Research Article

CONVERGENCE

Augmented play: An analysis of augmented reality features in location-based games

Convergence: The International Journal of Research into New Media Technologies
2023, Vol. 0(0) 1–20

DOI: 10.1177/13548565231156495
journals.sagepub.com/home/con


Kati Alha, Dale Leorke and Elina Koskinen
Independent Researcher, Finland

Janne Paavilainen
Jagame

Abstract

As well as popularising location-based games, *Pokémon GO* helped connect location-based play with augmented reality (AR), bringing this still-nascent technology into the mainstream. Despite growing use of AR, its long-promised revolutionary potential remains stifled by limited innovation, technical barriers and lack of uptake by users. To explore how AR figures into location-based games, we analysed 11 location-based games with AR features. We identify four overarching ways these games incorporate the physical environment into gameplay: through *superimposition*, *blending*, *immersivity* and *materiality*. Our findings show that AR is most commonly a gimmick rather than a central element of the game experience and remains substantially hindered by technical glitches and limitations. While more advanced and deeply integrated AR mechanics are emerging, its use in location-based games remain far from the 'technological imaginaries' that have accompanied its development as AR continually oscillates between its status as a 'mundane' and 'always-imminent' technology.

Keywords

Augmented reality, location-based games, mobile games

Introduction

Pokémon GO (Niantic, 2016) was one of the first mainstream mobile games to successfully integrate augmented reality (AR). Players use their smartphone's camera to take photos of virtual Pokémon in physical locations, for example playing in their backyard, standing on their kitchen table, or posing next to themselves or others. This feature, used in the game's promotional material, was a successful

Corresponding author:
Kati Alha, Tampere University, Kanslerinrinne 1, Tampere FI-33014, Finland.
Email: kati.alha@tuni.fi

viral marketing tactic. It sparked curiosity about AR as a technology which, at that point, had yet to achieve mainstream recognition. It also helped to 'spread the word' about a game that already had an existing fanbase. But it quickly became apparent that catching Pokémon was more efficient with the AR feature turned off, since throwing virtual PokéBalls requires a precision and finesse that AR only made more difficult. Previous player surveys indicate that most *Pokémon GO* players rarely or never use AR (Laato et al., 2021a; Paavilainen et al., 2017; Rapp et al., 2018). While the AR technology did interest players, the challenge of integrating it into the gameplay in a meaningful way meant this appeal quickly wore off (Alha et al., 2019; Paavilainen et al., 2018).

Since *Pokémon GO*, the technology behind AR has advanced with tech giants introducing new AR platforms – such as Apple's ARKit and Google's ARCore – into their smartphone operating systems. These platforms aim to enable more immersive and responsive AR interaction (see Gibbs, 2017). Platforms like Adobe Aero and Spark AR also allow AR to be incorporated into apps more easily and affordably than ever before, opening AR up to experimentation outside the corporate sector. Meanwhile, *Pokémon GO*'s success has spawned a slew of location-based games that blend location-based gaming with AR, such as *The Walking Dead: Our World* (Next Games, 2018), *Jurassic World Alive* (Ludia, 2018) and *The Witcher: Monster Slayer* (Spokko, 2021) – often coinciding with the release of new texts in these franchises. Niantic itself has heavily invested in AR by substantially expanding the technology's use in *Pokémon GO* and its subsequent games and platforms. In the process, 'location-based' and 'augmented reality' games have become increasingly synonymous and intertwined.

Despite this growing convergence of AR and location-based gaming, there has been little scholarly research discussing how different features and concepts of AR are used in these games and how they impact on the players' experience. Meanwhile, as location-based games and other commercial apps drive investment in AR and fuel visions and imaginaries around its potential, there is a growing need to contextualise these developments within the broader history and evolution of AR as it becomes increasingly ubiquitous. This article addresses these gaps by examining the history of AR and its specific incorporation into location-based gaming, before analysing 42 location-based games to determine how many include AR features and what form they take.

Through analytical play methods, we found that 26% of our sample – 11 games – included any AR elements. We outline four categories that these games' use of AR falls into: 1) *superimposing virtual content*, 2) *blending physical and virtual space*, 3) *immersing players in a 3D world* and 4) *utilising physical objects*. Our analysis reveals a conservative and often shallow and technically flawed use of AR that falls short of either the utopian or dystopian visions that have long circulated around AR, and which continue to inform its ongoing development. We argue that even as *Pokémon GO* has fuelled technological fascination around AR and rendered it mainstream, it has also closed off commercial experimentation and innovation around AR as subsequent location-based games seek to mimic its success. As a result, AR has become a simultaneously 'mundane' and 'always-imminent' technology. It is both an everyday, familiar technology and one that continues to attract marketing hype and predictions about its potential to reshape society as it is seamlessly woven into our everyday lives (see Pesce, 2020). While our sample indicates that this imminent potential remains firmly in a perpetual near-future, it also points to a variety of approaches to AR mechanics and signals the potential for further innovation in merging augmented and location-based play.

Location-based gaming and the augmented reality imaginary

AR dates back at least to the mid-20th century, through experimentation with cinema, architecture, military aircraft and head-mounted displays that aimed to create more 'immediate' and 'immersive'

experiences (see Carmigniani et al., 2011: 342–3; Vaughan-Nichols, 2009). It was not until the 1990s, however, that AR became popularised and more concretely defined (Azuma, 1997). It is often defined as the enhancement or augmentation of a physical environment or space, in real-time, through virtual, computer-generated information. This definition usually makes a clear distinction from virtual reality (VR), which immerses the user in a completely virtual environment. AR, in contrast, supplements, enhances, blends or even obscures an actual physical location with virtual content or data (Carmigniani et al., 2011: 342).

This definition is seemingly established, and the technology has become mainstream, perhaps even mundane, since its incorporation into smartphones – as evidence by its inclusion in various photo filters embedded in social media platforms (see Javornik et al., 2022). But this definition also overlaps and intersects with numerous other technologies and practices that have emerged since the 1990s that similarly blend the physical and virtual realms. These include mixed-reality games and experiences, ubiquitous computing, wearable computers, internet of things (IoT) devices, ambient intelligence and responsive architecture, among many others. As Lev Manovich (2006: 225) argues, AR is simply one strand of a broader shift towards 'augmented space', as the spaces people live in and move through – from the home to the public spaces of the street, museum or shopping centre – are increasingly overlaid with digital interfaces and content. This approach positions AR away from the *technology* that makes it possible, such as devices, interfaces and computer-generated information, reframing it as *cultural practice*. It widens the scope of what AR is, but at the same time makes distinctions between it, mixed-reality, ubiquitous computing, IoT and other practices even looser.

