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Abstract. The 1970 proposition that there is an Uncanny Valley which man-made characters inhabit as their human-likeness (both appearance and movement) increases has been a growing topic of debate in the fields of robotics, animation and computer games particularly since the turn of the century. However, what the theory and subsequent related writings do not account for is the role of sound in creating perceptions of uncanniness and fear, a particularly useful attribute in computer game genres such as survival horror. This paper has a dual purpose: to explore diverse writings on the uncanny as they relate to sound and to prepare the groundwork for future work investigating the possible relationship between sound and the Uncanny Valley.

The paper comprises, in large part, a survey of selected works on the uncanny and the Uncanny Valley from a variety of disciplines. It emphasizes the link between uncanniness and negative emotions, such as fear and apprehension, and discusses the genesis of the term uncanny in early psychoanalytical writings, relating this to more modern theories on human emotion. Writings on the uncanny, or related emotional states, from psychoacoustics, textiles research, films and computer games are assessed as to their validity and potential application to the fostering of an aural climate of fear in computer games and, where such writings do not explicitly deal with sound, attempts are made to apply the ideas contained within to sound as it exists within computer games. In dealing with the theory of the Uncanny Valley, the paper points out the theory's focus on appearance and movement to the exclusion of sound and suggests that there is an uncanny in sound that might, in future, be used to modify the Uncanny Valley theory. Throughout, there is the suggestion that the uncanny (and any future theory of an audio or audiovisual Uncanny Valley) can be harnassed to the design of horror computer games.

Ultimately, it is hoped, such work will be of use to computer game sound designers who wish to create a greater perception of fear and apprehension through the canny use of uncanny sound. Some of the design tips presented at the end of the discussion are already used instinctively by sound designers across a range of media, including computer games, whereas others are less obvious in their origin and affect. Recently published empirical data is provided to strengthen the case for the latter. In some cases, the design tips must await the coming of procedural audio to computer games.

1. Introduction

In 1970, Mori defined the Uncanny Valley as the low point in negative perception that a robot (or similar character) provokes as it increasingly takes on human appearance.[1] According to this theory, the effect is more pronounced when movement is involved (see *Fig. 1*).

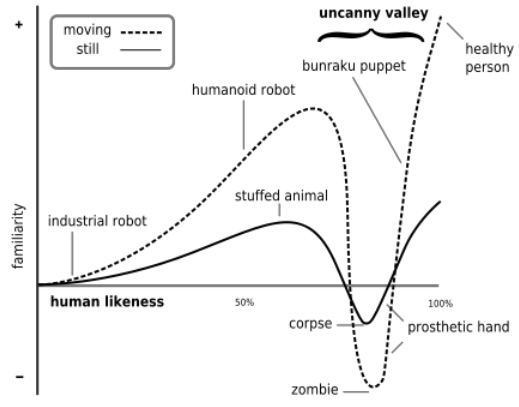

Figure 1: Mori's graph of the Uncanny Valley (from MacDorman)

Conceptually, the theory has its grounding in early psychoanalytical work. Freud expands upon Jentsch's 1906 definition of the uncanny as being something fundamentally familiar yet unfamiliar (life-like automata and waxworks being some of the examples cited) by adding definitional refinements of his own.[2] These include an uncanniness of coincidence, fear of one's eye-balls being gouged out (Freud characteristically equates this with the fear of castration), vestigial irrational beliefs surfacing uneasily in a rational world structure and, related to this, the uncovering of that which should not come to light. A common thread running through his analysis deals with the feelings of the person experiencing the uncanny – feelings of eeriness, strangeness and fear. The association of the uncanny with these emotional descriptors has been emphasized by later writers discussing Mori's theory. In particular, the emotion term fear has been equated to the uncanny (for example, Ho et al., [3]) and this equation forms a part of the underlying foundation of this paper.

