Game Sound Technology and Player Interaction: Concepts and Developments

Mark Grimshaw
University of Bolton, UK
Chapter 17
Guidelines for Sound Design in Computer Games

Valter Alves
University of Coimbra, Portugal & Polytechnic Institute of Viseu, Portugal
Licinio Roque
University of Coimbra, Portugal

ABSTRACT

The inconsequential exploitation of sound in most computer games, both in extent and nature, contrasts with its prominence in our daily lives and with the kind of associations that have been explored in domains such as music and cinema. Sound design remains the craft of a talented minority and the unavailability of a public body of knowledge on the subject has greatly contributed to this state of affairs. This leads to a mix of alienation and best-judgment improvisation in the broader development community. A sensitivity to the potential of sound for the enrichment of the experience—with emphasis on game specifics—is, therefore, necessary. This study presents a contribution to the practice of sound design for computer games. An approach to intentional sound design, informed by multi-disciplinary interpretations of concepts including emotion, context, acoustic ecology, soundscape, resonance, and entrainment, is distilled into a set of design guidelines that holistically address the different sound layers.

INTRODUCTION

Computer game sound design is in its infancy. It is still a practice almost reserved to a limited number of experts in the game industry who have typically made their own way through the field in the absence of a structured body of knowledge. The consequences are self-evident. To start with, there is no abundance of purposeful sound usage in computer games. More relevant to the study presented here, there is little theoretical support for someone, who is not one of those experts, to perform intentional sound design.

This situation is not an exception in the broader context of human-machine interfaces and interaction systems. Game development, though, is one of the fields where sound is deserving of greater attention as noted by a number of recent authors (Collins, 2008a; Ekman, 2005, 2008; Grimshaw, 2007; Peck, 2001, 2007). Additionally, in the

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wider field of Human Computer Interaction (HCI), research on sound is recognized as quite neglected (Brewster, 1994; Frauenberger, 2007; Hermann & Hunt, 2005; Kramer et al., 1997). One conspicuous sign of the lack of a relevant body of knowledge is the unavailability of clear guidelines or best practices. Yet, this kind of support does exist and is widely known with respect to the visual modality (Kramer et al., 1997).

What is more, researchers in HCI often resort to computer games as instruments to conduct studies on several aspects (Barr, 2008; A. Jørgensen, 2004) including those related to sound. Sound design in computer games is particularly interesting because it supplies evidence of the pertinence of multiple aspects of sound in interaction. To start with, computer game sound matters to usability, in the sense of “easing the use of the system by providing specific information to the player about states of the system” (K. Jørgensen, 2006, p. 48). It can also work as support to gameplay (K. Jørgensen, 2008). Additionally, sound is a valuable component of overall game aesthetics and affective perception. Furthermore, it may be used to create and enhance emotional impact (Ekman, 2008) and contribute to immersion (Collins, 2008a; Grimshaw, 2007, 2008). Nevertheless, it is important to be aware that interaction in HCI and computer games are not the same: applications typically bracketted under the HCI label are meant to be used, while games are meant to be played (Barr, 2008; Sotamaa, 2009).

The relevance of computer games in HCI research is also justified by a growing appreciation for the concept of User Experience (Hassenzahl & Roto, 2007; Hassenzahl & Tractinsky, 2006) which emerged as an attempt to promote a holistic interaction perspective beyond the more traditional efforts, such as usability. Aspects as efficiency or performance are no longer the sole design concerns: Subjective appreciation matters and also influences the former concerns. Yet again, the research has been much directed to visual modality, leaving others, like sound, less explored (Alves & Roque, 2009a).

The field that is acknowledged to be most contributive to game sound—and to many other aspects of game development, for that matter—is the movie industry. In fact, practices on game sound are strongly influenced by those from cinema. Still, although this is understandable and legitimate to some extent, it is crucial to understand that fundamental disparities exist between the two media that both impose and propose distinct approaches. It is exactly in this difference that we find most prospective development. Ultimately, what is needed is knowledge on how to compose sound attending to game scenario specifics including nonlinearity, dynamicity, and the need for variability (Collins, 2008a, 2008b).

The lack of guidance in sound design has proven to be damaging. On the one hand, developers are discouraged from integrating sound in their projects leading to unbalanced interfaces when compared to our experiences in daily life or even with other media. On the other hand, and possibly more harmfully, when developers venture into sound integration they have to resort to their best judgment, not necessarily achieving interesting results (Frauenberger, 2007). In turn, all these circumstances, have contributed to users/players becoming accustomed to the factual unimportance of sound, even developing some negative associations to sound from which the urge to the mute button is an emblematic example. Muting is interesting as a transient state, not as the defensive default.

Considering such a scenario and refocusing on research and development, two modes of attack seem to be imperative. One is sensitization. This means getting more people aware of the low-level appreciation that the audio component currently has and countering this by proposing innovative ways to explore sound potential. The other is to deliver support to enable the implementation of such ideas. This stretches from providing guidance on the potential concepts that may allow tackling
the intentionality of the design to pragmatic aspects of implementation.

In this chapter we contribute to both these approaches. We will start by addressing some fundamental questions. Then, we will present a contribution intended to aid sound design in the form of a set of design guidelines. These guidelines are an expression of findings that we have synthesized from an interdisciplinary literature review and from an extensive analysis of media products, particularly computer games. We brought together research and concepts that include: acoustic ecology; recent studies on emotion, including the latest findings on neuroscience; physical phenomena having repercussions on the psychology and physiology of perception, cognition, and emotion; and context engineering. We will present some background to these concepts and on their prominent relationships to each other. We will also present a report on an exemplary design exercise (Alves & Roque, 2009b), following the method here presented, carried out by a team of game developers with no prior experience in sound design for the purposes of demonstrating a possible practical interpretation of our suggestions.

INTENTIONAL SOUND DESIGN

It is essential that the exploration of the usage of sound in some interactive experience does not end up confused with the mere placing of sounds on top of things. Designers should not be searching for excuses to use sound: they should be designing ways in which sound may contribute to the purpose of the application. To put it another way, in this context, sound is a means, not an end. It is not about fitting; it is about profiting.

Failing to understand this enlarges the user’s perception that sound is expendable. And the truth is the user does not need our help to hear “things”. The user is not living in a vacuum being already surrounded by sounds. So, it is probably the case that, unless the sound coming from the application brings some value—which can be fun, certainly—it is just disturbing the surrounding sounds. And that is when the mute button becomes handy.

A sound designer must consider the project as a whole and ponder how sound will best serve the overall purposes in harmony with all other aspects. For that to be possible, it is crucial that sound designers become involved in the general design process as soon as it begins. Unless that happens, the range of possibilities will be severely curtailed by whatever other decisions have been taken. This is an issue that is documented regarding sound designers in movie industry (for example, Parker, 2003; Peck, 2001).