Since its popularisation as a concept in the 1990s, AR has gradually been incorporation into both commercial technologies and artistic/experimental practices (see Liao and Iliadis, 2021; Geroimenko, 2019). These developments have subsequently given rise to both utopian promises and dystopian anxieties about its social impact. As Liao and Iliadis (2021) note in their analysis of the discourse around AR, corporations, start-ups and futurists frequently linked AR to science fiction imagery, like the figure of the cyborg or superhero, with humans becoming empowered and enhanced as their surroundings are enhanced by virtual information (268–9). Google Glass's announcement in 2012 fuelled expectations that these possibilities would become reality. But they also gave rise to anxieties about privacy and data tracking – as reflected in parodies of its concept video and various dystopian-themed short films that followed its release – that ultimately lead to Glass's failure.[1]

AR continues to be shaped by such imaginaries, but these visions and anxieties remain largely unrealised. Both the development of AR and its uptake by consumers have been hindered by numerous technological and social barriers. The most notable of these remains what Azuma (1997: 18–9) calls the 'registration problem': achieving realism when blending virtual content with the physical environment, without clipping, distortion and other effects that break immersion. Other barriers include usability, battery life and privacy concerns around facial recognition, surveillance and data tracking. Nonetheless, dreams of an AR-driven society have not been abandoned, with Apple, Google and other companies continually improving and investing in the technology over both the long- and short-term (see Kastrenakes, 2021; Stein, 2021). Even as it becomes more familiar and mundane, then, AR perpetually inhabits what Liao and Iliadis deem 'a future so close' – an always imminent and emergent state that never quite seems to fully materialise.

Although the AR revolution has yet to arrive, location-based games have increasingly incorporated AR into the gameplay experience, making the technology tangible and accessible for a wider audience. *Pokémon GO*'s success contributed to location-based games' uptake of AR, but videogames have been experimenting with AR since the late 1990s.[2] Following the advent of

smartphones, location-based game apps began to incorporate AR elements, such as *Argh* (*Augmented Reality Ghost Hunter*) (see Gazzard, 2011) and Niantic's *Ingress* (2012). Although the latter does not use the phone's camera to augment the player's surroundings like *Argh*, *Ingress* is often nonetheless described as an 'augmented reality game' (see e.g. Metz, 2012; Winegarner, 2016) despite being better categorised as a location-based game or even an 'alternate reality' game (ARG). This reinforces the elusiveness of definitions of AR and its conflation with other technologies and practices like 'mixed-reality', 'locative media' and 'ubiquitous computing' – all of which imply the blending of physical and virtual space. Similarly, the term location-based gaming is also difficult to define and overlaps with many other terms, such as mixed-reality games, pervasive games and locative games (Leorke, 2018: 36–7).

Like the discourse around AR more broadly, the incorporation of AR in location-based gaming has been met with both optimistic and sceptical visions of its social impact. Niantic CEO John Hanke (2017) invokes earlier promises made about AR rooted in utopian science fiction fantasies when he speculates about AR's potential to bring about 'buildings, offices, homes, cities and transportation with live, dynamic interfaces customised to you and what you want to do' (n.p). Niantic has led the way with implementing these visions of AR in gaming through its 'occlusion' technology, 'buddy adventure' feature and 'AR mapping' research tasks in *Pokémon GO*.[3] Niantic has also developed a platform called *Lightship* for embedded AR in everyday environments described as a 'planet-scale augmented reality platform' and 'operating system for the world' (Niantic, 2021a: n.p.). While these developments have been met with enthusiasm by players, they have also fuelled familiar fears about pervasive surveillance, threats to privacy and disconnection from the real world (see e.g. Barbé, 2017; Carter and Egliston, 2020).

While various theorists have sought to examine the use of AR in gaming, they remain largely design-focused. Wetzel et al. (2008) have proposed design guidelines for mixed-reality games, offering an early perspective on what AR games should be, while Kalalahti (2015) has proposed heuristics for the usability of AR, which can be used as a lens to study how contemporary AR games support them. Meanwhile, in their work Laato et al. (2019, 2021b) examine the use of AR specifically in location-based games, including players' motivations for using it, finding that around 25% of all location-based games now include AR elements. Yet there is a growing need for further research into AR and location-based gaming that specifically unpacks *how* AR is used in these games and what impact it has on players' experiences. In turn, this approach can shed light on the extent to which AR's practical implementation fulfils the long-held visions around it, as it shifts from a 'speculative' or 'emergent' technology towards a more familiar and mundane one.

Methods and data

To address this gap in the literature, we created a list of current commercial location-based game apps and analysed their AR features. To create this list we searched the Google Play Store and Apple App Store with three different search terms: 'location-based game', 'GPS game' and 'geolocation game'. From the search results, we included the apps in our analysis that contained both location-based elements and were considered to be games based on their descriptions.

The search from Google Play resulted in 65 location-based games and from App Store in 46 location-based games. When duplicates were removed, 98 total games remained. From this full list of location-based games, we chose games that either had over one million downloads, an average rating of a minimum of 4 stars, or more than $5000 in revenue in February 2021 according to Sensor Tower.[4] With these criteria, we sought to predominantly capture successful games, since these games would be more likely to include higher quality or more widely used AR features. Four

games were excluded from analysis: two for not being available in the local stores of the authors, one due to being unplayable without a larger group of people, and one due to the location-based elements having been removed from the current version. This left 42 games.

Each of these games were played to check whether the game included any AR elements. We defined AR as *the use of the device's camera to alter or augment the physical environment in some way.* This definition excluded games without this feature and arguably overlooks broader conceptualisations of AR mentioned earlier, which consider AR under the broader rubric of 'augmented space' or 'augmented reality'. This approach focused our analysis more on the *technical* use of AR in location-based games than the *conceptual use*, although we revisit this broader conceptual approach to AR in our Discussion.

11 of the 42 games analysed featured AR elements (see Table 1). In addition, one game, *The Walking Dead: Our World* used to include AR, but the feature had since been quietly removed. The games with AR elements were more closely inspected to analyse these elements and their integration in the game. The analysis was done utilising the formal analysis of gameplay (Lankoski and Björk, 2015), examining game elements and their interactions with chosen focus points. All authors participated in the analysis process, and each game was analysed by two of the authors. As the chosen games and their AR features varied greatly, no strict time limit was agreed for the analysis; however, the analysis of each game was conducted in multiple sessions to find the different ways AR was included and implemented. Each individual use of AR was documented by describing how it functioned and how the feature was integrated in the gameplay. In addition, the analyser focused on the technical aspects of the implementation. One exception to this approach was *Men in Black: Global Invasion* (Ludare Group Inc, 2019), which could only briefly be analysed by one author before it was suddenly and without notice shut down. Despite this interruption we include it in our discussion, supplementing our notes with gameplay videos from YouTube.

Table 1. Analysed games including AR features.

