2
Scream	6	2	9	5	2	7	2	6	1	1	5	2	1	2
🔊	2	3	9	2	2	9	2	3	2	1	3	2	2	4
Manhole	7	2	7	4	3	6	3	4	5	4	5	3	5	4
🔊	5	2	4	4	3	8	3	4	5	3	4	2	4	6
Roar	6	3	7	2	2	6	2	7	4	4	4	5	5	6
🔊	3	2	7	2	2	9	2	5	1	3	2	2	4	5
Water	6	2	9	5	3	6	1	7	2	1	2	2	2	1
🔊	3	2	9	2	2	8	1	7	2	1	3	2	2	2

2.9 *The Sounds of Fear*: Complete activation online dataset (users 15-28)

	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Footsteps	5	2	5	5	4	3	5	3	5	6	5	5	5	5
🔊	5	2	5	5	4	3	2	4	5	4	5	3	5	4
Music Radio	4	7	4	4	5	7	3	5	5	3	5	3	4	5
🔊	4	6	4	4	5	6	2	3	5	3	5	4	5	4
Window	5	4	5	4	5	5	1	3	5	4	4	5	4	3
🔊	4	6	5	5	5	6	1	5	5	4	5	4	3	4
Zombie	4	5	4	4	5	1	3	5	3	4	3	5	7	3
🔊	5	2	5	3	3	1	5	1	3	1	3	5	1	2
Voice Radio	2	5	2	2	3	1	5	1	3	2	2	4	5	2
🔊	5	1	2	3	2	1	1	3	5	5	5	5	7	5
Tree fall	5	6	5	3	7	3	2	4	2	3	2	3	3	3
🔊	4	7	5	4	3	3	1	3	3	2	2	2	5	3
Church	4	7	4	3	3	1	2	5	5	5	1	4	7	5
🔊	5	3	4	5	6	4	5	5	4	4	4	3	4	3
Monster	4	5	4	4	3	2	2	3	3	5	3	7	7	4
🔊	4	4	4	5	2	5	3	4	2	5	5	2	5	4
Scream	3	3	2	2	5	1	2	3	5	3	4	3	5	4
🔊	3	8	3	2	1	1	4	3	1	5	5	3	9	5
Manhole	5	7	4	3	3	4	2	2	1	5	5	3	4	5
🔊	4	7	4	4	2	4	2	5	6	3	2	5	6	4
Roar	5	5	5	4	5	1	2	3	3	3	5	2	6	4
🔊	3	7	5	2	4	9	5	3	3	5	3	8	7	3
Water	3	8	3	6	5	5	3	2	4	3	2	2	5	3
🔊	3	8	3	5	5	7	3	5	6	2	1	5	6	5

iii) Preliminary Assessment of the Fear Value of Preselected Sound Parameters in a Survival Horror Game

3.1 Empirical & subjective datasets from three individual audio treatments and one untreated control group



Untreated Audio Player	Treatment Order	Completion Time	RTI	Mean Reaction Time	Run function Activations	Post-Game Intensity	Level Difficulty	Significant Emotion
1	1234	106.132	2.20	3.506	1	2.00	1.00	Anticipation
2	4321	54.543	2.00	2.231	7	3.00	1.00	Anticipation
3	3124	56.403	1.60	1.504	2	2.00	1.00	Trust
4	3412	54.829	2.00	1.898	1	3.00	2.00	Anticipation
5	2314	457.136	3.60	1.808	2	4.00	3.00	Anticipation
6	1342	396.392	4.60	4.318	0	4.00	3.00	Fear
7	4123	88.801	2.00	2.774	4	3.00	1.00	Anticipation
8	2134	53.442	1.40	2.018	3	2.00	1.00	Anticipation
9	1423	434.804	3.60	1.875	2	4.00	3.00	Fear
10	2413	401.560	4.60	3.454	2	5.00	3.00	Fear
11	3142	443.655	3.20	2.102	1	3.00	2.00	Anticipation
12	4213	384.474	4.00	4.119	0	4.00	3.00	Surprise