Emotions

We have already stated the scarce consideration that sound has so far received in most designed interactive processes. No less relevant is the fact that most of the efforts on leveraging sound usage have been focused on utilitarian issues. These include complex data display, event monitoring and reinforcement of critical messages, applications for visually impaired people, and interfaces for eyes-free devices. Of course, these are all most noble quests, but they do not explore a very powerful facet of sound, which is its association to emotions.

Research on emotion was not always popular although theories can be traced back at least to Plato and Aristotle. As an area of research, it has had a low profile for most of the 20th Century and only recently has it had a resurgence in interest (Damásio, 2003; Ledoux, 1998; Nettle, 2006) thanks largely to advances in neuroscience laboratory tools. The fact that it is now possible to have an internal perspective of emotion, rather than dealing with external observations alone, contributes decisively to a new consideration of emotions. To start with, it helps to set apart what is science and what is no more than wishful thinking, allowing for the credibility of the approaches that rightfully find support on the emotional plane. Also, it
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reveals new opportunities to act according to the physiological observations of emoting processes. But, and possibly more relevantly, recent scientific findings on brain phenomena and on how cognition and emotion are intertwined (Damásio, 2000, 2003, 2005; Lane, Nadel, Allen, & Kasznia, 2002; Ledoux, 1998) build support for unprecedented studies that aim to leverage cognitive attributes through the exploration of emotional aspects of the interaction (Norman, 2004).

The new thinking on emotion contributed to a new perspective on the interaction process itself, consistent with a move in the research focus from a functionalist view of usability to a broader notion of User Experience (Hassenzahl & Tractinsky, 2006; Mahlke, 2007; Mahlke & Thüring, 2007; Norman, 2002). User Experience privileges quality of interaction over instrumental aspects and introduces “the general notion of technology as a positive aspect of our daily lives” (Mahlke, 2007). In computer games, the experience and the explicit designing of emotions are core concepts (Freeman, 2003; Marks & Novak, 2009; Schell, 2008) and—apart from game categories such as “serious games”—they constitute the ultimate argument for consumption.

That said, it seems fair to argue for a more thoughtful exploration of sound, namely in what concerns its potential association to emotions (Ekman, 2008; Follett, 2007; Grimshaw, 2007; Peck, 2001), with both a focus on purely hedonic purposes and through an exploration of how the achievement of specific emotional states may indirectly contribute to pragmatic goals such as various aspects of performance: efficiency, effectiveness, perception, memory, and so forth. Interestingly, in other disciplines, sound has proven to be notably associated with emotion; relationships between sound and emotion have been traditionally explored in areas like music (Juslin & Sloboda, 2001) and cinema (Peck, 2001; Sider, 2003) with a solid body of knowledge.

One aspect that appears fundamental to the research of sound and emotion in interaction, and which also remains overlooked, is the need for a holistic perspective on sound, exploring the benefits of considering the auditory component not as a set of independent stimuli but as a coherent composition integrated with the context of the experience.

**Acoustic Ecology**

Acoustic ecology (Kallmann, Woog, & Westerkamp, 2007; World Soundscape Project, n.d.; Wrightson, 2000), an area founded mostly by music composers, is very insightful to an emotionally meaningful conception of contextualized sound. It is supported by the central concept of soundscape (Schafer, 1973, 1994) and the thereby developed musical composition (Truax, 1995, 2001). Together, they represent a meaningful body of knowledge with particular emphasis on context, emotion, and interaction between the listener and the environment. The term soundscape means the “sound heard in a real or virtual environment” (Wrightson, 2000, p. 10) considered as a whole.

A soundscape is an ecologically balanced entity where sound mediates the relationships between individuals and the environment. So, acoustic ecology implies a consideration of how the environment is understood by those living within it: regarding sound, the focus is on how it functions, not simply how it propagates.

Acoustic ecology also supports the idea that an acoustic environment can be understood as a musical composition. This emphasis on the concepts of harmony and orchestration is not mere lyricism. Studies on natural environments show balance in level, spectra, and rhythm. For instance, it was observed that “animal and insect vocalizations tended to occupy small bands of frequencies leaving ‘spectral niches’ (bands of little or no energy) into which the vocalizations (fundamental and formants) of other animals, birds or insects can fit” (Wrightson, 2000, p. 11).

Another implication is that the listener shares responsibility in composition (Wrightson, 2000).
The idea of the listener as a composer is very insightful. First, it gives relevance to the sound the listener himself produces (composes and/or interprets), intentionally or not. Second, and perhaps more impressively, it emphasizes that the user completes the composition by filling the “meaning” that is absent or that is not evident (Truax, 1995). This process of construction is assumed to be personal since the overall context, where an acoustic environment fits, is different for each person.

We consider that these insights from acoustic ecology can be adapted to inform sound design in computer games from which conceit it becomes relevant to conceive of a translation of the knowledge generated around the concept of soundscape: This will be driven by research on the implications of such an idea to overall perception and the emotional dimension of interaction.

**Resonance and Entrainment**

One goal inherent to game design is to allow for engaging experiences. Thus, it is important to reflect on reasons that may lead to a player not becoming engaged with a designed setting. Perhaps we have to recognize that, ultimately, such lack of engagement may be explained by the player’s own will and not by flaws in the design process. This is no excuse, however, for ignoring important sound design considerations.

In some circumstances, the deviation from the predicted behavior derives from the fact that there is no matching between the player’s state and some desired state in any particular moment. From physics, we borrow two related concepts that allow us to describe and to formalize a model to actuate design with the purpose of addressing this circumstance. These concepts are *resonance* and *entrainment* (Augoyard & Torgue, 2005; Sonnenschein, 2001), both physical phenomena having repercussions on the psychology and physiology of perception, cognition, and emotion (Leeds, 2001; Sonnenschein, 2001).

Resonance is the matching between vibratory rates and is found in all periodic, sinusoidal movements. It requires a concordance between the exciting frequency and that of the object put into vibration. A resonant system exists when an object is able to make another resonate. Natural resonance occurs when an object vibrates as a consequence of being excited with its own natural frequency. If the object has the ability to vibrate to a variety of frequencies, resonance can be forced.

Accordingly, we can describe the unengaging circumstances mentioned above as failures to achieve resonance: For diverse reasons, there is no match between the game sound features and the player. This is not just a figurative interpretation of the concept: Our interest in resonance is indeed related to how the body, as a system, responds to sound stimuli and this is no different from what has been exploited by music through the ages. One explanation for the failure in the desired matching, derived from the concept’s definition, is that the entities—the player and the setting—are in such different states that no resonance can even be forced.