Game	Developer	Published	Genre
Draconius GO: Catch a Dragon! (shortened to Draconius GO)	Elyland LLC	2017	Creature collection
Five Nights at Freddy's AR: Special Delivery (shortened to Five Nights)	Illumix Inc.	2019	Horror
GPS Monster Scouter	Tankenka	2016	Creature collection
Harry Potter: Wizards Unite (shortened to Wizards Unite)	Niantic, Inc.	2019	Role-playing game
Jurassic World Alive	Ludia	2018	Creature collection
Landlord GO	Reality Games LTD	2020	Property trading
Men in Black: Global Invasion (shortened to Men in Black)	Ludare Group Inc.	2019	Creature collection
Minecraft Earth	Mojang Studios	2019	Crafting
Monster Ball GO	Playfox Games World	2016	Creature collection
Munzee	Freeze Tag Games	2011	Treasure hunt
Pokémon GO	Niantic, Inc.	2016	Creature collection

Results

Augmented reality mechanics

The games with AR elements ($N = 11$) included various ways of implementing them, summarised in Table 2. In its simplest form, AR was used to show an alternative view of the game content. This was the case with *Landlord GO* (Reality Games Ltd, 2020), which offered a special AR map, changing how the surrounding points of interest were shown. Instead of a top-down map view, the player could move their phone to see at which direction the different locations were in the physical world. This did not add any new content or gameplay but merely provided an alternative map view.

Several games included a mechanic where the player can catch the in-game creatures in AR mode (*Pokémon GO, Draconius GO* (Elyland LLC, 2017)*, Monster Ball GO* (Playfox Games World, 2016)*, Men in Black*). In this mechanic, the creature appears against a real-world background when trying to catch it. In most games, the creature moves around to various degrees to evade the player as

Table 2. AR mechanics found in the analysed games.

Type	Description	Games
Alternative view	The game offers an alternative AR view of the same content as in the regular view	Landlord GO
Catching	The game shows a creature on the game screen against the player's camera view, and the player must aim and catch/shoot it	Pokémon GO, Draconius GO, Monster Ball GO, Men in Black
Placing	Placing game content in the players surroundings, often on a suitable, flat surface; this can be the first step before for instance the photoshoot or interaction mechanics	Pokémon GO, Jurassic World Alive, Five Nights, Wizards Unite, Minecraft Earth
Photoshoot	The game offers tools to take photos mixing game content and camera view	Pokémon GO, Jurassic World Alive, GPS Monster Scouter, Five Nights
Interacting	Player may interact with game creatures in their surroundings, shown through the camera view, such as feeding them or playing with them	Pokémon GO, Jurassic World Alive
Aligning patterns	Player aligns patterns in their surroundings, shown in the camera view and the game screen	Wizards Unite
Travelling through portals	The game shows a portal in the player's surroundings through the camera view, and the player walks through it	Wizards Unite
Searching	The player searches game content from their surroundings by moving the device and looking though the camera view	Wizards Unite, Five Nights
Reacting	Player tries to quickly react to something happening in a specific direction in their surroundings, shown by the camera view and sound cues	Five Nights
Scanning objects	Player scans physical objects in their surroundings through the in-game camera view	Munzee
Crafting	Player modifies the game worlds shown in their surroundings through the camera view, by breaking and building with in-game blocks	Minecraft Earth

they attempt to 'net' it or deplete its health. The use of AR in these games is mostly optional, but in *Pokémon GO*, for example, catching special Pokémon in specific situations requires the use of AR.

In many of these games, the player can take photos of the creatures against the real-world background (*Pokémon GO*, *Jurassic World Alive, GPS Monster Scouter* (Tankenka, 2016)*, Five Nights* (Illumix Inc, 2019)). In this mode the game offers in-game photo taking opportunities, and might also give other tools, such as resizing or turning the content and adding frames or filters. In *Jurassic World Alive*, the player can also record video of their captured dinosaurs interacting with the environment. In *GPS Monster Scouter*, the player can take pictures simultaneously of several of the game creatures, which are randomly placed on the screen. In *Harry Potter: Wizards Unite* (Niantic, 2019), the player can also take a picture of themselves for the 'Ministry ID' with different digital effects, like humorous accessories and makeup. Players can share these photos, which can function as viral marketing for the game. While this feature is often freely available, the player can sometimes buy new frames or filters for it, and in the case of *Five Nights*, accessing the feature requires in-game currency. This suggests that the photoshoot AR features can also be a way to monetise the game.

Some games allow the player to interact with their creatures (*Pokémon GO*, *Jurassic World Alive*) against a real-world background. In *Jurassic World Alive*, the player can feed and play with all the dinosaurs they have in their collection, while in *Pokémon GO*, the player can only feed and play with the Pokémon they currently have as their 'buddy'. The buddy Pokémon also appears on the game map alongside the player's avatar after being fed. Interacting with the buddy increases its 'friendship' level and unlocks new abilities, such as bringing gifts for the player. In both of these games, interaction with the creature requires the use of AR, although in *Pokémon GO* players can use the 'quick treat' feature to quickly feed their Pokémon against a blurred camera background. In a shared AR feature, up to three players in the same location can have their buddy Pokémon appear in a shared area and play, feed and take pictures of them all together.

In *Wizards Unite*, the player can use AR in 'trace encounters'. Traces appear on map and can be encountered with the AR mode on, starting the encounter against a real-world background. In the AR mode, the player locks a magical encounter or an enemy by aligning a pattern on the player's UI with the object and tapping the screen, which will then lock the object to be interacted with (see Figure 1). In the encounter, the actual fighting continues in a regular mode without AR. With the AR turned off, the encounter simply skips the beginning.

AR is also used when unlocking 'portkeys' in *Wizards Unite*. In this mode, the player finds a suitable spot from their environment by moving the device, and once found, they tap the screen to set the portkey on the ground. A portal appears, and the player must move and walk through it. A new environment appears after this, and while it can be viewed by moving the camera, the actual surroundings of the player are no longer shown in the background. The player then moves their phone around them to locate collectibles (see Figure 2).

Five Nights included two similar AR mechanics where players have to defend themselves. In one, the player receives a visit from a monster, who stalks them before attacking, while in another, the player collects light orbs. When attacked, the player must constantly turn around to search where the monster is hiding, which is hinted at by a static distortion effect of the camera view. When found, the player has to wait for the monster to sprint towards them and shock it at the right moment. In the other mechanic, players must search and collect light orbs, luring them with a torchlight. After some time, a shadow monster appears, indicated by a sound. The player again must quickly find it by turning around and dissolving it with light before it attacks.