Pitch Player	Completion Time	RTI	Mean Reaction Time	Run function Activations	Post-Game Intensity	Level Difficulty	Significant Emotion
1	107.561	4.000	3.00	1.648	3.00	2.00	Surprise
2	62.399	5.000	2.20	2.452	2.00	2.00	Anticipation
3	57.609	5.000	1.00	1.253	1.00	1.00	Trust
4	49.545	4.000	3.20	1.740	5.00	3.00	Fear
5	237.412	2.000	3.40	2.452	4.00	3.00	Surprise
6	107.673	1.000	2.40	2.469	3.00	2.00	Anticipation
7	98.361	5.000	2.00	2.557	3.00	1.00	Anticipation
8	116.023	4.000	1.40	2.242	3.00	1.00	Anticipation
9	234.985	2.000	4.00	2.411	4.00	3.00	Anticipation
10	345.888	2.000	2.60	2.601	4.00	3.00	Surprise
11	100.620	1.000	2.60	2.546	3.00	2.00	Anticipation
12	122.745	1.000	2.20	2.294	3.00	2.00	Fear

3D Localisation Player	Completion Time	RTI	Mean Reaction Time	Run function Activations	Post-Game Intensity	Level Difficulty	Significant Emotion
1	66.182	4.000	1.60	1.705	1.00	3.00	Boredom
2	168.815	5.000	2.20	2.528	2.00	3.00	Anticipation
3	62.264	5.000	2.00	1.438	2.00	2.00	Fear
4	80.296	4.000	2.80	1.911	3.00	3.00	Fear
5	229.760	2.000	3.40	2.607	4.00	3.00	Anticipation
6	706.558	1.000	4.40	2.040	3.00	4.00	Anticipation
7	156.169	5.000	2.00	2.504	4.00	1.00	Surprise
8	49.318	4.000	2.00	2.068	3.00	1.00	Anticipation
9	256.112	2.000	3.60	2.459	4.00	3.00	Anticipation
10	356.456	1.000	4.40	1.896	3.00	4.00	Surprise
11	203.008	2.000	3.40	2.607	4.00	3.00	Anticipation
12	281.020	1.000	4.40	2.143	4.00	4.00	Surprise

Loudness Boost Player	Completion Time	RTI	Mean Reaction Time	Run function Activations	Post-Game Intensity	Level Difficulty	Significant Emotion
1	53.281	4.000	2.40	1.521	3.00	2.00	Surprise
2	94.193	5.000	2.00	2.288	2.00	3.00	Anticipation
3	78.351	5.000	1.80	1.545	2.00	3.00	Anticipation
4	95.390	4.000	2.40	1.910	4.00	3.00	Anticipation
5	211.718	2.000	3.40	1.556	4.00	3.00	Boredom
6	352.680	1.000	3.80	4.358	3.00	2.00	Excited
7	88.086	5.000	2.60	3.338	3.00	1.00	Anticipation
8	63.300	4.000	2.00	1.937	3.00	1.00	Anticipation
9	199.900	2.000	3.20	1.344	4.00	3.00	Boredom
10	294.315	1.000	3.60	3.654	4.00	2.00	Anticipation
11	241.654	2.000	3.60	1.659	3.00	3.00	Anticipation
12	364.778	1.000	4.00	3.981	4.00	2.00	Surprise

3.2 Overall experience & personal information

Player	Immersion	Flow	Most Intense Level	Experience (hrs p/w)	Age	Gender	Impairments	Nationality
1	2	3	Loud	13	22	Male	None	British
2	3	3	Untreated	18	21	Male	None	British
3	3	2	Loud	18	24	Male	None	British
4	4	1	Pitch	14	25	Female	None	British
5	3	3	Untreated	3	26	Male	None	British
6	4	3	Untreated	0	55	Female	None	British
7	3	1	Loud	17	27	Male	None	British
8	3	2	Surround	14	24	Male	None	British
9	3	3	Loud	12	24	Male	None	British
10	4	3	Pitch	13	21	Male	None	British
11	3	1	Untreated	15	21	Male	None	British
12	2	3	Loud	15	22	Male	None	British

3.3 Event log data & real-time intensity responses

Quantitative Datasets obtained in Real-time During Gameplay [Player 1]