The second concept—entrainment—gives us a hint on how to work on that problem. Entrainment has to do with the synchronization between resonant systems. It “has been found so ubiquitous that we hardly notice it” (Sonnenschein, 2001, p. 97). Entrainment has long been used by music to induce specific states of consciousness (Leeds, 2001; Sonnenschein, 2001). In terms of psychoacoustics, the pertinence is to change the rate of brainwaves, heartbeat, or breath according to verified associations between those rates and cognitive and emotional states.

For entrainment to happen, three conditions must be met (Leeds, 2001). Firstly, a system will only entrain another if the latter is able to achieve the same vibratory rate. Secondly, the former needs power enough to prevail over the latter. Finally, the former needs to keep the same vibratory parameters until the latter is able to entrain. Regardless of whether we opt to take this liter-
ally or as an insightful metaphor, we must realize that if we want a player to resonate to a system’s desired state we may need to first get the system resonating with the player and then progressively bring the system—and the player along—into the desired state.

Resonance—including, for our purposes the related concepts of entrainment, sympathetic vibration, resonant frequencies, and resonant systems—has been said to be “the single most important concept to understand if you are to grasp the constructive or destructive role of sound in your life” (Leeds, 2001, p. 35). We believe resonance is fundamental to the exploration of sound in computer games, notably to support a model that serves as an aid to understanding and, hopefully, overcoming the issue of empathy between a game and its players.

GUIDELINES FOR SOUND DESIGN IN COMPUTER GAMES

Based on the concepts and findings here described, we have distilled a set of guidelines for sound design in computer games. We encourage readers to understand this set as a work-in-progress. Our purpose is to contribute to the research community by building knowledge that can give us and other researchers the confidence to consider it plausible and worth refining not least for its use value to computer game sound designers. Therefore, these guidelines have no claim (yet) of truth-value: instead, their value is strictly instrumental to the research and structuring of a body of knowledge in sound design. Also, the guidelines do not prescribe procedures but, instead, establish a mindset that can inform those procedures. In that sense, they state what to care about rather than stipulating how to do it in a particular instance. But, most of all, they are meant to generate understanding, not to be obeyed.

The guidelines attend to the identification of several affective aspects of sound design, including: considering the relevance of acoustic properties of elements selected for interaction, namely as to their emotional effect; conveying meaning and coherent consequence to diegetic sound, inside the gameworld; allowing to perform through the exploration of the sonic outcome of meaningful actions; exploring the activation of events and interaction elements through the interpretation of the corresponding acoustic expressions; integrating users’ context in the sonic composition; supporting and exploiting resonance and entrainment; and dealing with perception issues during a user’s experience. Each guideline is presented with a description, relevant context, and examples.

For the conception of these guidelines, we did not focus on speech-based interaction. Also, although we do not exclude the use of music, we are mainly interested in exploring interaction through non-musical sounds. In terms of sound layers (Peck, 2001, 2007), this does not mean we will not be considering dialog and music because that would ruin our commitment to the holistic approach underpinning our research: Depending on the purpose with which specific sound stimuli are added to the composition, they can play a role in any layer. It simply means we are not attempting to contribute guidelines that specifically go into such matters as dialog generation and interpretation or musical composition in the strict sense.

Guideline 1: Select Elements with High Sonic Potential

It is strategic that the inherent, potential sonic expressiveness is valued when selecting the interaction protagonists in early stages of design. This mindset applies to the full extent of the game’s components, including objects, characters, script, and features such as the gameplay. Actually, this guideline is the mother of all others here presented: In every each of them, for the designer to be able to implement the respective idea, a dedicated selection of these components is mandatory. We will avoid stating it as a prerequisite because it
is not supposed to happen before those ideas are set. Both the selection of the elements and the setting of the ideas that will explore them will profit from a tight process of decision-making along the progression which, in turn, ought to be carried out from the very early phases of the overall design process.

Also important to notice is that it is not about selecting sounds. It is about selecting game elements, taking into account how they will supply the sonic properties that are required to accomplish some design aspect. This distinction is absolutely fundamental. Unless that is kept in mind, then energies will be spent on enlarging the mistake of not using sound but covering with sound. Actually, using sound to wrap the elements in a game is not an error per se.

Metaphorically speaking, we do prefer our gifts when they come in a nice wrapping paper. Still, that nice paper can be discounted and disconnected from the gift itself: Even if we opt to keep the paper, the gift and the paper will still be independent entities, not contributing to the others accomplishments but being in their separate existences.

The attentive selection of interaction elements, prizing rich sonic expression, expands the space of possibilities in design time. This will allow fulfilling the intentionality of the soundscape whilst maintaining contextual consistency. Also, it should be easier to provide a good auditory perception of the environment if objects in it are identifiable or provide context through their sonic properties. Choosing and combining acoustic protagonists may be thought of as the construction of a dialect, specific to the project and which will allow supporting its communication model. This calls for a creative effort of collecting and combining possibilities. Still, it is useful to be attentive to some opportunities. One is that elements may have different states of sonic expression: roughly, the sound emitted while in customary or natural conditions and the sound emitted when the element is “activated”. In some cases, more states, or even variation in a continuum, may be identified. For example: a squeaky rubber duck has no sonic expression when left alone but possesses a very well known sonic identity when squeezed; conversely, a cicada has a customary expression that ceases when disturbed; a waterfall seems to have the same characteristic sound both on its own and when someone bathes in it; and, a flock of pigeons also emits sound in both situations but these are very distinct (mating and feeding versus alarm and flapping wings). In another vein, if we need a game character to drive fast through the rush-hour traffic, we might consider including a car horn and choose carefully its sound (according to Guideline 3 below). So, there are countless possibilities to explore, depending on what is intended to be communicated.

Although some acoustic elements may be added—or patched—along the project, without overall disturbance, others imply strategic decisions and consequently need to be analyzed in the early stages of design. In the latter case, above, resorting to a siren of some emergency vehicle service would imply the necessity to fit such decision in the design options: even considering it would be plausible in the scenario, it might be inappropriate if too many other design decisions had been taken.

Finally, a related challenge is to reunite elements, which are coherent among themselves, within the whole project. For instance, unless premeditated, dinosaur roars and bottle pops, would not be compatible, although each one would possibly be associated to ideas that we might need to combine (let’s say, angst and repose). The issue is compatibility, not verisimilitude: we are happy to hear the bad guys’ spaceship exploding in the void, although we know that would be impossible (The Curious Team, 1999).
Guideline 2: Select Elements Whose Changes in Sonic Expression May Support or Translate Emotions

When designing a game’s emotional script, the designer should evaluate how sound will contribute to it. There is no doubt emotions are core to computer games. Additionally, it is well documented that sounds can be used to support emotional contexts. Actually, that is a common practice—and sometimes the ultimate goal—in some mature fields as music (Gouk, 2004) and the cinema (Lynch, 2003). It is important to notice we are not claiming that sound should be the way to support emotions in computer games. Sound is one way to contribute to that but one way that should not be forgotten, considering its potential and particular strengths for these purposes.