Munzee (Freeze Tag Games, 2011) utilises physical content placed in the environment by other players. There are both virtual and physical 'Munzees', spots that can be deployed on the real-world

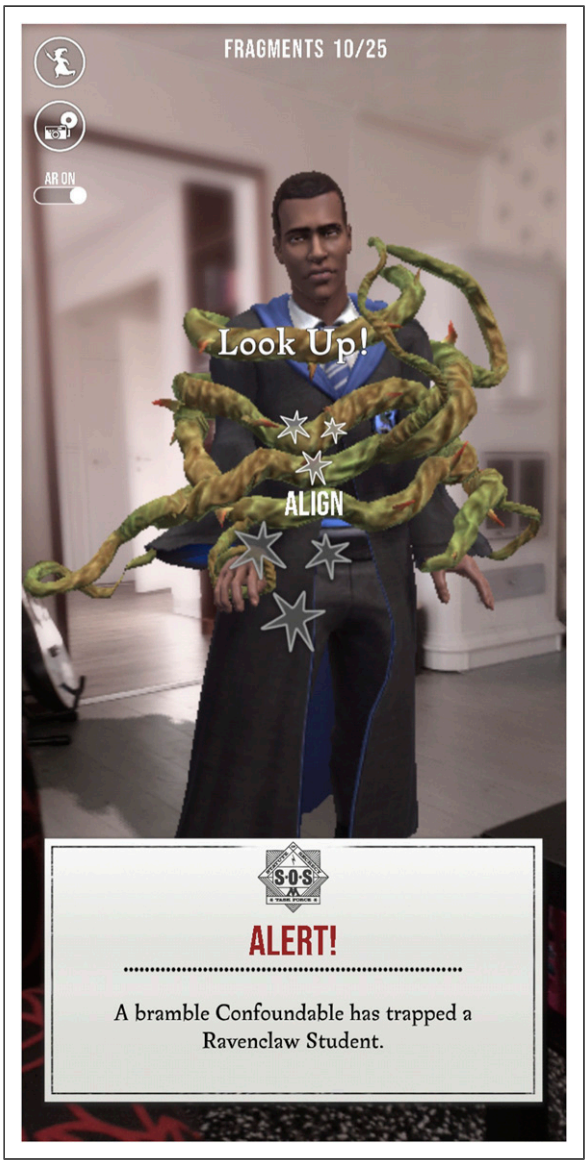

Figure 1. Aligning the pattern in Wizards Unite.

map for other players to find. While the virtual Munzees can be collected simply by tapping the screen when near enough, the physical Munzees – small QR code stickers – need to be found and scanned. The AR element is simple, as the player can see the physical sticker through the in-game user interface and scan it, which is then collected (see Figure 3).

Some games allow more complex interaction with the in-game elements through the AR view. This was most advanced in *Minecraft Earth* (Mojang Studios, 2019), where the main mechanics focused on crafting: building, modifying and adventuring in small Minecraft worlds. These

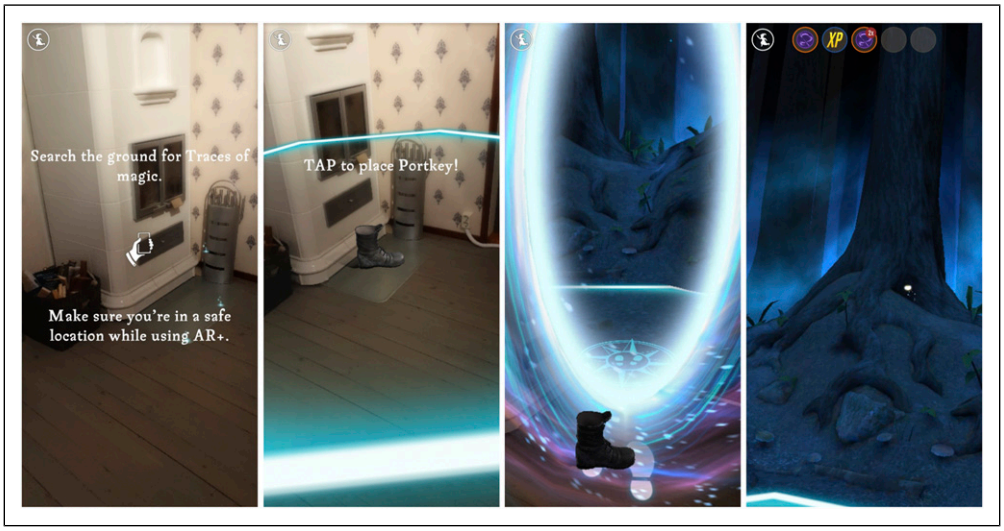

Figure 2. The steps in completing the portkeys in Wizards Unite: finding a suitable location, placing the portkey, stepping through the portal, and finding the collectibles inside the portal world.

mechanics were divided into two different playstyles: buildplates that focused on building and modifying the world, and adventures that have a limited time to find a treasure within them. These worlds were placed on a chosen spot in the player's environment, after which the player could point their phones towards it and see it from different angles by circling the world. The player could interact in similar ways as in the Minecraft game: use a pickaxe to break and collect blocks, a sword to kill enemies, an axe to hack down trees and build with the collected blocks and items.

Effect on gameplay

The inclusion of AR features did not typically affect the gameplay significantly. AR functioned as a technical gimmick or a marketing tool, since game content superimposed on the player's surroundings could easily be shown, captured and shared for instance on social media. The photo taking and sharing aspect has been further utilised in the different photo shooting mechanics where the player can better place the creatures into the surroundings or add filters or accessories to the photos, which utilizes the AR functionalities more even if it would not be a part of the core gameplay.

As the games have evolved, some games have moved from merely showing the player's surroundings as the background to incorporating more interactive content. For instance, in *Pokémon GO*, capturing the creature in AR mode starts with a minigame where the Pokémon has to first be located and tapped to start the actual capture. The buddy feature, where players can interact with their collected Pokémon, also involves a minigame to scan and situate the Pokémon in the physical environment. These make the AR element more integral to the gameplay, but they can also become laborious, as previous research shows (Laato et al., 2021a; Paavilainen et al., 2017; Rapp et al., 2018).

In most games AR either features as a minigame outside the core gameplay or otherwise plays a small role. In *Five Nights*, though, AR is included in the core mechanics of the game, and the horror

Figure 3. Scanning a QR code sticker in Tampere through Munzee.

theme of the game is emphasised and partly utilised through the AR features. The screen darkens the player's surroundings and uses different audio and visual cues to tell when the enemies are near or approaching (see Figure 4), including jump scares especially when the player fails. The game utilises the full surroundings of the player and may convey a feeling of urgency to locate the content within it, seeking to be more immersive. Importantly, this immersion is achieved not just visually but also through sound effects, as the monsters arrive at the player's 'door' and laugh maniacally.