The theory of the Uncanny Valley has been developed further in the field of robotics and computer games with writers such as MacDorman suggesting that the eerie sensations associated with the uncanny might be used to advantage in the appropriate context [4] (such as the survival horror genre of computer games – see also Hoeger and Huber [5]). Not all authorities accept the theory – Hanson suggests it is a pseudoscientific theory [6] – nevertheless, as a concept, it does provide the basis for some interesting discussion and can function as a stimulus for sound

design. What almost all studies dealing with the Uncanny Valley share, though, is a concentration on the image. Whether still or moving, such writings invariably deal with the appearance, and or motion, of the human-like character; there is a visual bias to the study of the uncanny.

This paper asks: *Is it possible to apply the Uncanny Valley theory to the emotions aroused by sound and thus to include sound as a factor in the Uncanny Valley?* Although it does not attempt to fully answer that question (such an answer must await more empirical research), the paper does seek to identify attributes of sound that contribute to the uncanny with the assumption that, should this identification be achieved, it will then be possible to codify aspects of computer game sound design that elicit or block negative emotions such as fear and its variants as the game genre requires. (In some future survival horror game, the author imagines a *less fear – more fear* sound FX slider in the game set-up interface, or a continual physiological monitoring of the player during gameplay that, through real-time sound synthesis and audio processing, keeps the player on a particular emotional roller-coaster.) Thus, where many visual modellers attempt to cross the Uncanny Valley, viewing it as an obstacle to overcome, this paper agrees with authors such as MacDorman and Hoeger et al. that the trough of the Uncanny Valley is, in some game genres, to be welcomed. Additionally, though, it also further supports earlier suggestions that, despite claims to the contrary, the obstacle that is the Uncanny Valley cannot, in fact, be overcome.[7]

2. Sound, the Uncanny and the Valley

In addition to psychoanalytical work, popular literature also contains descriptions of the uncanny and, in some cases, descriptions of uncanny sound. Some quotations from *The Beasts of Tarzan* demonstrate this: "From the lips of the ape-man came a weird, uncanny sound […] strange, uncanny notes that the girl could not ascribe to any particular night prowler – more terrible because of their mystery […] he was afraid of the jungle; uncanny noises that were indeed frightful came forth from its recesses".[8] Such uncanny sound is typically associated with negative emotions such as Plutchik's basic emotion of *terror* and its less intense outgrowths *fear* and *apprehension*.[9] (There are several theories of emotion but Plutchik's is an interesting one to use in this context because of its psychoevolutionary basis and the claim that emotions aid in the survival of the organism in the environment – interesting not merely because of similar claims made by writers on the uncanny, as illustrated below, but also because the exemplars used in many articles on fear in computer games tend to be first-person shooters or horror games where the player operates in a hostile environment.) These emotions, according to Plutchek, derive from the *threat* stimulus event which itself, as the Tarzan stories show, is often associated with the unknown, the unfamiliar, the darkness and the night. Such emotions and scenarios are the basic ingredients of the horror genre in literature, film and computer games.

There has been surprisingly little work on the association of emotions with sound (that is, sound FX as opposed to music or speech). In the area of sound design for the horror genre of cinema (which the parallel genre in computer games closely follows), and in the absence of any comprehensive and well-founded methodology, such design proceeds on the basis of experience, cliché or trial and error. It is usually no less effective for this. Some research in the area of computer games deals broadly with sound as a means to increase physiological and, therefore, emotional arousal in the player [10] and other work suggests this physiological arousal and associated emotion leads to player engagement and immersion in the 3-dimensional environments of first-person shooter games.[11] For a general overview of threat and associated emotions in computer games, see Perron.[12]