Game Type	Sound Event Name	Sound Event Time (α)	Intensity Rating	Audio Response Time (β)	Reaction Time (α-β)
Original	**Zombie Call**	28.144	3	42.866	4.722
	Twig Snap	57.362	1	59.650	2.288
	Woman Scream	69.389	2	72.363	2.974
	Monster Scream	78.733	3	82.556	3.829
	Animal Scream	94.838	2	98.555	3.717
Pitch	**Zombie Call**	11.789	2	13.991	2.202
	Twig Snap	20.337	3	21.131	0.794
	Woman Scream	82.935	3	84.161	1.226
	Monster Scream	89.901	3	91.835	1.934
	Animal Scream	98.093	4	100.177	2.084
3D Localisation	**Zombie Call**	6.229	2	8.051	1.822
	Twig Snap	14.082	1	15.172	1.090
	Woman Scream	39.437	1	41.198	1.761
	Monster Scream	47.432	2	49.639	2.207
	Animal Scream	59.020	2	60.665	1.645
Loudness Boost	**Zombie Call**	5.373	1	6.574	1.201
	Twig Snap	15.429	1	16.484	1.055
	Woman Scream	27.313	3	28.997	1.684
	Monster Scream	36.854	3	38.826	1.972
	Animal Scream	44.471	4	46.166	1.695

Quantitative Datasets obtained in Real-time During Gameplay [Player 2]

Game Type	Sound Event Name	Sound Event Time (α)	Intensity Rating	Audio Response Time (β)	Reaction Time (α-β)
Original	**Zombie Call**	6.105	2	9.676	3.571
	Twig Snap	13.876	1	14.314	0.438
	Woman Scream	24.919	2	27.360	2.441
	Monster Scream	34.425	2	36.836	2.411
	Animal Scream	47.899	3	50.149	2.250
Pitch	**Zombie Call**	8.007	2	11.744	3.737
	Twig Snap	16.394	1	18.050	1.656
	Woman Scream	27.873	2	30.095	2.222
	Monster Scream	43.700	3	46.145	2.445
	Animal Scream	55.322	3	57.523	2.201
3D Localisation	**Zombie Call**	20.755	2	23.925	3.170
	Twig Snap	50.288	1	51.886	1.598
	Woman Scream	101.267	2	103.505	2.238
	Monster Scream	110.761	3	113.481	2.72
	Animal Scream	159.710	3	162.623	2.913
Loudness Boost	**Zombie Call**	13.003	2	16.173	3.170
	Twig Snap	41.269	1	42.901	1.632
	Woman Scream	55.463	2	57.481	2.018
	Monster Scream	63.403	2	65.856	2.453
	Animal Scream	74.969	3	77.134	2.165

Quantitative Datasets obtained in Real-time During Gameplay [Player 3]

Game Type	Sound Event Name	Sound Event Time (α)	Intensity Rating	Audio Response Time (β)	Reaction Time (α-β)
Original	**Zombie Call**	6.631	2	7.762	1.131
	Twig Snap	13.129	1	14.505	1.376
	Woman Scream	21.990	1	23.881	1.891
	Monster Scream	30.198	2	31.923	1.725
	Animal Scream	40.070	2	41.466	1.396
Pitch	**Zombie Call**	8.530	1	9.397	0.867
	Twig Snap	14.844	1	15.837	0.993
	Woman Scream	23.365	1	24.946	1.581
	Monster Scream	31.476	1	33.154	1.678
	Animal Scream	41.817	1	42.964	1.147
3D Localisation	**Zombie Call**	8.566	2	10.368	1.802
	Twig Snap	24.068	1	25.015	0.947
	Woman Scream	35.185	3	37.194	2.009
	Monster Scream	45.977	2	47.037	1.060
	Animal Scream	53.373	2	54.745	1.372
Loudness Boost	**Zombie Call**	6.351	1	7.318	0.967
	Twig Snap	14.197	1	15.260	1.063
	Woman Scream	26.748	3	28.807	2.059
	Monster Scream	61.889	1	63.842	1.953
	Animal Scream	69.134	3	70.815	1.681

Quantitative Datasets obtained in Real-time During Gameplay [Player 4]