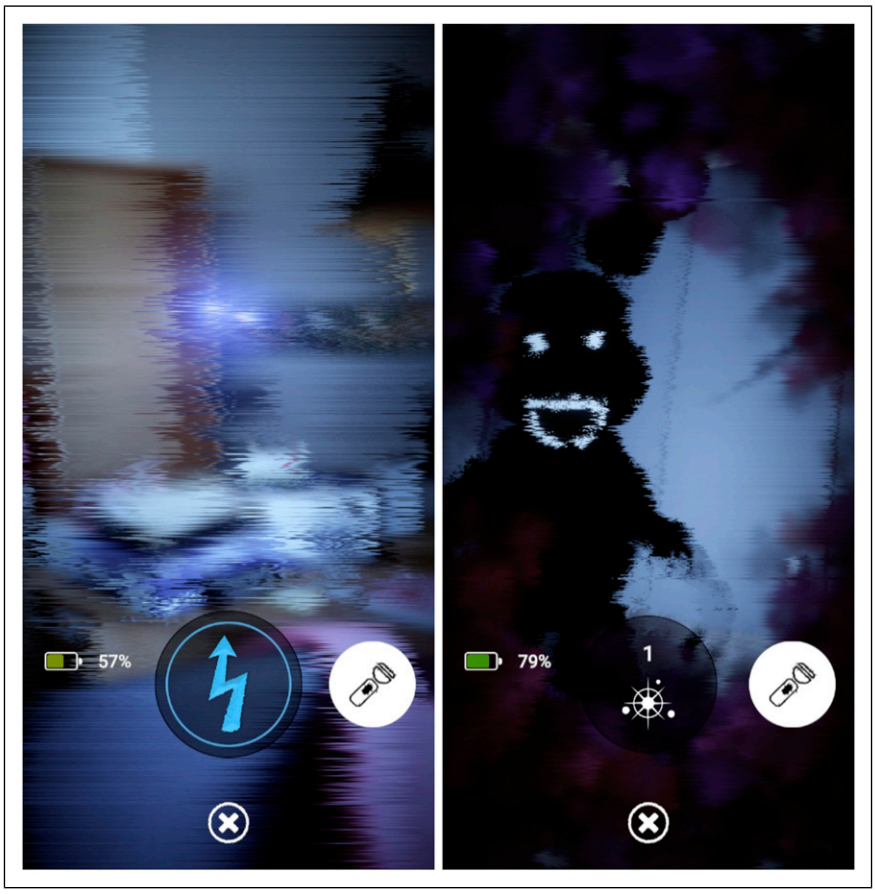

Figure 4. Approaching monsters in Five Nights.

The analysed games varied in whether the AR features could be turned off or were otherwise a voluntary part of the game. AR features still often make the gameplay more challenging and not all mobile phones have the technology to run them properly or at all, while in some games, the AR features can feel like extra labour for the player. As a solution, many games include a simple on-off switch to toggle between AR and normal mode. This option was used in situations where the player tries to catch something from the screen, either having the real world or the game world as the background. As the player loses resources if the catch attempt fails, the more challenging AR mode might be the less optimal choice from the gameplay point of view. *Wizards Unite* solves this by separating the AR part from the capturing part. However, because switching off the AR mode simply skips the beginning and the game does not reward using AR, it makes capturing slower and not beneficial purely from the point of view of progression, and thus might be less motivating for some players.

The mandatory AR features were found in varying mechanics in the games, ranging from non-essential parts of the game to core mechanics. For instance, the photoshoot mode in *GPS Monster Scouter* does not give an option to turn off AR but was in a minor role and not needed to progress in the game. When the AR features were both mandatory and essential for the game, their

implementation became more critical. In *Munzee*, the game could be played without AR if one concentrates solely on collecting virtual Munzees, but physical codes can be considered as a core mechanic of the game and require AR. In *Minecraft Earth* and *Five Nights*, the gameplay revolved around mechanics that included AR, and the games could not be played in full without them. As noted, these two games also had the most complex AR mechanics.

Technical aspects

The technical implementation of AR features is still lacking, which was visible in various crashes and bugs that occurred during the testing. Sometimes the crashes lead to losses; for instance, the adventure mode in *Minecraft Earth* sometimes crashed when the timer ran out, leading to the loss of all resources collected during it.

Some of the issues were tied to a suboptimal connection between the game content and the camera view. Most frequently, the content shown on the player's screen jittered when the player moved their phone, making it feel less integrated in the surroundings. In some cases, the game content was static, and moved as the player moved their phone. While this would make the content feel even more detached from the surroundings, it made it easier to for instance place the content in a suitable spot to make an artistic or a funny photo.

The slight movement of the virtual characters or objects on the screen made it more difficult to interact with them, especially when the player had to make more complicated gestures on the phone screen while trying to hold the phone steady. This was evident in the *Pokémon GO* type catching situations, while in *Minecraft Earth*, reaching the correct tiles inside a slightly moving 3D environment was sometimes challenging. The player might also have to be in uncomfortable physical positions to get into the inaccessible spots.

Most of the AR technology in these games did not take the environment into consideration, but merely showed content on top of the camera view. Most frequently the recognition could detect flat areas such as floors and ground by first asking the player to slowly move or wave their phone, and then showing suitable spots for the player to place the game content. There were a couple of exceptions to this. In *Five Nights*, the camera view was altered with different filters, adding static or distortion to different parts of the player's surroundings. In this solution, the game did not have to implement more complex technology to recognise elements from the player's surroundings but could still deliver a functioning effect. *Pokémon GO*'s AR+ feature uses occlusion technology and tries to recognise and use objects in the player's surroundings. However, the AR 'registration problem' remains and the creature might in some cases end up seeming to be inside walls and other objects (see Figure 5).

Categories for augmented reality implementation in location-based games

After identifying the different AR mechanics and analysing their use, we divided the different ways to implement AR as a part of a location-based game into four broad categories: content being superimposed on the physical environment; content blending with the physical environment; players being immersed within a 3D world; and content utilising material objects (see Table 3). While most of our games fit into only one of these categories, *Pokémon GO*'s option to switch between types of AR makes it overlap with two different categories, and *Wizards Unite* includes a few different AR mechanics which belong to different categories.

Superimposing content onto the physical environment is a simple way to add AR elements in a game and is often used in games *Pokémon GO* 'clones' when capturing or attacking game

Figure 5. Pokémon GO using occlusion in a successful and an unsuccessful way.

Table 3. Categories for AR implementation in location-based games.

Type	Description	Games
Superimposed on the environment	The game shows game content on top of the camera's view of the player's surroundings. Does not take the player's surroundings into account.	Draconius GO, GPS Monster Scouter, Landlord GO, Monster Ball GO, Pokémon GO, Wizards Unite
Blending with the environment	The game recognises suitable locations for the game content and might take the surrounding objects into account.	Jurassic World, Men in Black, Minecraft Earth, Pokémon GO, Wizards Unite
3D immersion	The game shows the game world around the player, transforming their surroundings and making them appear to be inside the game world.	Five Nights, Wizards Unite
Utilising material objects	The game includes physical objects that can be recognised with the in-game camera view and brought into the game.	Munzee

characters. In these cases, the player can see the game content on top of their real-world surroundings. However, the game does not recognise elements in the player's surroundings and the content merely floats on top of the camera view.

