‘That’s Not a Secure Area’

Physical-Digital Sound Links in Commercial Locative Games

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Abstract

Pervasive games break the boundary between digital and physical to make use of elements in the real world as part of the game. One form of pervasive games are locative mobile games, which utilize physical movement as game control. To facilitate eyes-free interaction during play, these games benefit from exploring sound-based content. However, it is currently unclear what type of sound-based interaction is feasible to the general audience. Another consideration is which sound design strategies best support the goal of *situated experiences*, and how to design sound that supports game experiences drawing upon location-awareness, and intermixing virtual content with physical reality.

A first generation of locative mobile games is already commercially available. The present contribution analyzes seven commercially available locative games (*Ingress*; *Shadow Cities*; *Zombies, Run!*; *Inception the App*; *The Dark Knight Rises Z+*; *CodeRunner*) and summarizes the sound design strategies employed to contextualize game content in real-world. Comparison to current themes in contextualized audio research indicates similarities but also challenges some assumptions regarding audio-heavy gameplay. The findings illustrate the need for simplicity regarding audio challenges, but generally confirm the view of audio-based gameplay as a facilitator of mobility. Sound is also centrally involved in shaping contextualized experiences, forging links between the physical and digital world, and *indexing* game content to context through *functionality, verbal references, spatialization,* and *remediation*. The

article discusses two complementary strategies to systematically manipulate the physical-digital relationship, and to promote strongly situated experiences.

Keywords

Game sound, audio, sound design, locative games, pervasive games, mobile context, contextual experience, situated experience, indexicality.

Introduction

Locative games (or location-based games) use the player's geographical position (derived via combinations of GPS, WiFi and cell positioning) to map game content to physical locations. Locative games are typically included under the umbrella of *pervasive games*, which refers to a family of games that break the traditional boundaries of games (Montola 2012). This boundary-breaking accounts for the unique attractiveness of pervasive gaming, but the strategies for combining digital and physical content also constitute a central design challenge to pervasive game designers (Waern et al. 2009). The open questions fall under what Benford and colleagues (2005) have referred to as "hefting domains": (1) where to use virtual content, (2) where to use physical content, and (3) how to tie the two domains together in a meaningful way.

Sound is of particular interest to pervasive games for many reasons. In terms of practical usability, audio offers a solution for overcoming the functional limitations of mobile interfaces, in particular by providing an alternative for screen-based information (Brewster 2002). Audio meets many of the demanding usability requirements of a mobile user, sometimes conceptualized as *situationally-induced impairments and disabilities* (Sears et al. 2003). For example, sound is the modality of choice for facilitating a blended focus of attention, allowing players to attend to game content alongside other ongoing tasks such as driving (Gustafsson et al. 2006). In game design in general, sound has been strongly indicted as triggering user

imagination (Liljedahl 2011), and the high temporal resolution of human auditory perception makes sound exceptionally suitable for real-time feedback (Collins 2013). Explorations of sound in mobile computing generally confirm these sentiments. Sound-based interfaces have been successfully employed in location-aware games (Paterson et al. 2010; 2011; Ekman et al. 2005; Herbst et al. 2008), mobile sound art (see the extensive overview by Behrendt 2010), and many other types of playful location-based experiences (e.g. Kurczak et al. 2011; Rowland et al. 2009; Stahl 2007; McGookin et al. 2009; Bichard et al. 2006).

However, practical field experiments also point to new *aesthetic challenges* that arise from a design setting which intends to draw simultaneously upon both digital and physical content (i.e. Rowland et al. 2009; Paterson et al. 2010; Behrendt 2012; Ekman 2013). Even as many locative sound designs seek added value specifically in situating content and bringing it into the players' physical everyday surroundings, it is not clear how to approach the design of such situated experiences. How can designers orchestrate outcomes that depend not only on the content designed into the system, but intentionally draw upon the matches and mismatches mobile sound creates in different contextual settings (Behrendt 2012; Paterson et al. 2010; Rowland et al. 2009; Ekman 2007)?

Prior sound design literature provides little insight for the design of sound in such situations. For example, to assess the overall quality of game sound, designers of mobile sound now need to factor in the experiential impact of contextual elements, such as the physical environment, social situations, and other ongoing tasks, and consider how the experience responds in various contextual settings. Such complex balancing acts have been unnecessary in previous design, and demand significant adaptations both to design and evaluation processes (e.g. for a discussion on authoring tools, see Woo et al. 2005). Another question concerns the transferability of design goals derived for sound in PC/console gaming into the mobile context, in particular the suitability of immersion-driven design paradigms for mobile contexts (Knowlton 2008; Ekman 2013). In particular,

many immersive sound design techniques operate by suppressing players' awareness of their physical surroundings, which makes them incompatible with a mobile scenario (Ekman 2013).

The present work contributes to the discussion regarding the aesthetic goals, purposes and design directions in locative game sound. To this end, the study systematically analyzes a handful of commercial games with locative functionality, that have recently emerged onto the consumer market. The study investigates how a locative sound design connects, refers, or responds to contextual factors and how situated experiences can be intentionally promoted through design.

The specific research questions can be formulated as follows:

Q1: How do current commercial locative games use sound to *create situated experiences,* which convey a sense that the virtual content is related to the players' current context?

Q2: How do these *strategies align with the way situated sound is employed in research* on locative sound, and where does the commercial practice indicate new directions for research?

The work proceeds as follows: Next comes an overview of how related work on sound in locative media has dealt with the situated experience. The section thereafter considers the motivations for looking at commercially published games as part of design research. After that, the material and method of analysis are presented, followed by the results of the study. The discussion covers separately ways in which applications are functionally employing detected/ sensed real-world contextual data, and how situated dependencies are expressed and communicated through sound. The work concludes with a summary of promising future directions for design and development of situated sound experiences.

Previous work on locative and situated sound

In the research literature, a number of interactive systems describe sound mapped to physical locations or bound to and influenced by

other contextual factors (such as social situations or time). This section will focus on summarizing how prior work in this area has addressed the user experience, and in particular how it has approached the aesthetic impact of context in the design of situated sound experiences.

Only a relatively small number of locative or augmented reality systems with locative audio content are actually games (Ekman 2007; Stahl 2007; Kurczak et al. 2011; Paterson et al. 2010). However, many game-relevant elements (exploration, playful interaction, goal-directed interaction) can also be found in location-based sound installations (Rozier et al. 2000; Goudeseune and Kaczmarski 2001; Rowland et al. 2009; Reid et al. 2005; Woo et al. 2005; Vazquez-Alvarez et al. 2010). Other projects have used locative sound for functions with imminent applicability in games, such as navigation (McGookin et al. 2009; Holland et al. 2002; Stahl 2007), or personalized mobile music experiences (Gaye and Holmquist 2004; Sawhney and Schmandt 1999). Finally, several publications address the technical aspects of mobile binaural rendering and augmented reality audio (e.g. Brock et al. 2003; Peltola et al. 2009; Albrecht et al. 2011; Mariette 2011).