Game Type	Sound Event Name	Sound Event Time (α)	Intensity Rating	Audio Response Time (β)	Reaction Time (α-β)
Original	**Zombie Call**	6.597	1	8.065	1.468
	Twig Snap	22.167	1	24.114	1.947
	Woman Scream	29.403	2	31.322	1.919
	Monster Scream	37.212	2	39.306	2.094
	Animal Scream	44.406	4	46.47	2.064
Pitch	**Zombie Call**	8.368	2	9.903	1.535
	Twig Snap	14.914	2	16.476	1.562
	Woman Scream	23.39	3	25.352	1.962
	Monster Scream	32.152	4	34.361	2.201
	Animal Scream	42.763	5	44.204	1.441
3D Localisation	**Zombie Call**	15.100	3	17.502	2.402
	Twig Snap	27.056	2	28.647	1.591
	Woman Scream	33.713	3	35.253	1.54
	Monster Scream	42.492	3	44.529	2.037
	Animal Scream	49.586	3	51.569	1.983
Loudness Boost	**Zombie Call**	7.432	2	9.701	2.269
	Twig Snap	15.497	1	17.041	1.544
	Woman Scream	24.292	2	26.918	2.626
	Monster Scream	46.402	3	48.172	1.77
	Animal Scream	68.953	4	70.294	1.341

Quantitative Datasets obtained in Real-time During Gameplay [Player 5]					
Game Type	**Sound Event Name**	**Sound Event Time (α)**	**Intensity Rating**	**Audio Response Time (β)**	**Reaction Time (α-β)**
Original	**Zombie Call**	18.263	3	20.132	1.869
	Twig Snap	39.960	2	41.529	1.569
	Woman Scream	152.882	4	155.200	2.318
	Monster Scream	329.045	4	330.676	1.631
	Animal Scream	426.920	5	428.573	1.653
Pitch	**Zombie Call**	21.725	3	25.061	3.336
	Twig Snap	37.764	1	41.111	3.347
	Woman Scream	69.260	4	71.274	2.014
	Monster Scream	156.490	4	158.862	2.372
	Animal Scream	196.107	5	197.300	1.193
3D Localisation	**Zombie Call**	20.546	3	22.214	1.668
	Twig Snap	58.828	2	61.42	2.592
	Woman Scream	92.010	3	93.752	1.742
	Monster Scream	112.593	4	115.441	2.848
	Animal Scream	205.047	5	206.231	1.184
Loudness Boost	**Zombie Call**	19.882	3	21.584	1.702
	Twig Snap	44.870	2	46.576	1.706
	Woman Scream	71.932	4	73.336	1.404
	Monster Scream	90.751	4	92.321	1.57
	Animal Scream	183.45	4	184.847	1.397

Quantitative Datasets obtained in Real-time During Gameplay [Player 6]

Game Type	Sound Event Name	Sound Event Time (α)	Intensity Rating	Audio Response Time (β)	Reaction Time (α-β)
Original	**Zombie Call**	39.809	4	50.620	10.811
	Twig Snap	87.615	4	91.561	3.946
	Woman Scream	243.115	5	245.415	2.300
	Monster Scream	321.840	5	323.993	2.153
	Animal Scream	373.000	5	375.378	2.378
Pitch	**Zombie Call**	32.089	3	35.058	2.969
	Twig Snap	44.235	3	47.371	3.136
	Woman Scream	60.797	2	62.853	2.056
	Monster Scream	72.897	2	75.031	2.134
	Animal Scream	95.702	2	97.754	2.052
3D Localisation	**Zombie Call**	7.249	4	9.418	2.169
	Twig Snap	24.319	4	25.668	1.349
	Woman Scream	115.017	5	116.992	1.975
	Monster Scream	220.860	4	222.898	2.038
	Animal Scream	675.282	5	677.953	2.671
Loudness Boost	**Zombie Call**	28.672	3	31.208	2.536
	Twig Snap	41.071	3	43.420	2.349
	Woman Scream	53.982	4	55.165	1.183
	Monster Scream	208.380	4	211.888	3.508
	Animal Scream	323.467	5	335.679	12.212

Quantitative Datasets obtained in Real-time During Gameplay [Player 7]