Blending content with the physical environment is a slightly more advanced use of AR and enables the game to be more responsive to the player's surroundings. In this category, the game typically recognises suitable areas for the content from the player's environment, such as flat surfaces. As the technology advances, the content can take the environment into account in more detail, for instance having a character disappear behind the furniture. The content might appear as a 3D object that the player can then approach or circle and see from different angles.

Instead of merely adding content in the player's surroundings, some games immerse players in a 3D world, transforming their entire surroundings into a part of the game and offering a 360-degree view to the fictional world. This might be done by transforming the camera view with different effects or filling the whole view with game content. In this technique, the player might imagine being inside the game world, possibly bringing a stronger sense of immersion.

In the last category, the game utilises material content from the physical environment, such as QR codes, and transforms them into game content. The content can be found from different locations, and the player needs to scan them with an in-game camera view. If the physical elements are specifically made for the game, the game needs to be locally organised or be popular enough to have enough active players to spread the content around.

Discussion

Across our analysis of location-based games with AR features, we would like to highlight two overarching findings. First, AR was rarely integral to the gameplay experience of these games, nor did it substantially impact the gameplay. Second, the AR features were often hindered by technical flaws and constraints: the more sophisticated the game's use of AR, the more obvious its technical limitations became. Both these findings have significant implications for the growing integration between location-based games and AR, as well as AR as a technology itself – and the discourses and imaginaries around it that we discussed at the start of this article.

As seen from the results, several of the games merely superimposed content over the camera view, rather than blending or integrating that content into the physical environment. Of the games that did take the environment into account – through blending, immersion and/or utilising material objects – these games typically only appropriated the environment as a flat 'canvas' on which to place virtual content. In this sense, most of the games we analysed used AR in a relatively minor way, perhaps to distinguish themselves from the competition and/or to build on *Pokémon GO*'s use of AR in its viral marketing, rather than actually pushing the boundaries of AR's capabilities. For all but three of the games we analysed (*Five Nights*, *Minecraft* and *Munzee*) the AR features could be considered optional or part of mini-games, and their removal would not substantially impact the gameplay experience. In fact, it would make the game more streamlined and less laborious. This strongly echoes similar findings by Alha, et al. (2019), Koskinen et al. (2019) and Laato, et al. (2021a: 7), whose respondents felt that AR hindered their ability to progress more rapidly and predominately only used it to take and share photos.

In almost all the games we analysed, AR presented technical problems and glitches despite the fact that none of these games, with the possible exception of *Pokémon GO*'s occlusion technology, pushed the technological boundaries of AR in any substantial way. From a design perspective, this shows that AR can potentially help attract interest in the game as a 'gimmick' or distinguishing feature – but its inclusion can also introduce bugs and design problems that might eventually put

players off the game. This is one explanation for why AR figures prominently in these games' marketing material but is most commonly 'downplayed' in the game itself, existing as an optional feature that is not essential for gameplay and can easily be toggled off. This conflict between the value of AR features for marketing and the actual game is highlighted in *The Walking Dead: Our World*. As we noted above, the game used AR features in its release version (superimposing zombies onto the players' surroundings). The AR feature had been removed from the game in 2020, signalling a lack of importance and, likely, a lack of use from the players. Nonetheless, its developer continues to show the AR feature in some of their marketing materials of the game, 2 years after the removal.[5]

Location-based games already present designers and players with additional technical challenges that hinder gameplay: most notably inaccurate, bouncing GPS signals and battery drain. On top of this, they ask players to physically move as part of the gameplay, which is often a drawcard for many players in terms of exercise, mental wellbeing and sightseeing; but can also require players to specifically set aside time for this if it is not part of their daily routine. Adding AR into the mix as well can likewise be both a drawcard and a burden. It can provide added value for the player (Paavilainen et al., 2018) and spur imagination and foster a closer connection between in-game and real-world content (Rauschnabel, 2021), but due to current technical limitations, these objectives can be difficult to meet by the developers. As Laato et al. (2021b: 7) observe, the current technical limitations of AR indicate that it 'should be used to support, not replace human imagination.'

This observation has additional implications when we consider the 'high turnover rate' for location-based games. As Leorke (2018: 113–118) notes, with few exceptions, location-based games have struggled to reach mainstream audiences *and* retain enough players to remain commercially viable over the long-term, often closing their servers within a few years of release. Indeed, two games within our sample with AR elements were closed down within 3 months of each other: *Minecraft Earth* did not move beyond Beta phase and was shut down in June 2021 while *Men in Black* disappeared from stores in the middle of our investigation. In addition, Niantic has since shut down *Wizards Unite* in early 2022. This suggests that location-based games with AR elements are similarly high-risk. They enable designers to break through and attract attention in a crowded mobile game market, but the expense in running their servers, designing new content and patching technical problems means they are likely to be short-lived if they struggle to retain players. Nonetheless, location-based games with AR elements continue to be released. After conducting our study, at least two more location-based games based on successful franchises, *The Witcher: Monster Slayer* and *Pikmin Bloom* (Niantic, 2021b), arrived, both prominently including AR elements. Niantic's *Lightship* platform also showcases original AR games. This continued interest in AR suggests that location-based games and AR will continue to co-develop in future, despite the challenges and risks associated with them.

More broadly, the technical limitations we identified in our study also indicate that AR is still far from realising either utopian or dystopian visions and promises that have long accompanied it. As our overview of AR at the beginning of this paper indicates, the potential of AR always seems to be 'just on the horizon', couched in hyperbolic claims, science fiction metaphors and concept demos. But the actual technology itself has only incrementally advanced and is yet to overcome most of the technical barriers identified by Azuma (1997) more than two decades ago, including the 'registration problem' as an ongoing usability and user experience dilemma (Kalalahti, 2015).

These limitations were evident in our analysis of location-based games with AR elements, with our sample games either avoiding them by minimising AR features, making them optional or 'living with' the glitches and crashes they produced. It is telling that Niantic, which has invested the most heavily in AR – both financially and discursively – has yet to achieve even the most basic level of

realism in its AR features. Our analysis showed that even placing a Pokémon in a furnished room without clipping or registration problems could not be consistently achieved. This will potentially change as smartphone hardware and software continues to improve. But it also reinforces that AR in location-based gaming – and we would argue, AR as a technology more broadly – is simultaneously 'mundane' and 'always imminent'.