Interestingly, most research and writing on emotion and sound in virtual reality and computer games deals with the negative emotions – terror, fear and apprehension (using Plutchik's terminology) and their semantic variants (using others' terminologies); this paper continues that tradition. Outside of 3D-worlds, there is a wider survey of the emotions associated with sound but, nevertheless, research is patchy. Owren and Bachorowski, studying primate vocalizations, suggest that primates use some sounds not to convey representational information to a listener but to directly or indirectly affect and arouse particular emotional states within the listener at a fundamental cognitive level.[13] To do this, they manipulate the parameters of the sound directly and the authors hypothesize that this is how some forms of human laughter work and calls for attention from babies, for example. Edworthy et al. conducted an experiment on the perception of urgency as various parameters of sound and harmonic patterns of audio alarms were altered.[14] Their observations include: sounds with a fast onset and offset of 20msecs. or less are perceived as more urgent than sounds with a longer onset than offset which are themselves perceived as more urgent than sounds with a shorter onset than offset; and the more random the harmonic pattern of the sounds, the more urgent the perception of those sounds. The interesting result that sounds with a longer onset than offset are perceived as more pressing than the reverse is explained by the authors with the suggestion that the former class of sounds has the characteristic amplitude envelope of approaching sound sources whereas the latter class of sounds has more of the character of receding sound sources. Although no explanation is offered for the effect of melodic randomness, it may be that the perception of urgency is related to the uncertainty (in the West at least) arising from less tonally-centred music and the consequent difficulty of processing the tones and identifying a melodic pattern. This association of uncertainty (a lack of fluency in the processing of sound) with urgency and apprehension is developed further by authors discussing fear and sound in horror computer games, a discussion detailed below.

Alarms presage previously unseen threats and threats, according to Plutchik are the stimulus events leading to feelings of terror, fear and apprehension. Threat sounds are used to great effect in the computer game *Left 4 Dead* particularly where the actions of a player alert the swarm of zombies.[15] In this case, a wolf-like howl heralds the swarm's attack and it is the predatory denotation and lycanthropic connotation that is designed to send a chill up the spine. Paralleling this, Halpern et al., analyzing the nerve-jarring sound of fingernails scraping across a blackboard, suggest aversion to such a sound either might be because of its similarity to predator sounds or it might be (an implicit suggestion in the paper) a vestigial response to proto-human warning calls due to its similarity to the macaque monkey's warning screech (this is acknowledged as pure speculation in the paper and one of the authors has since disowned the conjecture).[16]

Cho et al. conducted an investigation into the parameters of textile sounds (that is, the rustling sounds of a variety of fabrics) that, it was assumed, were responsible for negative feelings about the textile.[17] Their results suggest that increasing loudness and sharpness of timbre (the lowest sharpness acum

value for any of the fabrics was 2.38, equivalent to a band of high frequency energy centred on approximately 5kHz) produce physiological reactions associated with negative emotions. In other words, loud, sharp sounds are not generally pleasant. Compare this to Halpern et al. who, when discussing parameters of sound leading to unpleasant feelings, accept loudness as a factor but discount high frequencies instead pointing to low-mid frequencies as the cause (a high-pass filter, attenuating frequencies below 2kHz, decreased the subjective unpleasantness rating). This suggests that negative affect responses may well be provoked by the presence of certain frequencies but there are probably additional factors involved as well. Context, connotation or something more subconscious are suggested by the reference to predatory sounds or macaque monkeys and their warning calls; more unpleasant physical associations might be suggested by the sound of crackling static electricity close to the skin. That there might be instinctive negative emotional responses to unexpected loud sounds in general is supported by the Moro Reflex found through a limited period in pre- and post-natal babies – a reflex response to sound (or falling) which, it has been suggested, is founded upon the one unlearned and innate human fear.