As a result of the various different research perspectives, the understanding of what constitutes relevant context varies significantly between publications. Some areas and topics—particularly work seeking to establish an augmented reality environment (Cohen et al. 2004; Kurczak et al. 2011; Paterson et al. 2010; 2011; Brock et al. 2003; Mariette 2011; Albrecht et al. 2011; Woo et al. 2005) define context primarily as the properties of the physical environment (for example, nearby objects, background noise levels), additionally also incorporating sensor data about the user's orientation within the environment, such as head position or gaze direction. On the other hand, context may also extend to include considerations such as the social environment (Stahl 2007; Rozier et al. 2000; Ekman et al. 2005), ongoing task and temporality (Rowland et al. 2009; Gaye and Holmquist 2004), and even physiological and psychological user state (Fagerlönn 2005). Broadening to the scope of mobile computing

in general (not specific to sound, nor games), Jumisko-Pyykkö and Vainio (2010) reviewed the way 'context' was used in recent mobile literature, and found as many as five different contextual categories, spanning *technical, social, physical, temporal*, and *task* factors.

The literature on mobile sound covers a range of products and applications. In most cases, situational factors are so central to the design that the services would be rendered meaningless if context was removed. However, whereas the explicated intent of many of these efforts is to create novel forms of contextualized content, the way sound is perceived, evaluated and experienced *in context* and the added value of presenting sound as *situated experiences* has gained remarkably little attention. Designs are typically described in technical detail, but only provide hints regarding how designers perceive the flow of information and how represented content is linked to the current context. The audio material may consist of designer-edited content—quite often with a historical perspective (e.g. Reid et al. 2005; Rowland et al. 2009; Herbst et al. 2008; Paterson et al. 2010; 2011)—or offer a platform for visitors to share and annotate spaces with their personal stories and collected sound materials, creating a form of audio social commentary (Rozier et al. 2000; Rowland et al. 2009).

By the descriptions available, it appears most designs consider audio as an one-directional augmentation of physical location. Only a few authors point to the transformative effect of combining space with sound, and the novel interpretations that arise e.g. when a certain form of content is experienced in juxtaposition to a certain real-world context (e.g. Paterson et al. 2010; Ekman 2007; Rowland et al. 2009; Behrendt 2012). However, it is clear that in some serendipitous cases, the contextualized experience creates emergent experiences where the sum is more than its parts. For example, Paterson and colleagues (2010) as well as Behrendt (2012) discuss cases where aesthetic impact arises from specific and unique combinations of place and sound. Ekman (2007) points out the impact of the environment on semantically making sense of and interpreting game sound. And finally, Rowland and colleagues (2009) discuss a rare case of

intentional design when they describe how they placed locative content on the top of a steep hill in order to ensure that the participants would be out of breath (from climbing the hillside) simultaneously to experiencing the audio material.

Taxonomy of Locative Sound Art

As is evident from the previous section, a multitude of design cases have explored locative sound, yet the aesthetics of locative mobile sound has been rather poorly conceptualized. A notable exception is Behrendt's taxonomy of mobile sound art (Behrendt 2010), which has its primary focus in the aesthetic properties of contextualized sound. Her work is based on an extensive analysis of (over one hundred) mobile sound art projects, and offers a classification of the design approaches coupling mobile interactions with sounding interfaces. The taxonomy identifies four main design strategies for combining mobile interaction with audio material: The act of (1) *placing sounds* binds sound to specific physical locations. In contrast, by (2) *sonifying movement,* sound is connected to certain ways or patterns of moving, rather than any individual locations. Designers may also establish spatially defined areas for more complex sound-related activities. These (3) *sound platforms* offer stages for (often multi-user) sound crafting and manipulation through mobile interaction. Finally, the approach can also focus on the mobile device as a (4) *musical instrument*, turning the physical device and its sensors into an interface for musical expression.

The taxonomy is not specific to games, and it focuses on *mobility* which covers only a subset of the contextual factors we are interested in (as discussed in the previous section). Nevertheless, it provides an example of how aesthetic function can be dissected and analyzed thematically, in order to reveal common design strategies for specific aesthetic pursuits. Applying Behrendt's taxonomy, the location-based game-like interfaces in current research mostly fall into the category of placed sound, with some added elements of sonified mobility. For example, navigation-style interfaces such as *AudioBubbles* (McGookin et al. 2009), *The Roaring Navigator* (Stahl 2007), and

Growl Patrol (Kurczak et al. 2011) all use place-bound audio cues to playfully guide users towards set targets. Placed sound also forms the basis for the game-like explorations of the city in *Rider Spoke* (Rowland et al. 2009), and even if many installation-type games differ in the technology they apply to locate players (e.g. using Bluetooth instead of GPS), placed sound remains an underlying idea in games such as *Pirates!* (Björk et al. 2001) or *Syren* (Woo et al. 2005). In addition to placed sound, various gestural game interfaces have appropriated elements of the sonified movement category. These games may additionally connect experiences to specific locations, as in *Backseat Playground* (Bichard et al. 2006), or they may simply create the illusion of location-bound sound as movement establishes a spatial frame of reference, as in *AudioFlashlight* (Valente et al. 2008).

The work of Behrendt offers an excellent example of looking beyond the technological realization of mobile systems, to focus on the *aesthetic* design strategies of mapping sound and movement. However, the taxonomy falls short in categorizing more complex game-based interaction with sound, in particular interaction that takes place within an augmented-reality style audio setting, which easily ends up using elements from all four categories (e.g. Cohen et al. 2004; Ekman et al. 2005; Moustakas et al. 2009; Paterson et al. 2010; Paterson et al. 2011). Moreover, since the taxonomy puts sound in focus, it applies best to audio-only or audio-mostly concepts and the supportive function that sound plays in most audiovisual contexts falls outside the framework. As a consequence, the taxonomy is less helpful for analyzing audio in cases where interaction is primarily visually-driven, such as in the augmented-reality audiovisual game *TimeWarp* (Herbst et al. 2008).

Indexicality and the Contextualization of Information

To examine the contextualization of sound elements, we can apply another concept. Within mobile computing, Kjeldskov and Paay (2010) have suggested using *indexicality* as a conceptual tool for exploring and describing the flow of information between user-

interface representation and use context. Indexicality traces the ways in which the user interface points to information implicit in the current context. For example, when the service communicates that a restaurant is close to the user's present location, indexes are the pointers by which the service establishes that relationship, linking the represented information (restaurant) with user context (current location). The way contextual knowledge is communicated, and how these links are shaped, argue Kjeldskov and Paay, is the essential core design task of contextualized information design.

While Kjeldskov and Paay concentrate on the contextualization of (user-actionable) information, indexicality could be equally useful to understand the contextualization of meaning from an aesthetic perspective and also applied to less utility-focussed products such as games. Interestingly where the core design question Kjeldskov and Paay considers is how to establish the links between context and content, this question—what prompts users to perceive a connection between audio content and space—has been relatively absent in work on locative game sound. The lack of critical discussion might be taken as an indication that the contextualization of audio is unproblematic and situational dependencies are intuitively grasped. However, such an assumption has been questioned by Ekman et al. (2005), who found that without prior briefing, players of a locative game would not spontaneously discover the connection between place and game audio. It is difficult to assess how significant the impact of briefing has been in establishing the location-dependency of sound in prior studies.

Whereas Kjeldskov and Paay demonstrate how to use indexicality as an analytical concept, their examples only address visual interface elements. Even if indexicality appears to be very promising for describing contextualized gaming experiences, it is not straightforward to determine how the idea of indexical information applies to the audio modality; indeed, how does one point with sound? This question will require some further development. It would appear that apart from subject briefing prior to experiments, and seeking a certain thematic likeness between sound and location (e.g.