As Richardson et al. (2021: 4) note in relation to *Pokémon GO* as 'mundane media', the impact of new technologies is often 'most interesting when they become mundane, receding from the spotlight and absorbed as part of everyday and habitual rituals of mobility and communication'. *Pokémon GO* popularised the use of AR in commercial location-based games, but it has also settled into a mundane and 'safe' feature of these games – as exemplified by the standardised and largely uninventive use of the technology in the games we analysed. This mundaneness presents two possible trajectories for AR in location-based gaming. It can remain a gimmick, the equivalent of a Snapchat filter: providing players with a moment of amusement or producing a viral, sharable image, but not substantially adding to the gameplay or pushing the boundaries of AR. Or it can spur new, innovative uses of AR as both commercial and artistic location-based game designers seek to create the next 'breakthrough' app that recaptures and reinvigorates the technological fascination that accompanied *Pokémon GO*'s release. Our analysis shows that the former trajectory is currently dominant. But the lack of success that subsequent location-based games have achieved compared to *Pokémon GO* and the shutting down of several games in our sample signals that the time is ripe for a new wave of innovation that once again revives interest in the 'always-imminent' possibilities of AR.

Limitations and future research

The games we analysed are predominantly commercial location-based gaming apps designed to make a profit through microtransactions, advertisements, and/or players' data. There are many location-based games that include AR features that are not released on app stores but playable through specialised devices that we have not included in our analysis. Further, there are lesser known, artistic, experimental or publicly funded location-based game apps that use AR, but did not show up in our search because they are not available in all countries or simply not recognised as location-based or AR games by the app stores' search algorithm (see e.g. Innocent and Leorke, 2020). These games might present an alternative to our sample's gimmicky and unimaginative use of AR, since they are more likely to experiment and innovate with AR without the commercial imperatives that constrain our sample. In this article, we sought to examine the use of AR in the most popular and commercially successful location-based games, but a larger, more comprehensive study could also examine artistic location-based games.

Furthermore, we chose to focus solely on location-based games that incorporated AR features through the device's camera. As we noted above, this excludes games like *Ingress*, which Niantic considers as part of a wider 'shared alternate reality' by connecting information with place (Hanke, 2017: n.p.). We took this approach to avoid the definitional overlap between location-based gaming, augmented reality, augmented space, mixed-reality and pervasive games, to more specifically focus on AR as a *technology* rather than a *cultural practice* (Manovich, 2006). If we instead defined AR as the broader connection of virtual information to physical space in real-time, every location-based game could potentially be considered as 'augmenting reality'. Our approach provided us with a smaller sample and narrower lens in our game analysis, but we also sought to connect our findings to this broader discourse around AR through our discussion above. Nonetheless, we acknowledge other scholars may adopt a wider definitional approach and this may produce different results to

those we have presented here. Furthermore, while our analysis has reflected on subjective experiences of AR, such as players' affective and sensorial connection to place, further ethnographic research involving player interviews and observation can shed further light on the experiential nature of AR in location-based gaming. As we have argued, AR remains challenging to concretely define and is constantly in flux, and scholarly approaches to AR in location-based games similarly remain fluid and contextual.

Conclusions

AR has long been shaped by hyperbolic claims from futurists and technology companies about its potential, as well as concerns from scholars and commentators about its impact on privacy, social interaction and communication. Games have played an important role in these visions through experimentation with AR to create more immersive and realistic entertainment experiences, gamify elements of everyday life, and connect people with each other through playful augmented interfaces. To explore the impact of AR on location-based gaming and the growing synergy between these distinct, but overlapping, technologies, we examined the integration of AR features in one generation of location-based games. Our findings revealed four main ways that location-based games used AR to augment the physical environment, variously superimposing, blending, immersing or utilising material objects in it. These categories can be further utilised in future research when analysing or developing AR features in location-based games as they continue to evolve.

Our findings also showed that in many cases, despite figuring prominently in the marketing campaigns, the AR features were shallow or did not substantially impact on the gameplay experience. We also found that the AR features of these games remain entangled in familiar technical issues, indicating that AR as a technology remains far from realising either the utopian claims or dystopian anxieties that continually accompany it. Non-commercial, artistic location-based games might be more able to explore new, emergent uses of AR for gaming. And existing games may continue to evolve through updates, patches, and new content, which can sometimes substantially alter their gameplay or features. They might also be shut down, as several of our sample already have been. As such, this study represents a snapshot of location-based AR games from early 2021, which we hope future research can build on. As a simultaneously 'mundane' and 'always imminent' technology, we argue that AR's incorporation into location-based games and other technologies and practices ensures it will continue to be an important site for ongoing scholarly analysis.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This research was partially funded by the Academy of Finland project Centre of Excellence in Game Culture Studies (CoE-GameCult, 312395).

ORCID iDs

Kati Alha https://orcid.org/0000-0003-0160-7376
Dale Leorke https://orcid.org/0000-0001-8741-1758

Notes

1. See for example Jonathan McIntosh's 'ADmented Reality' remix of 'One Day' and Eran May-raz and Daniel Lazo's short film 'Sight'.
2. See for example http://www.tinmith.net/arquake and *Invizimals* (Novarama, 2009) for Playstation Portable and *Face Raiders* (HAL Laboratory, 2011) and *The Denpa Men: They Came by Wave* (Genius Sonority, 2012) for Nintendo 3DS.
3. https://nianticlabs.com/blog/nianticrealworldplatform/
4. https://sensortower.com/
5. https://www.nextgames.com/games/the-walking-dead-our-world (accessed 4 November 2022).

References

Alha K, Koskinen E, Paavilainen J, et al. (2019) Why do people play location-based augmented reality games: a study on Pokémon GO. *Computers in Human Behavior* 93: 114–122.

Azuma RT (1997) A survey of augmented reality. *Presence: Teleoperators & Virtual Environments* 6(4): 355–385.

Barbé M (2017) Strange Beasts [Film]. Available at https://vimeo.com/209070629 (accessed 18 November 2021).

Carmigniani J, Furht B, Anisetti M, et al. (2011) Augmented reality technologies, systems and applications. *Multimedia Tools and Applications* 51(1): 341–377.

Carter M and Egliston B (2020) Pokémon Go wants to make 3D scans of the whole world for 'planet-scale augmented reality experiences'. Is that good? The conversation. Available at: https://theconversation.com/pokemon-go-wants-to-make-3d-scans-of-the-whole-world-for-planet-scale-augmented-reality-experiences-is-that-good-140636 (accessed 18 November 2021).

Elyland LLC (2017) *Draconius GO: Catch a Dragon! [Mobile Game]*. Cyprus: Casual Azur Games.

Freeze Tag Games (2011) *Munzee [Mobile Game]*. Tustin, CA: Freeze Tag Games.

Gazzard A (2011) Location, location, location: collecting space and place in mobile media. *Convergence: The International Journal of Research Into New Media Technologies* 17(4): 405–417.