Moncrieff et al., in a study assessing the possibility of automatically classifying horror and thriller films by their audio content, analyzed the frequency of sound energy and affect events (these latter are an intentional emotional inflexion of the events visually portrayed).[18] Affect events are indexical, there being a "high level of semantic association between the sound energy and affect events" – where detected sound energy patterns correspond to an affect event (such as an alarm or sense of apprehension), they *affirm* the affect event and so the detection of many such patterns, according to the authors, can be used to classify film according to either horror or thriller genre. Given the typical intensity of the sound energy associated with the horror-type affect event, it would be interesting to see if the authors' classification method (tested on Western, Hollywood-style cinema) works for the cinema of other cultures. As Mala has stated: "Asian horror is often rooted in vision".[19] This contention is supported by *Ringu* [20] director Nakata: "Other people tend to use different sounds altogether to express horror, but I can increase the perception of it to the maximum by utilizing a very quiet sound".[21] The manifestation of threat stimulus events for fear and apprehension may well contain features that do not function uniformly across the human race but, instead, are culturally specific in their threat and meaning.

In a comparison of the uncanny in *Ringu* and the American remake *The Ring* [22], Ball provides a short section on aural uncanniness which, in *Ringu*, is exemplified for the author by the audio processing applied to the familiar sound of a ringing digital telephone.[23] Here, the uncanny is created through the process of making the familiar strange (the ringing heard is a combination of multiple telephone rings slightly processed to match the film's theme of water). According to Ball, it is this defamiliarization of a mundane sound – the distortion of a sound that yet retains its broadly recognizable original form and purpose – that leads to the uncanny. This is, perhaps, too broad and all-encompassing an explanation. There are many varieties of telephone ring, each approximating the classic and iconic telephone bell (both analogue and digital) but altering it in some way; there is no suggestion that any of these sounds are uncanny despite being defamiliarizing distortions of the original, familiar ring. Instead, the context of the ring plays an important role; not only is it framed within the horror film genre, it is signalled early as an apprehensive aural cue, a threat stimulus event, through the film's plot and narrative.

Ekman and Kajastila, rather than investigating the parameters of sound contributing to the feeling of being scared, conducted a small-scale, subjective study to determine the perceptual effect of localization on sounds already pre-judged to be 'scary'.[24] Importantly, sounds were played back to participants in the absence of any contextualizing image. Sounds comprised those made by "large predators, which motivates the importance of localizing the threat". The results support the authors' hypothesis "that the scariness of a (scary) sound is causally related to how well it affords localizing a potentially harmful source" and this, as the authors suggest, probably has its root cause in the evolutionary link between fear and survival. The inability to localize a sound is generalized to a lack of ease or fluency in processing sound; thus, according to the authors, "[t]he less information available, the more threatening the situation should be". This seems a surprisingly broad assessment. It is unlikely that de-localizing all types of sound will promote fear in the listener. Low-frequency sine waves, and similar natural sounds such as whale song, are difficult to localize yet are not necessarily threatening because of that – recordings of whale song are often used for relaxation purposes. The same could be said for the general hum of traffic outside my office or the 50-60Hz mains hum in a house. In the case of the authors' study, a predatory sound (already judged to be scary) is made more scary by removing the ability to localize it – generalizing this to all sounds is perhaps a step too far.

A sustaining thread in Ekman and Kajastila's argument is the impact of uncertainty on the perceived level of scariness of a sound. The concept of uncertainty also appears in Kromand's study of sound in the survival horror game genre; specifically, "a framework of uncertainty that constantly holds the player between knowledge and ignorance".[25] According to Kromand, the soundscapes of survival horror computer games purposefully mislead by making it unclear whether the sounds heard derive from within the game diegesis or without: this "collapse of the barrier between the diegetic and non-diegetic soundscape is a strategy to build a horror atmosphere". The removal of causality, an understanding of and awareness of the source of the sound, and its unsettling result is something that has been described by Chion in the context of cinema.[26] For sounds having no visible source on screen, Chion appropriates the electro-acoustic term *acousmatic*: "A sound or voice that remains acousmatic creates a mystery of the nature of its sound source, its properties and its powers". In film, the decision to unveil the mystery or not belongs solely to the director; in computer games, as Stockburger makes clear, such unveiling is more dynamic and sound sources may be unmasked by scripted events designed into the game (equivalent to the decisions of the cinematic director) or by the kinaesthetic intervention of the player.[27] In the cases that Kromand identifies, the sounds are destined to remain acousmatic and thus they are, as Parker and Heerama state, "instinctively threatening".[28]