Bichard et al. 2006; Stahl 2007) the primary cue to contextual dependency is how the system's sound output responds to user movement (placed sound and sonified mobility). If indexing relies only on this strategy, it would follow that technical constraints such as temporal resolution and location accuracy are central in establishing a connection between location and sound. Such indices would also leave the system very vulnerable to positioning and orientation errors. As would be expected in such a case, positioning errors have been found to lead to significant confusion, to the point of making functions incomprehensible (Kurzcak et al. 2011; Ekman et al. 2005; Holland et al. 2002). Furthermore, considering the wide variation in location accuracy of current devices[1], in the absence of proper briefing, the locative nature of sound might fail to become apparent to the user. Finally, successfully communicating contextualization through sound is likely to become more challenging in systems that (1) combine visual and auditory components, leading most users to expect visual-dominant interaction, (2) are used simultaneously by multiple users and autonomous game entities, which decreases the direct impact of the user's own actions, and (3) respond to input from several information sensors/sources at once (again, confounding the direct and observable impact of any single control action).

Commercial games as artifacts—exploring design strategies through Formal game analysis

This work looks for inspiration on how locative game sound could communicate across the digital-physical divide by exploring designs and strategies adopted in current commercially available locative and mobility gaming. I approach commercial games as artifacts that document and embody tacit design knowledge about the design ideas with value within the current product ecology. While it will be impossible to trace the precise reasons a design has materialized in

1. Studies show that the iPhones A-GPS has a median error of only 8m (compared to 1,5m on a dedicated GPS device), it is notable that whenever GPS is unavailable the error grows significantly; in areas with GPS shadow, the median error for WiFi was 74m and 600m for Cellular positioning (Zandbergen 2009). Similar results seem to apply for other smartphone models as well (Zandbergen and Barbeau 2011).

a particular way, commercial products nevertheless give a unique perspective on design expertise that pertains to the current consumer market, weighing in the various factors that impact design on a level rarely accessible by research projects conducted in a purely academic environment. This includes considerations such as technological penetration and feasibility (including infrastructure), production realities and workflow, target audience expectations, legal concerns, marketing strategies, branding and product identity etc. Analyzes of commercial games provide an angle for examining the types of design decisions that survive or even flourish in a true project ecology.

Moreover, the practical limitations that come from relying on off-the-shelf technology implies that added value must be sought solely through design. This provides a counterpart to constructive design research, which is often published in technical forums, and hence tends to favor new technological development over pure content design. Not only can this provide new insight about design solutions for overcoming technical obstacles; as pioneering products, these games may also set consumer expectations for future products, and determine the type of content strategies the general audience will find familiar and palatable in the future.

Game Material used in the Study

Games and game-like applications were sought for analysis by perusing the App store and Google play, as well as by following industry news. The games for analysis were selected using the following criteria: (1) they offer game-like interaction, (2) they contain non-trivial sound design elements (3) the game uses location information as game input, and (4) the game was available in the app market for iPhone or Android in Sweden during January 2012-January 2013.

The above selection criteria exclude a number of games that either had very trivial game sound or no sound at all, for example *Gbanga Famiglia* (Milliform Ltd., 2012). Moreover, apps that use a “check-in” style location paradigm have been excluded from the analysis

(e.g. games built on the Foursquare API). Local multiplayer games which cannot be played in single-player mode, such as *MobileWar* (Upright Media Concepts, 2012), were also intentionally left outside the analysis.

The resulting collection included the following seven games, available for the iPhone and Android platform:

- *Shadow Cities* (Grey Area, 2011)[2]
- *Ingress* (NianticLabs/Google, 2012)
- *CodeRunner* (RocketChicken Interactive, 2012)
- *Zombies, Run!* (Six to start and Alderman, 2011). Henceforth referred to as ZR.
- *Inception the App* (RjDj, 2010). Henceforth referred to as ItA.
- *Dimensions* (RjDj, 2011)
- *The Dark Knight Rises Z+* (RjDj, 2012). Henceforth referred to as TDKRZ+.

Method and Data Collection

Within game research, perhaps the most popular strategy for producing design knowledge from analyzing commercial games is to generalize over a large body of artifacts, identifying design patterns (Björk and Holopainen 2005). However, seven games provide limited material for pattern construction (by definition, a pattern is a *recurring* design solution). Whereas pattern-harvesting has been applied separately to game sound (Alves 2012) and locative games (Will 2013), there is little overlap between the two sets of patterns to provide a basis for investigating locative sound. Therefore, the present work applies formal analysis to systematically examine and collect the variety of approaches employed within this particular niche of game sound design. The theoretical framework of

2. As of 20.9.2013, Grey Area has announced Shadow Cities will be discontinued.

indexicality (Kjeldskov and Paay 2010) was chosen for this purpose. The analysis looks at the precise means by which games create contextualized sound experiences and tracks how the games are (a) *using sound* in order to (b) *point at the current context*. As a starting point, the work adopts the five index categories of Jumisko-Pyykkö and Vainio (2010), but the full set of index categories are allowed to evolve based on the encountered game material.

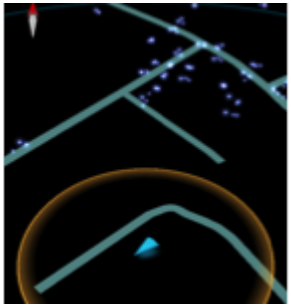
For analysis, all applications were played by the author, on a mobile smartphone (iPhone 4 for iOS applications, Samsung Galaxy S2 for Android applications), using the standard in-ear headphones provided with the devices. Playing styles were varied to gauge the aesthetics of the game, and to analyze the applications' detailed sonic behavior in various situations. As material was collected over a longer period of play, the games received a number of updates during the duration of the analysis. In the rare case where a client update had a noticeable difference to locative sound behavior, I have indicated the specific version it applies to in the footnote.

The analysis procedure for each game commenced with a period of free-form play to get a general feel for the game, to level up, and to gain access to game features that were locked at the beginning of the game. The length of this phase varied by game, from approximately 5 hours (*The Dark Knight Rises Z+*, which has no locked features or character development) to well over 20 hours of active play. This phase was followed by a period of more systematic research-play[3], exploring the game in different contexts, analyzing functional dependencies behind various sound designs, and cataloguing contextual references. Again, the duration of active play varied significantly between applications, from very briefly replaying certain events to engaging in over 40 hours of systematic play and replay (story-heavy games *CodeRunner* and *Zombies, Run*!).

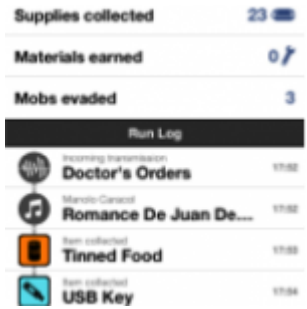
3. For analysis, play has been in compliance with the guides or instruction provided by the application, and no intentional subversive action or cheating has been explored; this was made to ensure analysis focuses on the uses designed into the system. When in doubt about the intended use, the author has referred to official instructions and guides about how to proceed with game action.

Game analyses were complemented with additional information on the applications gained through online sources, such as game reviews, designer texts and interviews, game forums and Twitter channels. This material was primarily used as a way of ensuring that no significant content or relevant playing context was left out of the analysis. Any use of complementary data in analysis is indicated by direct references to the source material.

Shadow Cities is a massively-multiplayer online roleplaying game. SC overlays a persistent game world on a map representation of the physical world. Players banish spirits, and harness energy from virtual structures built at hot-spots in the game world. SC divides its player base into two fractions, and gameplay is driven by a competition between fractions, both in player-to-player combat, area domination, and on a point-based basis in weekly campaigns.