Game Type	Sound Event Name	Sound Event Time (α)	Intensity Rating	Audio Response Time (β)	Reaction Time (α-β)
Original	**Zombie Call**	11.099	1	14.903	3.804
	Twig Snap	23.642	1	25.714	2.072
	Woman Scream	38.999	2	41.563	2.564
	Monster Scream	52.756	3	55.627	2.871
	Animal Scream	68.198	3	70.758	2.560
Pitch	**Zombie Call**	10.864	1	13.466	2.602
	Twig Snap	29.499	1	31.751	2.252
	Woman Scream	47.142	2	49.369	2.227
	Monster Scream	60.263	3	63.426	3.163
	Animal Scream	75.655	3	78.198	2.543
3D Localisation	**Zombie Call**	13.065	1	15.701	2.636
	Twig Snap	26.940	1	29.582	2.642
	Woman Scream	49.243	2	51.103	1.860
	Monster Scream	69.460	2	71.891	2.431
	Animal Scream	129.070	4	131.751	2.681
Loudness Boost	**Zombie Call**	13.346	2	16.817	3.471
	Twig Snap	27.659	1	30.864	3.205
	Woman Scream	44.122	3	47.681	3.559
	Monster Scream	57.692	3	61.061	3.369
	Animal Scream	67.985	4	71.071	3.086

Quantitative Datasets obtained in Real-time During Gameplay [Player 8]					
Game Type	**Sound Event Name**	**Sound Event Time (α)**	**Intensity Rating**	**Audio Response Time (β)**	**Reaction Time (α-β)**
Original	**Zombie Call**	8.894	1	11.153	2.259
	Twig Snap	17.437	1	19.394	1.957
	Woman Scream	27.234	2	29.004	1.770
	Monster Scream	34.424	2	36.512	2.088
	Animal Scream	41.370	1	43.385	2.015
Pitch	**Zombie Call**	10.548	1	12.165	1.617
	Twig Snap	17.220	1	19.924	2.704
	Woman Scream	47.800	1	49.456	1.656
	Monster Scream	56.897	1	60.497	3.600
	Animal Scream	76.517	3	78.148	1.631
3D Localisation	**Zombie Call**	6.544	1	9.014	2.47
	Twig Snap	12.694	1	14.819	2.125
	Woman Scream	22.054	2	23.728	1.674
	Monster Scream	30.808	3	32.904	2.096
	Animal Scream	42.339	3	44.316	1.977
Loudness Boost	**Zombie Call**	6.881	1	9.183	2.302
	Twig Snap	13.349	1	15.056	1.707
	Woman Scream	24.874	3	26.667	1.793
	Monster Scream	32.219	1	34.308	2.089
	Animal Scream	42.723	4	44.519	1.796

Quantitative Datasets obtained in Real-time During Gameplay [Player 9]

Game Type	Sound Event Name	Sound Event Time (α)	Intensity Rating	Audio Response Time (β)	Reaction Time (α-β)
Original	**Zombie Call**	20.665	3	19.718	0.947
	Twig Snap	101.331	3	99.326	2.005
	Woman Scream	143.985	4	142.184	1.801
	Monster Scream	305.884	3	303.772	2.112
	Animal Scream	410.351	5	407.841	2.510
Pitch	**Zombie Call**	5.687	3	3.684	2.003
	Twig Snap	24.953	3	22.152	2.801
	Woman Scream	86.64	5	84.162	2.478
	Monster Scream	149.561	4	146.893	2.668
	Animal Scream	201.561	5	199.456	2.105
3D Localisation	**Zombie Call**	23.347	3	21.045	2.302
	Twig Snap	98.78	4	96.666	2.114
	Woman Scream	126.648	4	125.05	1.598
	Monster Scream	200.154	3	197.208	2.946
	Animal Scream	245.228	4	241.893	3.335
Loudness Boost	**Zombie Call**	15.014	3	13.222	1.792
	Twig Snap	90.15	3	89.129	1.021
	Woman Scream	123.447	4	122.215	1.232
	Monster Scream	143.687	5	142.02	1.667
	Animal Scream	187.186	5	186.178	1.008