One approach that can be further explored, when selecting each acoustic element according to its association to emotion, is to evaluate it with an emphasis on its ability to support different emotions, that is to say, to express emotional changes through its own sonic alteration. This is not mandatory, since emotional changes may be achieved by resorting to different elements—possibly one to support each different emotion—but it may be advantageous to explore the use of elements capable of supporting several emotional states and signaling the correspondent change. That, for instance, may relieve the user from interpreting new sonic elements for their emotive associations, and may provide gains in effectiveness. Moreover, the swapping of distinct sonic elements in the soundscape is more prone to erroneous interpretations, such as motion of their respective sources, although visual information may be enough for disambiguation. Finally, and more relevantly, this approach is more likely to offer continuity and emotional gradations.

As in Guideline 1, this is a matter of creative gathering and the selection of possibilities. A few illustrative examples of elements and their possible associate emotional states would be: birds (relaxation, attentiveness, fleeing); weather elements (calm, scaring); baby sounds (joy, tranquility, agitation, affliction); nice breakable materials (aesthetic contemplation, trespassing, destruction).

Guideline 3: Allow Sound to Matter in the Gameworld

The nature of the interaction, as perceived by the user, should be extended in order to genuinely integrate sound as an instrument for action in the environment. This is perhaps the most neglected use of sound in computer games. Sound, if used, is predominantly relegated to complement the visual rendering. It serves as output, which is good but just half the idea. In fact, acting through sound makes perfect sense in a system with a bidirectional interface. There is no reason for sound driven actions not to deserve the same kind of appreciation as running, jumping, grabbing, or shooting. Allowing the player to perform through sound, either as a consequence of some contextualized and meaningful action or by explicitly deploying some sonic event, has the potential to greatly extend the value of the experience. Moreover, it significantly enlarges the space of possibilities in terms of design of the gameplay. Reasons for the under-exploration of this kind of approach may be that this is something that could hardly be borrowed from music or cinema—the chief contributors for sound design practices in computer games (Deutsch, 2003)—and that it is also commonly neglected in computer application interfaces.

It should be noted that we are thinking beyond speech-activated commands. Speech recognition is not a goal in our study. Also, the kind of input suggested in this guideline is particularly meaningful if it does not consist of a mere mapping of commands that otherwise would be entered by pressing a key or button. Although the latter may be useful, it doesn’t truly represent a change in the interaction itself but only in its activation. In
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fact, to observe this guideline, the actual activation, at the level of the interface, can still resort to a typical key press instead of true sound input.

In our non-digital lives we often resort to sound to make things happen: We open our way into the crowd by saying “excuse me, excuse me” rather than pushing or shooting; we yell to the annoying neighbor’s dog to counter its attack (sometimes it gets worse but we still do it); we cough to make someone notice us; we use the car horn to stop another driver hitting us; we walk more or less loudly according to our intention to make ourselves noticed, even if unconsciously; and so on. Sound plays a huge part as input in the communicational model, not only as dialog, in a strict sense, but also in more indirect ways. So, we have the means to get inspired about what could be different in computer games. In fact, when put this way, it seems that it is not about how to let sound in, but rather how to stop forcing it out of the game: How to escape from the bias of visual predominance and derived solutions, and how to allow for more balanced approaches.

One aspect that we believe ought to deserve careful attention is the construction of a sense of coherence. In truth, when we claim the need to consider sound consequences, we are already addressing the issue of coherence between the value of what is seen and what is—or should be—heard. But let us confine, for now, our reasoning to what is heard: The inclusion of aspects in the game that are sound-driven may turn out to be improper if they reveal an incomprehensibly unequal treatment regarding other aspects that are evident candidates for the same behavior. This is not about realism: the coherence is relative to the gameworld, not necessarily to the real world. Instead, it is related to the holistic perspective that is dominant in the notion of the soundscape.

Of course, incoherence can become accepted based on the willing suspension of disbelief. The player can indeed adapt to the game’s reality where, for instance, a very noisy event does not trigger any kind of reaction from enemies but the slightest imprudence regarding noise in the scope of some other specific event can unleash the devil. Even so, and excluding the merit of well-designed alternate realities, such adaptation demands at least a first effort from the player. That effort has little to do with playing: it is exterior to the gaming experience itself. The player—the game user—gets confronted with the implausible and has to solve it consciously before eventually coming to accept it. In turn, that compromises flow and game immersion. If indeed the required suspension of disbelief comes at a cost with no intended value, just as the player is able to overlook the limitations of a compromised game design, efforts ought to be made to minimize the effect.

Some examples of the ideas expressed in this guideline can, in fact, be found in a few existing computer games. In the Thief game series—for example, Thief: Deadly Shadows (Ion Storm Inc, 2004)—and Metal Gear Solid 4 (Kojima Productions, 2008), both stealth games, some items can be thrown in order to make noise and consequently divert enemies’ attention to them. In the latter, it is even possible to knock on nearby objects with similar purpose. In both games and others, such as The Elder Scrolls IV: Oblivion (Bethesda Game Studios, 2006) the sound of the character’s footsteps can broadcast his position.

Other hypothetical examples would be: yelling to frighten or as part of the strategy to defeat beasts, whistling to call our dog or horse, clapping hands to scare birds and so on.

Guideline 4: Allow Meaningful Sonic Control for Intended Actions

This works as an inversion of the cause-effect relationship in events with a natural or associated sonic expression. As in Guideline 3, this guideline relates sound and acting, however, this time instead of performing some event X and expecting that other events Y are triggered or shaped by its sonic expression, we are suggesting a way to trigger an event Z by performing its own sonic expres-
sion. The idea is to allow the player/character to produce the sound that translates the actions that are intended to occur. An interesting collateral effect is that, in this process, the player/character substitutes or participates in the correspondent sound and, consequently integrates into the overall composition. In contrast to the former guideline, in order to cope with this one, it seems relevant to allow for actual sound input.