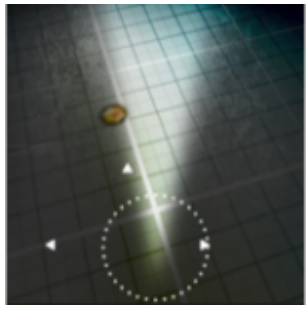


Ingress, similarly to *SC*, is a multi-player game with persistent game worlds connected to a map-layout of the physical environment. Players are split into two factions, competing to take control over the world by conquering and linking in-game portal locations with the help of items collected from the game world. The locative gameplay additionally provides material which feeds into an alternate reality game, played on other platforms.



CodeRunner utilizes a semi-permanent game world over a map display, offering an espionage-themed interactive experience fueled by location-based quests. The player performs missions consisting of visiting locations marked on the map, or following moving targets. At in-game locations, players also solve visual riddles to discover the information they need to break into systems. The experience is primarily single-player, even if the game draws on its (multi)player base for content creation.

Zombies, Run! is a zombie-themed fitness application, offering an audio narrative that progresses in bite size chunks, designed to accompany physical exercise such as walking, jogging and running. Zombies, Run! complements regular run tracker application features with a game-like interface that visualizes overall training progress. It also features zombie chases as a (optional) mini-game for interval training.



Inception the App (top left), *Dimensions* (middle left), and *The Dark Knight Rises Z+* (bottom left), are three different variations of contextually responsive personal music applications. The applications offer contextually responsive music tracks that respond to a range of sensor and derived data: movement, sound, touch, date, time of day, and weather.

	While all three applications afford distinctly playful use, *Dimensions* is most decidedly a game, with players advancing along an explicit progression line (tracked on the Apple Game Center) by collecting gemstone-like artifacts and fighting off adversaries.
	The playfulness in *Inceptions the App* and *The Dark Knight Rises Z+* revolves more around exploring the full extent of the musical experience with content based on the soundtracks of the movies Inception and The Dark Knight Rises.All three applications are primarily solitary experiences, but incorporate a mode for co-use amongst a select number of friends.

Table 1: Description of the general style and content of the seven analyzed games

Results of game analysis

The applications analyzed for this work approach locative sound from different perspectives, but they also share some similarities. In order to focus on generalizable design strategies rather than surface thematics, the detailed analysis will primarily look beyond choices of genre and style, and instead focus on how the systems approach locative content and mobility. However, as a way of contextualizing the analysis, Table 1 provides a brief summary of the content style of each application. The remainder of this work will discuss the formal design strategies in more detail, and examine separately how sound

is involved functionally in the context of gameplay, as well as what sound-based indices are used to link virtual content to real-world context.

Gameplay Interaction, and Utilization of Locative Data

In the distribution channels, all but one of the applications (*TDKRZ+*) are classed as games. Active gameplay provides the core content in four of the apps (*Ingress, SC, CodeRunner, Dimensions*). *ItA* and *TDKRZ+*, while both offer playful interaction, lack explicit goals or a system for tracking individual progress and are more accurately described as augmented sound experiences. In contrast, *ZR* introduces gameplay elements in the form of zombie chases, but they occur only sporadically (and can be turned off completely) among otherwise linearly progressing content.

Locative data is also used to varying degrees. Physical movement is in a primary role for using *Ingress* and *CodeRunner*, and the games offer no progress for the stationary player. *Ingress* requires that players move around both to gather energy, which is spread around in the environment, and to find game content. Since interacting with portals necessitates proximity to specific geographical locations, this limits the amount of active play in areas with no portals and benefits players who travel actively. Depending on the density of the map, players may need to cover significant distances, or simply walk the short distance between closely positioned portals (portals have a 35m radius, and do not overlap). *CodeRunner* is slightly more flexible in terms of specific locations and the game will always generate a number of randomly location-mapped targets around the player, regardless of how populated the location-specific map happens to be. However, missions will require significant physical activity (automatically generated targets will generally be at least some hundred meters away) and the game explicitly rewards the player for covering longer distances (accumulated distance up to 1000km, or 50km in one step).

In contrast, movement is less of a necessity for enjoying *SC,*

TDKRZ+, ItA, and *Dimensions*. The applications use GPS data, but while location-based features add to the experience, they do so without removing the option for stationary use. *ZR* uses GPS data to track run metrics, and provides an option to upload runs to an online map view. However, GPS is not required and there is a treadmill mode that uses accelerometer data. Moreover, detected movement is not required; the story will progress and item pickups will occur regardless of (any) player movement. The single element in which progress is tied to detected physical movement are the (optional) zombie chases.[4]

SC offers some benefits for physically located players (harvesting energy from in-game structures requires physical proximity), however, the game is fully playable without moving. Moreover, players can use in-game beacons to gain (and provide) access to game areas mapped to other physical locations freeing exploration from ties to actual mobility. Likewise, the music applications *TDKRZ+, ItA* and *Dimensions* all three derive some information based on location data, but the impact of location is optional. All three offer basic functionality (reactive music) regardless of specific location and are therefore fully enjoyable also in stationary mode.

Sound Design Strategies and Sound-based Functionality

Since audio was one of the selection criteria, all titles involve game sound. Many of the game titles are also audio-heavy, and sound forms the main content in *ZR, ItA* and *TDKRZ+* and remains indispensable in *CodeRunner* and *Dimensions*. The designs combine sounds from four categories: embellishing/interface sounds, spoken commands, radio play style narratives, and music. *Ingress* and *SC* use audio only sparingly, with simple sound effects (fire, electricity) set against a sonic background of winds and musical drones. Unlike the other applications, the sound design offers no unique content and the information design of the user experience is visually-oriented. *ZR* and

4. Early versions of Z,R! offered zombie chases only when GPS was activated. Accelerometer-based zombie chases were introduced as an experimental feature in version 1.2., released in April 2012.

CodeRunner are more audio heavy, developing stories in the style of radio plays. The player is connected to the base of operations over a radio/phone connection, and the narrative progresses primarily in the dialogue that is conveyed over this channel: overheard conversations, spoken instructions and recordings. In *CodeRunner*, the player can also examine found media clips, and operate remote connections (command-line interfaces) to break into data repositories. Finally, music drives *TDKRZ+*, *ItA* and *Dimensions* (the latter also involves a limited number of spoken instruction and interface sounds). These apps feature unique contextually responsive music. They also take input from the device microphone, and captured environmental sounds are elaborately processed and incorporated into the musical mix in different ways, playing sounds stretched or backward, or turning recorded samples into rhythmical patterns or virtual sound elements that swoosh past the listener.

The primarily sound based experiences in *ZR, CodeRunner, TDKRZ+, ItA* and *Dimensions* facilitate mobility by allowing a greater portion of visual attention to the environment. Moreover, the type of audio we find in these games is meticulously tailored to integrate with the everyday. Even if most of the games aim for dedicated use scenarios, high levels of flexibility is achieved either by distinctly episodic progress, or by casual and therefore easily interruptible play. *CodeRunner* and *ZR* offer mission-based play where the temporal structure of missions demands a dedicated time slot set aside for gaming. To add some flexibility, *CodeRunner* will let users choose between several simultaneous missions, whereas *ZR* will let users tailor the length of episodes (choosing between 30 or 60 minutes workout) and missions can be paused. *Ingress*, *SC* and *Dimensions* split play into yet shorter, bite-sized engagements with immediate returns, which increases casual play alongside other activities.