Brenton et al. review a number of theories on presence, realism and the Uncanny Valley from which they derive five hypotheses on the relationship of the Uncanny Valley to presence in virtual worlds.[29] The Gestalt-derived theory of presence suggests the brain chooses one of a set of hypotheses relating either to what we perceive of a virtual world or to where we physically are. Engaging in the arcana of a virtual world yet still aware of the mundanity of reality (the weighty effect of gravity or the physical environment around the computer monitor, for example), the brain will pick one or the other hypothesis. The hypothesis chosen dictates where we feel present; in virtuality or reality. A switch from virtual hypothesis to reality hypothesis is a *break in presence*. As a conjecture, Brenton et al. theorize

that, in some cases, a break in presence may be related to the Uncanny Valley because both concern a change between the perception of two similar states or hypotheses. Further, describing as a switch the acceptance of one perceptual hypothesis over another, might, they suggest, be incorrect. The alternative theory they propose is that hypotheses are superimposed and, at any one time, one or the other is dominant.

In suggesting that a break in presence is related to perception of the uncanny and a realization of the Uncanny Valley, Brenton et al. state that "[a]n uncanny character […] may be a weak link that causes an unwanted break in presence". However, if uncanniness is related to negative emotions, such as fear and apprehension, then such a perception, presumably, is, in fact, wanted in the horror computer game. Tellingly, the authors recount a previous study in which it was reported that a virtual character elicited an uncanny response because its high level of graphical realism was not matched by a similar level of behavioural realism; the avatar seemed "like a zombie". This bears similarity to Laurel's statement that "we tend to expect that the modalities involved in a representation will have roughly the same "resolution" [...] A computer game that incorporates breathtakingly high-resolution, high-speed animation but produces only little beeps seems brain-damaged".[30] It is interesting, in the context of a discussion on uncanny sound and the horror computer game, that both sets of authors choose to report or use terms such as 'zombie' or 'brain-damaged' when talking of a mismatch of modality.

Brenton et al. make no mention of sound in their paper. However, the reported mismatch between appearance and behaviour, and its apparently consequential uncanny result, can be compared to a recent paper by Tinwell and Grimshaw that did include the voices of virtual characters (as well as their facial expression and facial behaviour) in a relatively large-sample qualitative study of the Uncanny Valley.[31] The results of this study led to the conclusions that, with increasing visual human-likeness of the character, perceptions of the uncanny increased: with a lack of human-likeness of the voice; with an increasing exaggeration of the articulation of the mouth while speaking; and with increasing lack of synchronization between lips and voice. In addition to noting that this is a study of the Uncanny Valley that combines image and sound, it is worth noting that all three of these uncanny factors involve some form of mismatch between the visual and aural modalities. It is interesting to speculate on why it is the case that the reverse of the first conclusion above (that an aural resolution that is low compared to the visual resolution leads to perceptions of uncanniness) does not appear to lead to the uncanny. Television and cinema are replete with examples of human animations of varying visual resolution over which real human voices are dubbed. I have suggested previously that "the [human] voice and its expression of language […] is the primary marker of the human being as opposed to other species […] using a real human voice dubbed onto an animation strengthens its anthropomorphic nature" and that cultural recognition of the primacy of the human voice (and the cognitive faculties it implies) may be found in a range of creation myths from Christianity (*In the beginning was the word*) to Mayan Popul Vuh (*Tepeu, Gucumatz and Juracán met and devised new beings capable of understanding, of speaking, of revering them* [32]).[33]