Conceptually, this differs from strict voice commands in the sense that the input does not reflect an order for something to happen but rather the actual sonic expression of something as if it were already happening. This is indeed a relevant distinction, with some implications both in format and semantics. One difference is the nature of the emitted message: Text versus expression. Another is the timing and duration of the message. In the case of voice commands the order precedes the action and its duration does not depend on that of the action; in the case of the approach we are suggesting, the stimulus and the action are theoretically simultaneous: The action starts as soon as the stimulus is identified (despite, in practice, that this will imply some latency) and lasts for as long as the stimulus is maintained. Consequently, there are also differences in the kind of control that is possible for actions that are flexible regarding duration. Also, it is conceivable that we interpret variances in the acoustic parameters along the stimulus (intensity, pitch and so forth) and dynamically shape the action according to preset conventions. Furthermore, there are significant aesthetic differences: For instance, the proposed approach evidences great potential regarding the exploration of the input sound as a component of the game’s artistic value. Finally, there are differences in terms of the emotional impact underlying each approach: For example, if we are actually giving orders, as in some war games such as Tom Clancy’s EndWar (Ubisoft Shanghai, 2008), voice commands may feel more appropriate, while, in some other scenarios, making non-verbal sounds may provide a better experience. Again, we emphasize that we are not arguing the value of one approach over the other: our aim is to contribute to the enrichment of the space of possibilities.

One final point that should not be overlooked is the potential ludic value inherent to making sounds: that is, in performing at the interface. Thus, not only the ludic meaning of the triggered actions but also the activation itself becomes part of the game. This is a rare opportunity. Typically, the activation level is not conceived of for the purposes of providing fun. There is not much joy in the act of pressing keys at the keyboard, moving the mouse, pushing buttons in controllers and so on (although, to be fair, there is fun inherent to the use of some interface devices such as steering wheel and pedals, musical instrument imitations, and some modern game console controllers). Of course, the design of the sounds that are supposed to be input—a matter that fits into Guideline 1—has a determinant importance on the kind of achievements that may become possible at this level of the game.

Other hypothetical examples would be: driving a cart on a path while avoiding running over crossing animals by producing the sounds of the engine and possibly the emergency brake, gaining focus over a wooden box to move it on a rock floor by imitating the sound it would make and controlling directions with mouse or keys, making a ball jump different heights according to the modulation of some established sound, shooting a gun by vocalizing the shots, shooting different guns using a feature of automatic weapon selection based on their distinct shot sounds and so forth.

**Guideline 5: Allow Integration of Player’s Context into the Soundscape Composition**

Context plays an important role in interaction processes. Also, sound is both part of that context and a way to express it. It is worthwhile to explore the possibilities in terms of soundscape composition and, particularly in respect to affec-
tive sound, allowed by the consideration of the player’s context.

Actually, all guidelines here presented have been strongly influenced by a constant attention to context. In all aspects—interaction protagonists, emotional support, consequent sound, action through sound—there is always an emphasis on the need to consider a global perspective, both concerning the integration of the different modalities and regarding the different combining approaches in the particular case of sound. The bottom line is that no approach is good unless it fits in the whole. If it does not, either the approach or the whole needs to be adjusted.

This guideline goes a little further in terms of the consideration for context. The argument is that the context is not limited to the game itself. A game is played by someone who actually has—and is—context too. So there is no point in trying to figure out how to turn a game into a perfectly designed context piece if we leave out the only element of the context who would possibly appreciate it: the player.

Some concepts that have recently become well-known in game design, such as immersion (Grimshaw, 2008) and flow (Csikszentmihályi, 2008), emphasize, in different ways, the pertinence of getting the player and the game into the same plane of existence. These approaches focus mostly on the migration of the player into the game. We suggest tackling the same issue in a complementary way, which is somehow the reverse method: To extend the game in order to embrace the player, that is, to build the game around the player.

Dealing with context poses complex challenges. Conceptually, all aspects of the player’s context matter to whatever is done in the scope of that context. In practice, this has two related implications. One is that, since it is not technically viable to seize all context parameters, it becomes necessary to identify and capture the most meaningful parameters of that context, considering the process we are designing. The other is that we cannot afford to neglect some aspect of the context that turns out to be indeed influential to that process, bearing in mind the problem that contextual aspects are inherently non-evident. Another class of challenges is the actual reading of the contextual parameters which, in many cases, demands the usage of probes or sensors. In turn, this is potentially problematic not only in terms of the availability of those devices but because some of them can be considered intrusive or uncomfortable to use.

An example of contextual parameters, which we suggest for the sound designer to consider, is the player’s ambient sound (as in Cunningham, Caulder, & Grout, 2008 and Cunningham, Grout, & Picking, 2011). This might be useful to dynamically equalize each of the categories of game sounds according to the expected ability of the player to perceive them. Or, in a more complex endeavor, it might become interesting to integrate the players’ ambient sound, or some of its acoustic parameters, into the game’s sound. Still, we should not restrict ourselves to sound-to-sound explorations: all possible combinations are relevant to game design, at the very least those that have sound in either of the extremes fit the present guideline. For instance, we are particularly sensible to acoustic explorations that can be develop from the readings of the players’ physiological indicators, namely heartbeat, breath, and brainwaves. In truth, there are some classical examples of similar exploration in other domains, as evidenced by the relationship between music rhythm and the heartbeat. We believe that, since these indicators provide hints on the player’s emotional state, it will be interesting to consider their potential to dynamically set compositional aspects of sound in game scenarios thus aiming at a better resonance and possibly as the basis for entrainment. This is suggested in Guideline 7 below (see also, Nacke & Grimshaw (2011) on the monitoring of psychophysiological states of players and implications for game sound design).

An aspect that also deserves some commentary is the possible contradiction between leading
the player into the context of a fantasy world and bonding with the context of the real world. Indeed, once a resonance state between player and game has been established, the player might appreciate being transported to another context. Actually, the sense of escapism is part of the argument for playing computer games. Even so, this is not contradictory with the effort suggested in this guideline. To start with, because it is a prerequisite to first be able to empathize with the player (something we will explore in Guideline 7 which concerns entrainment). Next, the kind of context that is integrated in the experience and the way that context is translated into the experience do not necessarily evidence the bonds in such a manner that they anchor the player to a former state or to the consciousness of a real world existence. Ultimately, the designer may decide that the more immersive the current state the less binding there is with the player’s outer context. But even then, the ability to evaluate the immersion level will probably require reading certain parameters from the player’s current context. Most of all, it seems to be a matter of dynamically adjusting the components of the context that are the most critical to resonance management.

Guideline 6: Consider Shared Context in Multi-player Environments

This is an extension of the previous guideline through the consideration of multi-player environments. Each player’s context may include the perception of aspects of the other players’ context. The argument is that, in a multi-player environment, context is both local and global (Roque, 2005 and discussed in terms of a virtual acoustic ecology by Grimshaw, 2008). It may be advantageous if each player perceives not only other player’s actions but also relevant elements of the context that shaped those actions.