The high demands for integration is also reflected in how external audio content is handled. Both *ZR* and *CodeRunner* will encourage players to listen to their own music while playing, and include this as a fundamental part of the end user experience by flexibly alternating

between the playlist and game-based alerts; *ZR* will even schedule its main content to fit between songs to minimize the disruption. *Ingress* allows music playing in the background during use but *SC*, *Dimensions*, *TDKRZ+* and *ItA* will stop other ongoing sound players upon start. While *Dimensions* mixes gameplay functionality and music, *TDKRZ+* and *ItA* frames the experience as background, rather than a foreground playing activity.

Sound-based Gameplay

While the significant shift towards using audio for main content is well in line with how research has envisioned sound in mobile computing, the precise design strategies for shaping audio-based gameplay and situated experiences differ somewhat from those typically seen in research prototypes. Despite generally audio-heavy designs, the games use sound cautiously when shaping gameplay challenges. For example, instead of capitalizing on challenges inherent in listening (cues, directions, recognition), these efforts are minimized in the commercial designs. Whenever possible, game-relevant information is provided primarily, and sometimes only, in visual form. In the few cases where player action is based on audio information alone, the information design avoids ambiguity at all cost. This is achieved by combining identifiable alerts with clear verbal instructions. For example, *ZR* zombie chases are announced with audio only. The fact that zombies are on one's tail is communicated by introducing as many as three new sounds: spoken instructions, zombie growls, and a geiger-style beeping signal, which all serve the sole purpose of informing the player of a need to speed up. Additional spoken confirmation will signal when the mob has been evaded. In a similar manner, *CodeRunner* and *Dimensions* back up all non-speech audio cues with clear and unambiguous spoken prompts; all the player needs to do is obey the instructions.

In addition to audio-only information, some of the games also use more complex audio information designs, but only in accompaniment with visual information. For example, *Ingress* provides a spatialized audio navigation beacon as a directional cue to targeted portals.

However, the sound beacon will disappear when the phone is in an upright position, and be misplaced if the phone is pointed sideways to the user's line of sight. Thus, the beacon will only display (correctly) in the exact same situations as the player has access to the visual map. Neither is navigating by ear very feasible in practice: sound localization is not very accurate and additionally quite sensitive to compass interference.

The unambiguity of audio design is particularly interesting to take notice of, and it gives some indication about the type of audio challenges that are feasible for pervasive and mobile use in the mainstream market. Unlike typical[5] audio-based games—where the player, for example, navigates by ear, detects specific sound cues, or times their actions to the beat of the music—the analyzed games avoid making listening a challenge. Even in audio-heavy designs there is nothing to *listen for* only *listen to*. This is a clear divergence from the functionality-driven approach adopted in audio-based gaming (e.g. Rovithis 2012; Friberg and Gärdenfors 2004). Notably, also previous research within locative sound (e.g. Kurczak et al. 2011; Stahl 2007; Vazquez-Alvarez et al. 2010; Cohen et al. 2004) has featured far more complex listening tasks than found in the analyzed games.

Playful Music and Unlocking Sonic Content

The three musical applications *ItA*, *Dimensions* and *TDKRZ+* are special in the sense that while they do not appropriate audio to make a traditional game, they are nevertheless very playful. Of the three, *Dimensions* actually offers a bona fide game, however, the main content in all these applications is in the contextually reactive music experience. Additionally, all three applications promote a very active stance towards context and operate solely by audio, offering a musical background that changes in response to small elements in a whole range of contextual factors (making maximum use of the phone's sensors). By making sound immediately responsive to so many factors at once, the design offers something of a musical puzzle-toy,

5. E.g. www.audiogames.net

prompting the player to try out the application in new environments and seek new ways of triggering novel musical material. At the same time, by not strictly demanding that the player engages in any specific listening task, the score-like reactive soundscape is allowed to latch onto any other activities (regardless of how demanding they are). This way, the application seamlessly shifts between its two roles as either reactive background music or interactive musical toy.

ItA and *Dimensions* further develop the reactivity into a new form of contextual sound game, by inviting players to explore new contexts more generally to unlock novel musical material[6]. This becomes an active pursuit; the applications openly describe the relevant contexts required to gain access to the new content. For example, the player is instructed to log into the app late at night to get into the 'Ghost dimension' (*Dimensions*). By making context relevant in such an explicit fashion, players are further encouraged to pay attention to details in their context, seeking clues or signs that will qualify as criteria to unlock the new experience (Oh, is it a full moon tonight? How can I convince the app it is sunny?). Some contexts define rare or very special situations, which makes fulfilling the contextual demands something of an achievement in itself. For example, one level in *ItA* is only made available upon visiting Africa (yes, the continent). *TDKRZ+* does not use contextual elements as a way for unlocking new sonic material, nevertheless it promotes the same very active stance to context, and also allows the user to navigate the sonic material they possess (a few scenes are available for free, more can be purchased) through this similar approach.

Discussion

Sonic contextualized experiences

The previous section reviewed how sound is functionally employed in the analyzed games. Applying the notion of indexicality, we can also identify a number of pointers which direct players to associate game

6. While TDKRZ+ uses contextual exploration as a way to interact with the content, additional tracks are available only through purchase.

elements to the environment. The sound-based indexes reveal several different approaches to make the actions of the service appear to have a meaning that is specific or connected to the current use context, be it physical, technical, social, temporal or task-based.

Indexing with Sound

As noted previously, making *elements functionally responsive to context* is one way to make contextual connections apparent to the user and signaling contextualized meaning. Functional dependency—such as the audio beacon in Ingress or the playful soundscapes in *ItA, Dimensions* and *TDKRZ+*—provide the user both with an incentive to explore use in various contexts, and also turn attention to the context as part of framing the system response. However, only tracking the ways in which context is made necessary or required for interaction overlooks the many subtler design aspects that go into shaping and invoking a sense of contextualized experience. A comprehensive look at all the pointers provides a more complex picture of how the service shapes connections with the current use context. Despite not requiring location data to function several other design techniques are utilized, both to invite and guide the contextualization of the overall experience.

CodeRunner and *ZR* make frequent *verbal references to the player’s current context*—the environment, use situation, time, equipment, and task. By pointing to contextual factors and claiming them as game-relevant, the player is invited to seek elements in the current context that match what is described. Even if some references are based on observed sensor data, others are more or less arbitrary. Some of the references by *CodeRunner* are functionally backed up, such as relative target directions (“north of your location”), or when the game chides a stationary player who fails to obey instructions (“ok, I’m serious here—get walking”). However, other references connect story content to environmental features that are rather based on plausibility than actual checked facts, or they are simply vague or general enough to accept almost any target (“people”). Likewise, *ZR* will index liberally to contextual factors without any concern

for factual accuracy, including not only physical structures, but also including time ("it's getting late"), physical effort ("you're doing great"), and relative direction ("twelve o'clock"). The game even incorporates references to the user's pre-selected playlist ("a special song").

There are also certain purely auditory cues that can be used as ways of indexing sound to contextual factors. By using *spatialized audio*, it is possible to perceptually place sound sources so that they draw attention to a specific direction, or even a specific point in the environment. The analyzed applications use spatialized audio sparingly and only Ingress features a navigation beacon that combines physical location and directional cues (from the phone, i.e. not head position) with sound spatialization.