3. Conclusion

Having described a range of aural factors (or relationships between sound and image) that appear to influence perceptions of uncanniness, one might suppose that, in order to engender fear and apprehension in a horror computer game, all one needs do is apply these factors to the design of sound or its relationship to the image. It is, of course, not so simple. While bad cinematic over-dubbing (or careless foreign language dubbing) can be annoying and even, perhaps, unsettling to experience (uncanniness is hinted at by Pollick [34]), in another context, another frame, it can be humorous. Re-dubbing of Hong Kong Chock-Socky movies, with exaggeratedly unsynchronized voices, are a recurrent comedic staple as are high-pitched, helium-influenced voices dubbed onto men and gruff, low-pitched voices on women. Context is all important and, in the comedic examples given here, there is no suggestion that there is anything uncanny or that there is something to be fearful of (unlike the telephone ringing in *Ringu* described above). This context, or framing, might, in fact, be another of the Gestalt-like hypotheses – a choice, for example, that this is a comedy, and so should be laughed at, rather than a horror film, with which to experience delicious dread. If so, this lends credence to Brenton et al.'s suggestion that such hypotheses might be superimposed on each other but with the refinement that dominant hypotheses might co-exist. In the case of a first-person, survival horror computer game, the dominant hypotheses are a virtual presence hypothesis (leading to engagement and immersion in the game world) and a framing hypothesis (cueing fear and apprehension rather than – a typical defence against terror – laughter) co-existing above the hypothesis of reality and other framing hypotheses. Furthermore, if the uncanny really is, as Brenton et al. suggest, associated with the break in presence phenomenon, then the choice of a horror context as the framing hypothesis guards against the dislocation; the fear and unease associated with the uncanny are an *expected* part of the fabric of the virtual world and so there is no break in presence.

Brenton et al. and Minato et al. [35] have discussed aspects of (visual) habituation to appearance and behaviour in relation to the uncanny. The fatal flaw in computer game sound design as it currently stands, is that sound samples do not significantly change across multiple re-playings of a game and thus what might once have been unfamiliar and uncanny, becomes familiar and mundane. The user becomes habituated to the sounds and their use within the game world and knowledge replaces uncertainty thus increasing confidence at the expense of fear. Real-time sound synthesis (procedural audio) may go some way to solving this issue (increasing rather than lessening uncertainty and fear) by allowing the game engine to sonically respond in a relatively unpredictable manner in real-time to the player's presence and actions in the game world. Additionally, increasing use of biofeedback coupled with procedural audio techniques may well allow game engines to more precisely manipulate the player's emotions through real-time analysis of the player's emotional state. In this case, the game engine can then itself make flexible decisions as to how to play with the player's emotions – the player is too calm? then perhaps increase the level of sonic uncertainty.

Whilst there is much, much more to understand about the emotional effects of sound, the following general factors can be used to either design in or design out uncanniness (and, by extension, fear and apprehension) in the perception of a sound. They are provided as a rough rule of thumb only, are based on the small body of available research and may well work better in

combination. Above all, though, the sound designer should be aware of the omnipotence of the framing context:

- Certain amplitude envelopes applied to sound affect perceptions of urgency.
- Frequency might have an effect on the unpleasantness of sound and this might lead to negative affect.
- Familiar or iconic sounds can be defamiliarized and this can lead to perceptions of uncanniness.
- Uncertainty about the location of a sound source, its cause or its meaning in the virtual world increases the fear emotion.
- An aural resolution that is lower than a high quality, human-like visual resolution might lead to the uncanny.
- An exaggerated articulation of the mouth whilst speaking might lead to the uncanny.
- A lack of synchronization between lips and voice for photo-realistic virtual characters leads to a perception of the uncanny.