The implementation of this guideline calls for the combination of elements deriving from different players, which, in turn, are captured or integrated according to the techniques mentioned in Guideline 5. Regarding the combination of the stimuli, it is important to be attentive to the insights from acoustic ecology and consider that the design of a shared-context soundscape should support the fitting of individual interventions rather than superposing their disconnected sounds (Wrightson, 2000).

This approach may be considered with different purposes: for example, simply aesthetic, taking advantage of aspects of the global complexity; as a mechanism to deliver a sense of presence and of activity of the respective community; as part of the gameplay, making available some aspects and hiding others according to what best serves the game mechanics.

Guideline 7: Integrate Acoustic Elements that May Support Entrainment

Entrainment can be used to support the maintenance or the change of emotional states. Sound is one prominent way to implement entrainment which can be achieved by progressively moving from one state of resonance into another. In terms of game experience, keeping the player emotionally involved along time, as complexity grows and emotions unfold, is crucial. As the term entrainment suggests, the idea will be to create the conditions for the player to engage with and to be transported on a journey. Still, the path can be too turbulent for the designer to assume the player will have enough of a pleasurable experience to warrant reaching the end.

The consequences of such an observation are relevant. The most important is that any tool a game designer has to monitor and direct the course of action in order to avoid losing players will be valuable. In this sense, entrainment, and its support through sound, is instrumental. Also, regarding each particular instant of the experience, the managing of the proximity between a player’s emotional state and the expected (or even required)
emotional state may be addressed through the idea of resonance. Finally, and although resonance must be granted during the whole experience, the initial moment—that is, the first resonant achievement—is particularly challenging. It is clear that it will be harder to go from a state of no resonance to a state of resonance than it will be (later) to move between resonance states. The latter situation, being well designed, should allow a more continuous transition.

To address the achievement of initial resonance, at least two approaches can be explored. One is to speculate about the initial mindset and emotional state of the player and gently move from there. That is no different from what is done in other forms of communication: It is a good idea to perform some sort of introduction before getting into the core of the message. Still, the contents of the introduction have to be tuned according to the context of the listeners, which frequently has to be estimated. Although this approach is technically simple it may be ineffective due to the lack of indicators about both the starting context and the evolution of the process. So, a second class of approaches, where there is some way to read indicators that permit a better judgment about those aspects, will allow more efficiency. For this purpose, any known technique to dynamically infer a player’s emotional state will be useful. In the scope of the present study we find particular relevance in those techniques that take into account the player’s physiological rhythms, namely heartbeat, breath rate, and brain waves because of their potential exploitation in terms of sound (see Guideline 5). The problem with the actual reading of such indicators is the device apparatus which is likely to be found intrusive and, as such, contraindicated in terms of the experience.

The relationships between emotions and heartbeat, breath rate, and brain waves have long been explored (for example, Atwater, 1997; Leeds, 2001). Musical examples are Shamic drumming, that induce theta brain waves with consequent approximation to deep sleep and trance state, and Balinese Gamelan, which has a beat phenomenon that generates frequencies of about 4 to 8 Hz and this also targets the theta brain waves. Another example, more commonly acknowledged, including in computer games—for instance, inFamous (Sucker Punch Productions, 2009) and Uncharted: Drake’s Fortune (Naughty Dog, 2007)—is the use of strong beats that gradually increase in rhythm and intensity in order to emulate the heart rate that would match the designed emotional state.

Depending on the intended purpose, these practices may be used to inform game design. Once again, the acoustic elements used to design the conditions for entrainment should fit in with the design of the soundscape according to the principles covered in Guideline 1.

APPLYING THE GUIDELINES

When we argue for the relevance of the integration of sound in the design of interaction processes, based on the observation of the discrepancy between current game sound use and the value that sound assumes in everyday life, it may seem we are implicitly claiming for a balancing in the gameworld similar to that in real world regarding the prominence of sound in interaction. This is not the case. We are addressing the design of a virtual world where, in principle, there is no reason for us to be anchored to the constraints of the real world. So, the designer should pursue not fidelity to reality but, rather, creativity.

Again, this should not be confused with a discussion around the search for realism, although that is also an interesting matter to approach in the context of this text (see Farnell, 2011). It may be clear by now that we prize an exploration of sound that goes beyond the concerns for realism. We acknowledge that a rich experience does not require a realistic approach to sound. Of course, the ability to achieve realistic features—at some sound layers—is interesting in the sense that it enlarges the boundaries of the space of possibilities, but it
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seems fairly evident that it is not a requisite. What is more, paradoxically, approaching realism can be troublesome in terms of perception and emotional response, as is the case of the “uncanny valley” phenomenon (Grimshaw, 2009; Tinwell, Grimshaw, & Williams, 2011) that comprises a feeling of strong discomfort with greater humanlikeness. That is, plausibility and precise realism become issues, and failure to achieve them contributes severely to the degradation of the experience.

Considering that we have been presenting foundations to possible insights that might inform game sound design, we feel the need to not let pass unnoticed the importance of the designer having a background in gaming and possessing an extensive analysis of the widest possible universe of computer games. Particularly, once one is sensible to sound design, one develops attentiveness to sound facets when playing computer games, even unintentionally. Experimenting with computer games in a genuine setting—that is, playing games—and possibly becoming or taking advantage of being a hardcore player, is also one rich source of information and insights (Aarseth, 2003). Even gaming experiences that are perceived as poor, become sometimes most valuable if one can rationalize what seems wrong and what would be an alternative.

A different reason why it is relevant to actually play computer games, with a behavioral pattern similar to that of the players who are the typical consumers of the kind of games we are addressing, is that, as we argued, a player’s perceptions are strongly influenced by context. In turn, the context of a certain player is also shaped by the number and diversity of games played before, amount of time usually dedicated to playing, the number of playing hours in a given moment and so forth. Adding this to the inherent difficulty in grasping other people’s contexts, it seems appropriate to say that the more the researcher or designer is able to feel like a player, the closer the judgments reached will be to those of players (even when considering that no two players are equal, nor even that one player remains the same through the passage of time).

Finally, and somehow in the same vein, it is fundamental to recognize that we will never be designing the players’ behaviors or feelings. Instead, through sound design, we are working with the conditions that will influence those players into what is intended to be a desired emotional experience. But, again, since those players will always be subject not only to the designed conditions but also to other conditions that constitute their own current context—including manifesting their own will and deciding, for example, not to engage—it is not reasonable to be assertive and didactic about effectiveness. In fact, because games are mostly forms of participatory media, the players also are, to some extent, designers of their own experiences.