Another sound design technique which is found in the material and used for indexing is *remediation*, which refers to the practice of masking mediated content as another type of media (Bolter and Grusin 2000). In the case of these games, game content (game audio) is remediated by presenting it as on-line communication and audio recordings heard over an (unreliable) radio channel. This is a way of indexing that points to the technological context, whereby the experience involves listening at sound context through headphones. Notably, while many of the games (*Ingress, ZR, CodeRunner, Dimensions* and *ItA*) offer some form of general explanation for using headphones in the game instructions, the audio realization of many seeks to dissolve the technological interface. In contrast, *ZR* and *CodeRunner* use the sound design to further strengthen the sense of interface, but remediate it to fit the game's version of the story and thus extend the fiction to cover also the physical technological equipment that is being used to play the game. By using a crackling radio signal, the sound material points to the real-world fact that the player is carrying a phone and wearing headphones, but simultaneously also provides a good in-game reason for carrying that technology.

Strategies for Shaping Situated Experiences In particular, the liberal

indexing to non-factual contextual parameters suggests that from an experiential perspective, only focusing on the functional dependencies is a gross oversimplification of the design techniques that contextualize play experiences. Rather, the design of situated experiences can be thought of in terms of two separate functions. The first function subjects the service to certain contexts, either by making the service dependent on certain contextual data (e.g. requiring movement as input, demanding the player visit Africa), or alternatively by softer means, by selectively promoting and facilitating targeted use contexts[7]. When a service is in the target context, situated experiences can be created by various different strategies that index game content to the current context, establishing it as an integral part of the overall experience. A summary of indices is presented in Table 2.

The strategy of facilitation and indexing as a way of creating situated experiences has a number of implications for design. A common feature to many of the examined applications is that context is viewed proactively. It is not something that the game is passively dropped into. Rather, context is either adopted as a part of the control mechanism for using the device, or contextual references are considered malleable and open-ended. The reviewed material shows that the link goes both ways; it invites players to consider the impact of environment on the game, but the game also lends something magical to the everyday. This interaction has previously been discussed as the *three-sixty illusion* (Waern et al. 2009), and the reviewed material helps identify tools in the design arsenal for strengthening this two-way interchange through sound.

7. Neither are contextualized experiences restricted to designed aspects of the service. However for the purpose of looking at how such experiences can be shaped by design, this work will limit the discussion to ways in which the applications do this by actively calling upon the user to pay attention to such connections.

Context	Shadow	Ingress	Code	Zombies	Inception	Dimen	TDKR
specific physical location		F			F		
relative location		F	F	(F)		F	
objects in physical environment			X	X	(F)	(F)	(F)
environmental sound					F	F	F
other environmental factors					(F)	(F)	
current time				X	F	F	
ongoing task		F	F/X	(F)/X	F	F	F
social context			X				
simultaneously playing music			X	X			
mobile device			X	X	F	F	F

Table 2: Contextual sound indices. F indicates functional dependence. (F) points to derived functional dependencies in which the contextualization uses functional dependencies, but in a different form from how they are being represented to the player. X indicates a non-functional reference where contextualization is implied, but no functional dependence exists between context and representation.

Technically, the malleability identified in the analyzed games

suggests a more forgiving design scenario exists alongside rigorous context-detection. For example, while using sensors to determine the exact context of use is typically very challenging to get right, the proactive approach turns the challenge of contextual matching into a game where the user is tasked with actively searching contexts that would qualify for purposes of the game. As demonstrated by *ItA, TDKRZ+* and *Dimensions*, this form of situational play can be quite enjoyable if it is coupled with the right kind of sound. Furthermore, some games within the collection (*Ingress* and *CodeRunner*) employ user-created content to define physical spots as game-relevant places. *CodeRunner* and *ZR* are both tapping into the players' personal music reserve which is potentially very valuable material for sound designers. While *ZR* is the only game to also explicitly index to this type of user-selected content, simply allowing players to use their own music in the background (*ZR, CodeRunner*) is a way of drawing on the emotional significance of user-selected musical content. By tagging selected physical structures in their environment (*CodeRunner, Ingress*), players are also providing the service with specific information of meaningful contextual elements in their surroundings.

Moreover, verbal indexing suggests that potent situated interpretations can arise even if contextual matching is not backed up by functionality. While some of the contextualizations may lack factual accuracy, this type of contextualization nevertheless seems to acknowledge and explain the user's environment by reconciling the reality of play within the fictive frame of the game. What appears most important to the success of indexes is not the factual accuracy, but precisely the reconciliation between the physical and digital representations. From cognitive science, we know that the human mind shows a preference for "good stories" over accurate content (Kahneman 2012). Interestingly, as especially the verbal references in *ZR* and *CodeRunner* demonstrate, even slightly mismatching information can seem quite palatable; the author's experience was that it was only upon clearly contradictory information that the mind protests. For example, the locative audio beacon that *Ingress* uses to point towards target portals is very sensitive to errors because any

shift in position will cause the target to appear to jump from one place to another. Such jumping is inherently irreconcilable with how places behave in physical reality and completely destroys the perception of a stationary beacon. On the other hand, when open-ended references actually match to the environment (be it through sheer coincidence), it was very memorable.

Comparing to prior work again, at its core, the proactive stance to context is not uniquely novel. Many prior locative sound prototypes also come with the explicit purpose to somehow manipulate user context, most typically by promoting spatial exploration (McGookin et al. 2009; Rowland et al. 2009; Paterson et al. 2010; 2011; Kurczak et al. 2011; Stahl 2007). Interlinked with this vision, is also the idea—popular within alternate reality gaming—of using game design to cause very tangible change, in McGonigal's (2011) words, to "fix what's wrong with reality". To this end, the analyzed games show practical techniques for how the combined use of indexes and functional response can be employed to establish a stronger two-way connection between the virtual and physical domains. Furthermore, the present analysis points to the possibility of using open-ended indexing techniques in the interface to strengthen situated experiences regardless of function. The natural ambiguity of sound indexes appear uniquely suited to this purpose, leaving the user room for selectively picking matches from the environment which satisfy the indexing functions of the game and riding on coincidental matches for experiential effect. Whereas the intentional designing for coincidence has been addressed before, the strategies for this have focused on increasing the potential for serendipitous matches by selectively picking highly plausible contextual targets (Reid 2008). The work here shows a way of manipulating the representational aspects instead, which provides significantly more flexibility for designers.

Conclusions

The aim of the present work was to (Q1) identify how current commercial locative games use sound to create situated experiences, and to (Q2) compare how commercially explored ideas align with

prior research perspectives into locative sound aesthetics. The specific novel contribution of this work is a *detailed analysis of the sound strategies employed in seven commercial locative games* for current generation handheld devices. This work provides an *overview of how situated sound is used* presently within locative and mobility game/entertainment, and summarizes the design solutions that industry developers have considered most promising, feasible or interesting to pursue in this early stage of locative gaming. Moreover, the analysis also looks into how well the goals and strategies of sound design align with current research directions for locative sound, offering *a comparison between research and industry design.*

To investigate the involvement of contextual factors in experience design, formal game analysis is used to explore how designs actively invite the player to actively attend to elements within their current physical, technological, social, temporal and task context. The analyzed collection suggests a two-step strategy is particularly promising for promoting frequent and meaningful contextualizations: a) The game can proactively push the players into experientially desired contexts to influence play experience. Additionally, b) the game can invite contextual elements to become part of the experience by indexes, which draw in external information to game content. The work identifies four types[8] of *sound-based indices* that can be used to tie virtual content to the user's current content: 1) functionally responsive audio, 2) verbal references, 3) spatialized audio, and 4) remediation.