In a later empirical paper, Tinwell and Grimshaw suggest that, despite claims to the contrary as industry personnel unveil the latest human-like character, the Uncanny Valley cannot be traversed.[36] Whereas Brenton et al. suggest the Uncanny Valley is subject to change over time (uncanny characters can 'climb out of' the valley as they become familiar through experience and use), Tinwell and Grimshaw hypothesize that a traversal (to the rightmost lip of the valley and out of it) is impossible (assuming there is an element of uncanniness in the artefact to begin with). On the basis of the results of their study, the authors suggest that it is not familiarity but increasing technological discernment on the part of the audience that forbids the traverse. Like parallel railway tracks that meet at the horizon, technological advances and human quality speed into the distance seemingly ever closer. Yet, upon closer inspection and further up the tracks, this convergence is shown to be merely an illusion and the two are destined to remain separate.[1] Accordingly, the authors suggest that the Uncanny Valley should rather be thought of as an Uncanny Wall. However, this is merely a hypothesis to be tested and, for now, the theory Uncanny Valley provides enough conceptual grist to still be of use. Should the Uncanny Valley or similar prove to exist for (human-like) sound, critics should, perhaps, be equally wary of attempts to claim it has been overcome. Naturally, in the horror game genre, the news that there is an impassable Uncanny Wall rather than a traversable Uncanny Valley is, presumably, to be welcomed.

The theory of the Uncanny Valley (and its various expositions thus far) deals solely with visual appearance, movement and/or behaviour. It is clear, though, that there are parameters and ways of representing sound that lead to perceptions of uncanniness and associated negative affect. Future work, based on further empirical research, will investigate whether the Uncanny Valley can be used as a model for the perception of uncanny sound or whether that sound follows its own uncanny logic.

[1] The author, an atheist, is aware that this is an argument for a distinguishing divine spark in humans.

References

[1] Mori, M., *The uncanny valley*, Energy. Volume 7, 33-35 (1970)

[2] Freud, S., *The uncanny*, The Standard Edition of the Complete Psychological Works of Sigmund Freud, Volume 17, London, Hogarth Press, 219-256 (1955)

[3] Ho, C.-C., MacDorman, K., & Pramono, Z. A. D., *Human emotion and the uncanny valley. A GLM, MDS, and ISOMAP analysis of robot video ratings*, Proceedings of the Third ACM/IEEE International Conference on Human-Robot Interaction, Amsterdam, 169-176, (2008)

[4] MacDorman, K. F., *Subjective ratings of robot video clips for human likeness, familiarity, and eeriness: An exploration of the uncanny valley*, ICCS/CogSci-2006 Long Symposium: Toward Social Mechanisms of Android Science, Vancouver, Canada, (2006)

[5] Hoeger, L., & Huber, W., *Ghostly manipulation: Fatal Frame II and the videogame uncanny*, Situated Play, Proceedings of DiGRA 2007, 152-156 (2007)

[6] Ferber, D., *The man who mistook his girlfriend for a robot*, Popular Science, http://iiae.utdallas.edu/news/pop_science.html [accessed: 27 April 2009], (2003)

[7] Plantec, P., *Image Metrics attempts to leap the uncanny valley*, The Digital Eye, http://vfxworld.com/?atype=articles&id=3723&page=1 [accessed: 27 April 2009], (2008)

[8] Burroughs, E. R., *The beasts of Tarzan*, Project Gutenberg, http://www.gutenberg.org/etext/85 [accessed 2 May 2009], (2008)

[9] Plutchik, R., *A general psychoevolutionary theory of emotion*, R. Plutchik & H. Kellerman (Eds.), Emotion: Theory, research, and experience: Volume 1, Theories of emotion, New York, Academic, 3-33 (1980)

[10] Shilling, R., Zyda, M., & Wardynski, E. C., *Introducing emotion into military simulation and videogame design: America's Army: Operations and VIRTE*, GameOn, London, (2002)

[11] Grimshaw, M., Nacke, L., & Lindley, C. A., *Sound and immersion in the first-person shooter: Mixed measurement of the player's sonic experience*, Audio Mostly 2008, Piteå, Sweden, (2008)

[12] Perron, B., *Sign of a threat: The effects of warning systems in survival horror games*, COSIGN 2004, University of Split, Croatia, (2004)