A DESIGN EXERCISE

We present an example of the application of the guidelines by a group of developers with no prior experience in game sound design. The exercise involved a team of 5 Master’s students on a course in game design and development (Alves & Roque, 2009b). The team was commissioned with the design of a game specifically intended to demonstrate the importance of sound in gameplay. This prompted them to think about a game that could not otherwise be played except with and through sound.

Our argument for attaching this example to this chapter is twofold. On the one hand, it serves as an instantiation that may be useful to illustrate a possible interpretation of some of the suggestions this study provides. On the other hand, it goes some way to verifying the plausibility of the guidelines we have presented. Of course, at this point, the simple observance of this experiment does not provide the support for a generalization of the results, but the results are an encouraging indicator nonetheless.
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Game Plot and Setting

The game is a single-player adventure, suitable for audiences over the age of 6. It is about a castaway and his rescuing from an island inhabited by fictitious creatures. The plot comprises gaining the sympathy of the native creatures in order to get their help in calling the attention of some passing ships. Two input methods were designed: vocalized sound input through a microphone and, alternatively, the use of keystrokes to model the corresponding programmed sounds.

The game takes place in an island scenario where the playing character interacts with a set of creatures, one at a time, by interpreting their sound manifestations in the context of the game diegesis. As an example, the player has to “gain trust” of a creature by imitating its pitch, its rhythm and so on with two end results: unlocking some progress in the game and training the ability to recognize and reproduce specific sound characteristics, in the context of other sound sources, in order to achieve a specific composition. The coordination abilities thus gained by the player will then be put to a final test in a final setting.

Story

A castaway gets into an island inhabited by strange creatures. He notices that ships pass at a distance and that they might rescue him, but, when he tries to signal his presence by yelling to them, he fails to get noticed. On the island, there are several accessible zones and each zone is inhabited by one species. A species population consists of a bunch of cubs and a parent: The cubs are curious, the parent is neutral though vigilant. The cubs’ behavior triggers communication-learning episodes where the castaway iteratively tries to replicate their utterances. After a certain number of successful such episodes, the parent becomes receptive to communication and the castaway, combining expressions learned from the cubs, starts a communication process to conquer its sympathy. When he has succeeded, the parent volunteers to accompany the castaway to the beach and to help him to yell for the attention of the ships passing by. While they yell, someone, in one of the ships, appears to have noticed something but assumes it was an illusion because the stimuli coming from the beach were too weak. In each of the other zones in the island the plot repeats: each time a parent becomes a friend, the entire group gathers at the beach for another attempt to catch the attention of the passing ships. With each attempt, the perception grows that the aim is about to be achieved until, after enlisting the aid of a certain number of creatures, the goal is finally reached and the castaway rescued.

Non-interactive (cinematographic) scenes include the arrival at the island and lonely call for passing ships, moving onto the beach accompanied by friendly creatures and yelling to the passing ships, and a ship’s crew member wondering about the yelling sounds (this is a distinct scene each time a new creature joins the group).

Gameplay

The castaway moves through the island’s zones (there being no predefined sequence) and in each zone there are two types of interaction: with cub creatures and with their parent. All interactions happen between the castaway and only one creature at a time with each interaction comprising an iterative process of alternate interventions in a dialog. The interaction can be aborted before success is achieved by the player’s decision or because a certain number of iterations has been reached. There is no enforced order to the interactions but it is mandatory to successfully interact with several cubs before being able to complete with success the interaction with the parent. The dialog with a cub is initiated and conducted by it while the dialog with the parent is initiated and conducted by the castaway. The success condition in the relationship with a cub depends on sufficiently matching its utterances and the success
condition in the relationship with a parent depends, firstly, on its receptivity to communicate—which, in turn depends on the number of cubs with whom a successful conversation has been carried out—and, secondly, on the level of satisfaction to which the castaway can lead the creature in a process where, in response to each castaway’s sound sequence, the creature manifests the correspondent sympathy reaction. The level of sympathy may drop during the interaction with the parent. Every zone in the island shares the same game mechanics: what differs are the sound stimuli.

The relationship with the cubs can be understood as a learning process of the sound stimuli that will eventually allow a successful relationship between the castaway and the cubs’ parent. On the other hand, the relationship with the parent is an exploratory exercise of composition through the combination of these stimuli with some room for creativity.

Regarding similarity evaluation criteria of the sound stimuli used in interactions, in a first approach, the following acoustic variables were considered: duration, loudness, and pitch. In practice this means sounds do not have to be strictly identical: they only have to match according to those variables.

**Critical Reflection on the Exercise**

The observation of the design experience surrounding this exercise provided a reinforcement of the idea that the observance of this set of guidelines implies that they must be considered from the early stages of the overall game design process. The guidelines involve fundamental aspects of the interaction which could hardly be tuned and achieved if too much design features had already been decided. That is an important consideration. We may have the need to put it as a prerequisite or accept the limitation of this effort if used upon an already well-developed design. Although, in this exercise, there were the optimal conditions to escape this struggle (the exercise was designed from scratch), keeping a faithfulness to the principle still demanded tenacity, despite the passionate attentiveness to the guidelines.

Ironically, despite all that freedom, it was not particularly easy to come up with a satisfying idea that permitted one to experiment with the set of guidelines. Actually, that was a time consuming task and a valuable lesson that deserves some commentary. It was evident, for those involved in the exercise, that the team was particularly unaccustomed to the opportunity of thinking in auditory terms. For instance, the insights often suffer from too much visual bias: In a moment when auditory possibilities were being experimented with, the team agreed it was desirable to go beyond a simple mapping to visual elements and worked instead to make the gameplay itself as strongly influenced by the audio component as it is by the visual modality.

In the early stages of this exercise the team was uneasy about how long the observance of the proposed guidelines would have to be explicitly carried. Yet, and although the circumstances of the research did not allow designers to forget about them, once the design was defined, particularly the game flow and interaction, their requirements became embedded into the whole design and, as intended, subsequent steps related to sound became merely a matter of implementation.

One difficulty, more operational than conceptual, had to do with which sound files to use. This was not exactly a surprise since we knew beforehand that “sound designers are often limited by having poor, outdated equipment, not enough off-the-shelf sound libraries, but most importantly, not enough time to go out and get new, original sounds for the game project” and that “sound is art [and] to make a game sound artful […] sound designers [must] have the time and money to practice their art” (Peck, 2001, p. 1). There are several reasons for us to mention our experiences regarding this practical aspect. First, to note paucity of existing sounds and lack of time to record new ones were critical factors in this particular exercise.
Second, and more important, to remind one how significant such a bottleneck may be for this kind of endeavor in general. Finally, to acknowledge that, despite the predictability of such difficulties, a priori conditioning the space of possibilities as a function of the already available sound materials would be extraordinarily limiting.