Regarding sound functionality, adopting a proactive stance towards contextual matching helps push the player towards desired situations. Making gameplay location-dependent is a natural way to steer action, however the cautious approach to using location data observed in the analyzed collection is telling: Only two games (out of 7 location-aware titles) necessitate movement, and only one game ties gameplay

8. Other possibilities are available as well, which are less applicable to the mobile domain. For example, film typically uses synchronicity to attach a sound to a concurrent visual event. Sound material can also semantically attach to objects, such as a female voice will connect to a female speaker, or a lullaby will be associated with a crib.

to fixed physical locations. On the other hand, several of the games facilitate playing while actually on the move, increasing the likeliness that players will experience the service in different contexts: Five of the games achieve this turning to audio-heavy content designs. The musical games ItA and Dimensions offer the player sonic rewards for seeking out new contexts and turn contextual matching into a kind of puzzle activity.

Of particular practical interest, however, is the finding that many games rely on techniques for situating experience that depends on no functional verification or context-sensing technology at all. Instead, following the idea of indexicality, open-ended references to context are frequently created to suggest contextual dependency even when none exists. Such incomplete references become anchored to contextual elements only in the user's mind, where contextual elements can be selectively attended to in order to satisfy the qualities indicated as targets. While such indexes will fail at times, inaccurate or incomplete references seem to behave in relatively unproblematic ways. The most critical failures arise with overt contradictions, when the information clashes with observable physical reality.

Comparison to current themes in contextualized audio research indicates similarities but also challenges some assumptions regarding locative audio experiences. While the observed material generally confirms the view of audio-based gameplay as a facilitator of mobility, the games contain only extremely clear and simple audio-based gameplay and no perceptually challenging tasks whatsoever. Sound is centrally involved in shaping contextualized experiences, forging links between the physical and digital world, but the techniques to achieve this are both novel and surprising. Whereas previous work on contextual audio has sought to create contextualized experiences primarily with functional contextualization, the present analysis suggests that it is equally interesting to look at how this connection can be constructed regardless of function, or by alternative ways of representing detected dependencies. Moreover, between functionally verified and completely arbitrary contextual indexes exists an area of probability

that depends both on the available context and the flexibility and adaptability of the applied indexes. This could be a sweet spot for contextual design as the use of open-ended contextual indices increases the chance of serendipitous matches.

Among the open questions from this study is to find out what types of contexts would be most desirable to catch by such open-ended indexing, and also how to most effectively use proactive contextual design in combination with open indexes, to lure/push/guide the player towards the contextual hooks embedded in the design. A particularly promising area of making memorable references could be the greater utilization of user-created or user-tagged content. While somxe games already involve player-generated content, this material is used sparsely as the end point of indexes. For sound design in particular, the increased use of preselected playlists as part of the game experience offers a potent source for tapping into audio material which is both generally considered emotionally significant, as well as highly personalized.

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Bibliography

Albrecht, Robert, Tapio Lokki, and Lauri Savioja. "A Mobile Augmented Reality Audio System with Binaural Microphones." In *Proc. Interacting with Sound Workshop: Exploring Context-Aware, Local and Social Audio Applications,* 2011: 7–11. http://doi.acm.org/10.1145/2019335.2019337.

Alves, Valter. "Sound Design Guidance as a Contribution Towards the Empowerment of Indie Game Developers". Ph.D. diss., University of Coimbra, 2012.

Behrendt, Frauke. “Mobile Sound: Media Art in Hybrid Spaces”. Ph.D. diss., University of Sussex, 2010. http://sro.sussex.ac.uk/6336/.

Behrendt, Frauke. “The Sound of Locative Media.” *Convergence: The Journal of Research into New Media Technologies* vol. 18, no. 3, 2012: 283–295.

Benford, Steve, Carsten Magerkurth, and Peter Ljungstrand. “Bridging the Physical and Digital in Pervasive Gaming.” *Communications of the ACM* vol. 48, no. 3, 2005: 54–57.

Bichard, John, Liselott Brunnberg, Marco Combetto, Anton Gustafsson, and Oskar Juhlin. “Backseat Playgrounds: Pervasive Storytelling in Vast Location Based Games.” *Proc. International Conference on Entertainment Computing*, 2006: 117–122.

Björk, S., Falk, J., Hansson, R., and Ljungstrand, P. “Pirates!–using the physical world as a game board.” *Proceedings of Interact*, 2001: 423–430.

Björk, Staffan, and Jussi Holopainen. *Patterns In Game Design*. Cengage Learning, 2005.

Bolter, Jay David, and Richard Grusin. *Remediation: Understanding New Media*. 1st ed. The MIT Press, 2000.

Brewster, Stephen. “Overcoming the Lack of Screen Space on Mobile Computers.” *Personal and Ubiquitous Computing* vol. 6, no. 3, 2002: 188–205.

Brock, Derek, James A. Ballas, and Brian McClimens. “Perceptual Issues for the Use of 3D Auditory Displays in Operational Environments.” *Proc. International Symposium on Information and Communication Technologies*, 2003: 445–448.

Cohen, Yishay, Jolanda Dekker, Arnout Hulskamp, David Kousemaker, Tim Olden, Cees Taal, and Wouter Verspaget. “Demor – Een Location-based 3D Audiogame”. Hogeschool voor de Kunsten

Utrecht, 2004. http://student-kmt.hku.nl/~g7/site/research/Demor_resesarch.pdf.

Collins, Karen. *Playing with Sound: A Theory of Interacting with Sound and Music in Video Games.* The MIT Press, 2013.

Ekman, I. "Sound-based Gaming for Sighted Audiences–Experiences from a Mobile Multiplayer Location Aware Game." *Proc. AudioMostly*. Ilmenau, Germany, 2007: 148–153.

Ekman, I., L. Ermi, J. Lahti, J. Nummela, P. Lankoski, and F. Mäyrä. "Designing Sound for a Pervasive Mobile Game." *Proc. ACM Advances in Computer Entertainment Technology*, 2005: 110–116.

Ekman, Inger. "On the Desire to Not Kill Your Players: Rethinking Sound in Pervasive and Mixed Reality Games." *Proc. Foundations of Digital Games*, Chania, Greece, 2013. http://www.fdg2013.org/program/papers/paper19_ekman.pdf.

Fagerlönn, Johan. "BodyResT: a prototype using music responding to heart rate for stress reduction". MSc Programmes in Engineering, Luleå University, Sweden, 2005. http://epubl.ltu.se/1402-1617/2005/283/index-en.html.

Friberg, J., and D. Gärdenfors. "Audio Games: New Perspectives on Game Audio." *Proc. Advances in Computer Entertainment Technology*, 2004: 148–154.

Gaye, L., and L. E. Holmquist. "In Duet with Everyday Urban Settings: a User Study of Sonic City." *Proc. NIME*, 2004: 161–164.

Goudeseune, Camille, and Hank Kaczmarski. "Composing Outdoor Augmented-reality Sound Environments." *Proc. ICMC,* 2001: 83–86.

Grey Area. *Shadow Cities* [iOS]. Apple, 2011.