[13] Owren, M. J., & Bachorowski, J.-A., *Reconsidering the evolution of nonlinguistic communication: The case of laughter*, Journal of Nonverbal Behavior, Volume 27(3), 183–200 (2003)

[14] Edworthy, J., Loxley, S., & Dennis, I., *Improving auditory warning design: Relationship between warning sound parameters and perceived urgency*, Human Factors, Volume 33(2), 205–231 (1991)

[15] Valve, *Left 4 Dead*, (2008)

[16] Halpern, D. Lynn., Blake, R., & Hillenbrand, J., *Psychoacoustics of a chilling sound*, Percept Psychophys, Volume 39(2), 77–80 (1986)

[17] Cho, J., Yi, E., & Cho, G., *Physiological responses evoked by fabric sounds and related mechanical and acoustical properties*, Textile Research Journal, Volume 71(12), 1068–1073 (2001)

[18] Moncrieff, S., Venkatesh, S., & Dorai, C., *Horror film genre typing and scene labelling via audio analysis*, International Conference on Multimedia and Expo, (2003)

[19] Mala, E., *The sound of horror*, Newsweek, (2008)
[20] Nakata, H., *Ringu*, (1998)
[21] Naito, T., Interview with Hideo Nakata, Specter Director, *Kateigaho*, (2005)
[22] Verbinski, G., *The Ring*, (2002)
[23] Ball, S. K. V. M., The uncanny in Japanese and American horror film: Hideo Nakata's Ringu and Gore Verbinski's Ring, Unpublished master's thesis, North Carolina State University, Raleigh, NC, (2006)
[24] Ekman, I., & Kajastila, R., *Localisation cues affect emotional judgements: Results from a user study on scary sound*, AES 35th International Conference, London, (2009)
[25] Kromand, D., *Sound and the diegesis in survival-horror games*, Audio Mostly 2008, Piteå, Sweden, (2008)
[26] Chion, M., *Audio-vision: Sound on screen* (C. Gorbman, Trans.), New York, Columbia University Press, (1994)
[27] Stockburger, A., *The rendered arena: Modalities of space in video and computer games*, Unpublished PhD thesis, University of the Arts, London, (2006)
[28] Parker, J. R., & Heerama, J., *Audio interaction in computer mediated games*, International Journal of Computer Games Technology, 2008, http://www.hindawi.com/GetArticle.aspx?doi=10.1155/2008/178923 [accessed: 27 December 2007], (2008)
[29] Brenton, H., Gillies, M., Ballin, D., & Chatting DJ., *The uncanny valley: Does it exist?* Proceedings of the Human-Animated Characters Interaction, HCI 2005: The Bigger Picture, (2008)
[30] Laurel, B., *Computers as theatre*. New York, Addison-Wesley, (1993)
[31] Tinwell, A. & Grimshaw, M., *Survival horror games - An uncanny modality*, Thinking After Dark, Montreal, (2009)
[32] Acoyauh (trans.), *The creation*, http://www.geocities.com/Athens/Academy/3088/pv-creation.html [accessed 2 May 2009]
[33] Grimshaw, M., *The acoustic ecology of the first-person shooter: The player experience of sound in the first-person shooter computer game*, Saarbrücken, VDM Verlag, (2008)
[34] Pollick, F. E., *In search of the uncanny valley*, In K. Grammer, & A. Juett (Eds.), Analog communication: Evolution, brain mechanisms, dynamics, simulation, Cambridge, MA: MIT Press, The Vienna Series in Theoretical Biology, (in press)
[35] Minato, T., Shimda, M., Ishiguro, H., & Itakura, S., *Development of an android robot for studying human-robot interaction*, In Orchard, R., Yang, C and Ali, M., (Eds), Innovations in Applied Artificial Intelligence, Volume 3029, 424-434 Berlin: Springer (2004)
[36] Tinwell, A. & Grimshaw, M., *Bridging the uncanny: An impossible traverse?*, Mindtrek, Tampere, (2009)