Finally, we realize the designed gameplay includes a tacit approach to the problem of the players’ adaptation to the game model, in terms of both interface and game mechanics. This addresses an early concern: The introduction of uncommon ingredients in interaction, unless carefully accomplished, can pose difficulties for players. In the case of this exercise, the interaction with the island creatures occurs as an iterative procedure which is, in fact, a learning process. Most pleasing is that such learning makes sense inside and along the game: It is not an introductory level with a tutorial goal. In that sense, it is the character, not the player, who learns.

CONCLUSION

We exposed the discrepancy that exists between current exploitation of sound in computer games and the value that sound assumes in interaction processes in our daily-lives. We reinforced this point by mentioning that in other domains, such as music and cinema, sound has proven to be effective in many aspects that are also critical to the experience of computer games. We also contextualized current game sound design with sound design in the wider scenario of interaction systems, namely those addressed by HCI.

We made a point of the fact that noticing the relevance of sound in other fields is insightful and can provide relevant synergy. However, computer games have their own specifics that oblige proper adaptation and, most of all, they provide opportunities that are particular to the field.

Considering our assessment of the current status, we argue the need for a collective sensitivity to the importance of the integration of sound design in game development practices and advocate the requirement of conceptual guidelines for those who will undertake sound design.

We reiterate that sound design should serve the project’s intentionality and constitute a whole along with all other aspects of game design. Attempts to do sound design directed by the need to provide “something to be heard” are limited, do not honor sound’s potential, and may even cause problems with other aspects of the game. Implicit in this thought is that this conceptual sound design ought to be performed right from the early stages of the project and be applied to all semantic layers of game sound.

We contributed to the recognition of the value of sound design by presenting an approach that is based on a multi-disciplinary interpretation of several concepts. These include: emotions, regarding which we have empathy for the neurological approach because it provides a less context-dependent way to deal with personal behavior; context, which allows us to understand the individual as a complex being blended with others, with the environment, with own prior experiences, and so on; acoustic ecology, which provides a contextual conceptualization of sound with emphasis on the affective dimension; soundscape and soundscape composition, both concepts derived from acoustic ecology; resonance and entrainment, two physical concepts with repercussions for perception, cognition, and emotion and that inspire interpretations of emotion management through a game experience.

From a holistic consideration of principles and insights subsidiary to these concepts, a set of guidelines for sound design in computer games has been drawn up. The guidelines address several affective aspects of sound design, including: valuing the acoustic properties of all interaction protagonists and their influence on perception and emotions; conveying meaning to the presence of sound in terms of consequence inside the designed world; acting through sound by performing meaningful actions which have valuable sonic expression;
using sound associated to events as an input to control them; ensuring coherence in the use of sound; integrating the player’s context in the sonic composition, including in multi-player games; exploring resonance as a instrument to achieve a binding between the player and the designed intent; and the use of entrainment as a model to create a dynamism of resonance states according to the emotional script.

We also presented a report on a brief design case where those guidelines were exercised and conducted by a team of game developers with no prior experience in sound design. We registered some uneasiness on the part of designers to work with the acoustic field as well as they do with the visual field: Fighting the visual bias that leads to sound merely being an extension of visual representations becomes a primary task. Difficulties also arise with quality audio sampling and with communicating sonic design ideas or intentions when compared to drawing visual renderings on paper.

In further research we intend to augment and refine the set of design guidelines and to build a significant understanding of their application. Particularly, we will be considering how to enhance the approach to dynamic composition of soundscapes in computer games, with special relevance to designing the experience with non-musical layers of sound.

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**KEY TERMS AND DEFINITIONS**

**Context:** Context encompasses intrinsic and extrinsic aspects that surround and influence interaction phenomena. Disregarding context can
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make all the difference, namely, deviation from a predicted outcome. Context has long challenged engineering and design disciplines.

**Emotion:** There are many possible levels to approach and therefore define emotions. In this text we adopt the cognitive neuroscience perspective, which explains emotions as body reactions that include releasing chemicals in brain and blood. Acknowledging this biological basis emphasizes how seriously the matter ought to be taken: It is definitely not something oneself can decide whether to attend to or not, once exposed to “competent” stimuli. This perspective also supports the notion that changes occurring in the body are accompanied by automatic associations, for instance, joy makes our cognition tend to speed up while sadness slows it down.

**Entrainment:** Entrainment refers to the synchronization of resonant systems. Breath, heartbeat, and brainwaves are examples of resonant systems for which entrainment may be explored as studied in psychoacoustics. There are two types of entrainment: internal-to-internal and external-to-internal. Internal-to-internal refers to entrainment among one person’s pulse systems, namely heart, breath, and brain. For instance, when heartbeat increases so does breath rate. External-to-internal has to do with the changing of internal rhythms through external stimulation, in our case, through sound. The latter is what allows for entrainment through design; the former augments the opportunities regarding the system at which that entrainment is target.

**Resonance:** Resonance is the phenomenon in which an object is put into sympathetic vibration by finding a concordance between its frequency and an exciting frequency. There are two types of resonance: natural (also called free), when an object vibrates as a consequence of being excited with its own natural frequency; and forced, if the object has the ability to vibrate to a variety of external frequencies. The functioning of the tympanic membrane is an example of the principle of forced resonance and, here, the limits of what can be forced establish the audible range. The human body is subject to resonance at many levels, depending on the frequencies to which it is exposed.

**Sound Layers and Semantics:** One way to address the complexity of the components of sound design is by classifying sound stimuli in layers according to their semantics. Classifications, as borrowed from the body of knowledge and practice in film, might include: dialog, which is the discourse; music, for setting the emotional tone; foley, which is the sound of actions; ambience, comprising the sounds of the environment; and sound effects, which are the sounds of abstract or imaginary objects.

**Soundscape:** Soundscape is a concept that derives from the field of acoustic ecology and refers to the sound of an environment heard as a whole. A soundscape is an ecologically balanced entity where sound mediates relationships between individuals and the environment. This holistic consideration puts emphasis on context, emotion, and interaction between the listener and the environment.

**Soundscape Composition:** Acoustic ecology supports the notion that a soundscape can be understood as a composition: like a musical composition. What is more, soundscapes can be composed. This inherent sense of harmony and orchestration is not mere lyricism: for instance, studies on animal vocalizations, in natural environments, evidence balance in level, spectra, and rhythm.

**Willing Suspension of Disbelief:** The term comes from the early 19th Century British poet Samuel Taylor Coleridge who argued that an infusion of reality into the fantastical was required for readers to accept implausible narratives. It has since been widely adapted for the study of computer games and immersive environments.