Gustafsson, Anton, John Bichard, Liselott Brunnberg, Oskar Juhlin, and Marco Combetto. "Believable Environments: Generating

Interactive Storytelling in Vast Location-based Pervasive Games." *Proc. Advances in Computer Entertainment Technology,* 2006.

Herbst, Iris, Anne-Kathrin Braun, Rod McCall, and Wolfgang Broll. "TimeWarp: Interactive Time Travel with a Mobile Mixed Reality Game." *Proc. MobileHCI,* 2008.

Holland, Simon, David R. Morse, and Henrik Gedenryd. "AudioGPS: Spatial Audio Navigation with a Minimal Attention Interface." *Personal and Ubiquitous Computing* vol. 6, no. 4, 2002: 253–259.

Jumisko-Pyykkö, Satu, and Teija Vainio. 2010. "Framing the Context of Use for Mobile HCI." *International Journal of Mobile Human Computer Interaction* vol. 2, no.4, 2010: 1–28.

Kahneman, Daniel. *Thinking, Fast and Slow*. Penguin, 2012.

Kjeldskov, Jesper, and Jeni Paay. 2010. "Indexicality." *ACM Transactions on Computer-Human Interaction* vol. 17, no. 4, 2010: 1–28.

Knowlton, Jeff. "Eversion and Locative Media". Presentation at the 2nd Inclusiva-net Meeting: Digital Networks and Physical Space, MediaLab Prado, Madrid, Spain, 2008. http://medialab-prado.es/article/eversion_and_locative_media.

Kurczak, Jason, T. C. Nicholas Graham, Claire Joly, and Regan L. Mandryk. "Hearing Is Believing: Evaluating Ambient Audio for Location-based Games." In *Proc. Advances in Computer Entertainment Technology,* 2011.

Liljedahl, Mats. "Sound for Fantasy and Freedom." In *Game Sound Technology and Player Interaction: Concepts and Developments.*, edited by M. Grimshaw. Hershey, New York: IGI Global, 2011: 22–43.

Mariette, Nicholas. "Perceptual Evaluation of Personal, Location-

Aware Spatial Audio". Ph.D. diss. University of New South Wales, 2011.

McGonigal, Jane. *Reality Is Broken: Why Games Make Us Better and How They Can Change the World.* Random House, 2011.

McGookin, D., S. Brewster, and P. Priego. "Audio Bubbles: Employing Non-speech Audio to Support Tourist Wayfinding." In *Proc. HAID,* 2009: 41–50.

Milliform Ltd. *Gbanga Famiglia* [iOS]. Apple, 2012.

Montola, Markus. "On the Edge of the Magic Circle: Understanding Pervasive Games and Role-Playing". Ph.D. diss. University of Tampere, 2012.

Moustakas, Nikolaos; Floros, Andreas; Kanellopoulos, Nikolaos, Andreas Floros, and Nikolaos Kanellopoulos. "Eidola: An Interactive Augmented Reality Audio-Game Prototype." In *Proc. Audio Engineering Society Convention 127*, 2009.

NianticLabs. *Ingress* [Android]. Google, 2012.

Paterson, N., K. Naliuka, T. Carrigy, M. Haahr, and F. Conway. "Location-aware Interactive Game Audio." In *Proc. AES Conference Audio for Games,* 2011.

Paterson, Natasa, Katsiaryna Naliuka, Soren Kristian Jensen, Tara Carrigy, Mads Haahr, and Fionnuala Conway. "Design, Implementation and Evaluation of Audio for a Location Aware Augmented Reality Game." In *Proc. Fun and Games*, 2010: 149–156.

Peltola, Mikko, Tapio Lokki, and Lauri Savioja. "Augmented Reality Audio for Location-Based Games." In *Proc. AES Conference Audio for Games,* 2009.

Reid, Josephine. "Design for Coincidence: Incorporating Real World

Artifacts in Location Based Games." In *Proc. Digital Interactive Media in Entertainment and Arts*, 2008: 18–25.

Reid, Josephine, Erik Geelhoed, Richard Hull, Kirsten Cater, and Ben Clayton. "Parallel Worlds: Immersion in Location-based Experiences." In *CHI Extended Abstracts*, 2005: 1733–1736.

RjDj. *Inception the App* [iOS]. Apple, 2010.

RjDj. *Dimensions* [iOS]. Apple, 2011.

RjDj. *The Dark Knight Rises Z+* [iOS]. Apple, 2012.

RocketChicken Interactive. *CodeRunner* [iOS]. Apple, 2012.

Rovithis, Emmanouel. "A Classification of Audio-based Games in Terms of Sonic Gameplay and the Introduction of the Audio-role-playing-game: Kronos." In *Proc. Audio Mostly*, 2012: 160–164.

Rowland, Duncan, Martin Flintham, Leif Oppermann, Joe Marshall, Alan Chamberlain, Boriana Koleva, Steve Benford, and Citlali Perez. 2009. "Ubikequitous Computing: Designing Interactive Experiences for Cyclists." In *Proc. MobileHCI,* 2009.

Rozier, J., K. Karahalios, and J. Donath. "Hear&There: An Augmented Reality System of Linked Audio." In *Proc. ICAD,* 2000.

Sawhney, Nitin, and Chris Schmandt. "Nomadic Radio: Scaleable and Contextual Notification for Wearable Audio Messaging." In *Proc. CHI*, 1999: 96–103.

Sears, A, M Lin, J Jacko, and Y Xiao. "When Computers Fade Pervasive Computing and Situationally-induced Impairments and Disabilities." *HCI International* Vol. 2, 2003: 1298–1302.

Six to start and N. Alderman. *Zombies, Run!* [iOS]. Apple, 2011.

Stahl, Christoph. "The Roaring Navigator: a Group Guide for the

Zoo with Shared Auditory Landmark Display." In *Proc. MobileHCI*, 2007: 383–386.

Upright Media Concepts, *MobileWar.* [Android]. Google, 2012.

Valente, Luis, Clarisse Sieckenius de Souza, and Bruno Feijó. "An Exploratory Study on Non-visual Mobile Phone Interfaces for Games." In *Proc. VIII Brazilian Symposium on Human Factors in Computing Systems*, 2008: 31–39.

Vazquez-Alvarez, Y., I. Oakley, and SA Brewster. "Urban Sound Gardens: Supporting Overlapping Audio Landmarks in Exploratory Environments." In *Proc. Multimodal Location Based Techniques for Extreme Navigation workshop, Pervasive,* 2010.

Waern, Annika, Markus Montola, and Jaakko Stenros. "The Three-sixty Illusion: Designing for Immersion in Pervasive Games." In *Proc. CHI*, 2009: 1549–1558.

Will, Christoph. "A Pattern Language for Designing Location-based Games". Ph.D. diss. RWTH Aachen University, 2013.

Woo, D., N. Mariette, N. Helyer, and C. Rizos. "Syren-A Ship Based Location-Aware Audio Experience." *Journal of Global Positioning Systems* vol. 4, nr. 1-2, 2005: 41–47.

Zandbergen, Paul A. "Accuracy of iPhone Locations: A Comparison of Assisted GPS, WiFi and Cellular Positioning." *Transactions in GIS,* vol. 13, 2009: 5–25.

Zandbergen, Paul A., and Sean J. Barbeau. "Positional Accuracy of Assisted Gps Data from High-sensitivity Gps-enabled Mobile Phones." *Journal of Navigation* vol. 64, nr. 3, 2011: 381–399.