Quantitative Datasets obtained in Real-time During Gameplay [Player 10]					
Game Type	**Sound Event Name**	**Sound Event Time (α)**	**Intensity Rating**	**Audio Response Time (β)**	**Reaction Time (α-β)**
Original	**Zombie Call**	12.758	4	8.917	3.841
	Twig Snap	165.675	4	162.218	3.457
	Woman Scream	256.98	5	253.875	3.105
	Monster Scream	304.445	5	301	3.445
	Animal Scream	381.875	5	378.453	3.422
Pitch	**Zombie Call**	38.155	2	35.698	2.457
	Twig Snap	184.765	1	182.79	1.975
	Woman Scream	246.557	3	244.085	2.472
	Monster Scream	305.48	3	302.694	2.786
	Animal Scream	332.564	4	329.249	3.315
3D Localisation	**Zombie Call**	10.547	4	9.062	1.485
	Twig Snap	104.65	3	102.654	1.996
	Woman Scream	201.756	5	200.056	1.7
	Monster Scream	246.56	5	243.798	2.762
	Animal Scream	346.982	5	345.445	1.537
Loudness Boost	**Zombie Call**	16.975	3	12.96	4.015
	Twig Snap	83.954	3	81.37	2.584
	Woman Scream	156.655	4	153.501	3.154
	Monster Scream	186.645	4	182.749	3.896
	Animal Scream	280.114	4	275.493	4.621

Quantitative Datasets obtained in Real-time During Gameplay [Player 11]

Game Type	Sound Event Name	Sound Event Time (α)	Intensity Rating	Audio Response Time (β)	Reaction Time (α-β)
Original	**Zombie Call**	15.947	3	14.3	1.647
	Twig Snap	46.471	3	43.984	2.487
	Woman Scream	319.775	3	317.298	2.477
	Monster Scream	401.607	4	400.117	1.49
	Animal Scream	429.647	3	427.238	2.409
Pitch	**Zombie Call**	9.995	2	8.121	1.874
	Twig Snap	30.017	1	28.063	1.954
	Woman Scream	56.782	3	54.586	2.196
	Monster Scream	76.775	3	73.094	3.681
	Animal Scream	94.504	4	91.479	3.025
3D Localisation	**Zombie Call**	23.881	3	20.424	3.457
	Twig Snap	46.345	2	44.86	1.485
	Woman Scream	91.015	4	88.864	2.151
	Monster Scream	104.666	4	101.721	2.945
	Animal Scream	180.264	4	177.267	2.997
Loudness Boost	**Zombie Call**	27.993	3	26.948	1.045
	Twig Snap	40.677	2	39.023	1.654
	Woman Scream	104.751	4	102.906	1.845
	Monster Scream	156.364	4	154.52	1.844
	Animal Scream	210.784	5	202.489	8.295

Quantitative Datasets obtained in Real-time During Gameplay [Player 12]					
Game Type	**Sound Event Name**	**Sound Event Time (α)**	**Intensity Rating**	**Audio Response Time (β)**	**Reaction Time (α-β)**
Original	**Zombie Call**	56.751	3	52.076	4.675
	Twig Snap	106.446	3	102.989	3.457
	Woman Scream	241.915	5	237.891	4.024
	Monster Scream	304.554	4	301.453	3.101
	Animal Scream	361.457	5	356.119	5.338
Pitch	**Zombie Call**	20.115	2	18.568	1.547
	Twig Snap	34.197	1	30.74	3.457
	Woman Scream	65.485	3	62.531	2.954
	Monster Scream	81.467	2	79.82	1.647
	Animal Scream	102.45	3	90.98	11.47
3D Localisation	**Zombie Call**	63.473	4	62.021	1.452
	Twig Snap	104.555	3	102.56	1.995
	Woman Scream	156.778	5	154.293	2.485
	Monster Scream	201.468	5	198.467	3.001
	Animal Scream	267.648	5	265.866	1.782
Loudness Boost	**Zombie Call**	19.998	4	15.484	4.514
	Twig Snap	101.798	3	98.541	3.257
	Woman Scream	243.765	4	239.77	3.995
	Monster Scream	311.645	4	306.691	4.954
	Animal Scream	340.151	5	331.856	3.185