Geroimenko V (2019) *Augmented Reality Art: From an Emerging Technology to a Novel Creative Medium*. 2nd edition. Plymouth: Springer.

Gibbs S (2017) Augmented reality: Apple and Google's next battleground. The guardian. Available at: https://www.theguardian.com/technology/2017/aug/30/ar-augmented-reality-apple-google-smartphone-ikea-pokemon-go (accessed 18 November 2021).

HAL Laboratory (2011) *Face Raiders [Handheld Console Game]*. Nintendo.

Hanke J (2017) Did we just glimpse the future of augmented reality? Niantic Labs. Available at: https://nianticlabs.com/blog/arfuture/ (accessed 18 November 2021).

Illumix Inc (2019) *Five Nights at Freddy's AR: Special Delivery [Mobile Game]*. Redwood City, CA: Illumix Inc.

Innocent T and Leorke D (2020) Decoding the city: analyzing urban play through Wayfinder Live. *American Journal of Play* 12(3): 270–304.

Javornik A, Marder B, Barhorst JB, et al. (2022) 'What lies behind the filter?' Uncovering the motivations for using augmented reality (AR) face filters on social media and their effect on well-being. *Computers in Human Behavior* 128: 107126.

Kalalahti J (2015) *Developing Usability Evaluation Heuristics for Augmented Reality Applications*. Master's Thesis, Lappeenranta University of Technology, Lappeenranta. Available at: https://lutpub.lut.fi/handle/10024/103081 (accessed 18 November 2021).

Kastrenakes J (2021) Tim Cook says Apple wants to use AR to make conversations better. The Verge. Available at: https://www.theverge.com/2021/4/5/22367715/tim-cook-augmented-reality-apple-car-hints-interview (accessed 18 November 2021).

Koskinen E, Leorke D, Alha K, et al. (2019) Player Experiences in Location-based Games: Memorable Moments with Pokémon Go. In: Vladimir Geroimenko (ed). *Augmented Reality Games I: Understanding the Phenomenon of Pokémon Go*. Springer, 95–116.

Laato S, Pietarinen T, Rauti S, et al. (2019) Review of location-based games: do they all support exercise, social interaction and cartographical training? In: Proceedings of the 11th international conference on computer supported education (CSEDU 2019), Setúbal: Scitepress, pp. 616–627. DOI: 10.5220/0007801206160627

Laato S, Inaba N, and Hamari J (2021a) Convergence between the real and the augmented: experiences and perceptions in location-based games. *Telematics and Informatics* 65: 101716. DOI: 10.1016/j.tele.2021.101716

Laato S, Rauti S, Najmul Islam AKM, et al. (2021b) Why playing augmented reality games feels meaningful to players? The roles of imagination and social experience. *Computers in Human Behavior* 121: 106816. DOI: 10.1016/j.chb.2021.106816

Lankoski P and Björk S (2015) Formal analysis of gameplay. In: P Lankoski and S Björk (eds), *Game Research Methods: An Overview*. Middleton, WI: ETC Press, pp. 23–35.

Leorke D (2018) *Location-based Gaming: Play in Public Space*. Singapore: Palgrave Macmillan.

Liao T and Iliadis A (2021) A future so close: mapping 10 years of promises and futures across the augmented reality development cycle. *New Media & Society* 23(2): 258–283. DOI: 10.1177/1461444820924623

Ludare Group Inc (2019) *Men in Black: Global Invasion [Mobile Game]*. Vancouver, BC: Ludare Group Inc.

Ludia (2018) *Jurassic World Alive [Mobile Game]*. Montreal, QC: Ludia.

Manovich L (2006) The poetics of augmented space. *Visual Communication* 5(2): 219–240.

Metz R (2012) Google game could be augmented reality's first killer app. MIT technology review. Available at: https://www.technologyreview.com/s/507681/google-game-could-be-augmented-realitys-first-killer-app/ (accessed 18 November 2021).

Mojang Studios (2019) *Minecraft Earth [Mobile Game]*. Washington, DC: Xbox Game Studios.

Next Games (2018) *The Walking Dead: Our World [Mobile Game]*. Helsinki, Southern Finland: Next Games.

Niantic (2012) *Ingress [Mobile Game]*. San Francisco, CA: Niantic.

Niantic (2016) *Pokémon GO [Mobile Game]*. San Francisco, CA: Niantic.

Niantic (2019) *Harry Potter: Wizards Unite [Mobile Game]*. San Francisco, CA: Niantic.

Niantic (2021a) Niantic planet-scale AR alliance accelerates social AR future in Codename: Urban Legends. Available at: https://nianticlabs.com/blog/niantic-planet-scale-ar-5g-urban-legends/

Niantic (2021b) *Pikmin Bloom [Mobile Game]*. San Francisco, CA: Niantic.

Novarama (2009) *Invizimals [Handheld Console Game]*. Sony Computer Entertainment.

Paavilainen J, Korhonen H, Alha K, et al. (2017) The Pokémon GO experience: A location-based augmented reality mobile game goes mainstream. In: *Proceedings of the 2017 CHI conference on human factors in computing systems*. New York, NY: Association for Computing Machinery, pp. 2493–2498.

Paavilainen J, Heljakka K, Arjoranta J, et al. (2018) *Hybrid Social Play Final Report*. Finland: Faculty of Communication Sciences, University of Tampere. Available at: https://trepo.tuni.fi/handle/10024/103277 (accessed 18 November 2021).

Pesce M (2020) *Augmented Reality: Unboxing Technology's Next Big Thing*. New York, NY: John Wiley & Sons.

Playfox Games World (2016) *Monster Ball GO [Mobile Game]*. Recife: Playfox Games World.

Rapp D, Niebling F, and Latoschik ME (2018) The impact of Pokémon Go and why it's not about augmented reality-results from a qualitative survey. In: 2018 10th International Conference on Virtual Worlds and Games for Serious Applications (VS-Games), IEEE, Piscataway, NJ, pp. 1–2.

Reality Games Ltd (2020) *Landlord GO Business Simulator Games [Mobile Game]*. London: Reality Games Ltd.

Richardson I, Hjorth L, and Piera-Jimenez J (2021) The emergent potential of mundane media: playing Pokémon GO in Badalona, Spain. *New Media & Society* 24(3): 667–683.

Rauschnabel P.A. (2021) Augmented reality is eating the real-world! The substitution of physical products by holograms. *International Journal of Information Management* 57: 102279.

Sonority Genius (2012) *The Denpa Men: They Came by Wave [Handheld Console Game]*. Genius Sonority.

Spokko (2021) *The Witcher: Monster Slayer [Mobile Game]*. Warszawa, Mazowieckie: Spokko.

Stein S (2021) *Lidar is One of the iPhone and iPad's Coolest Tricks, and It's Only Getting Better*. San Francisco, CA: CNET. Available at: https://www.cnet.com/how-to/lidar-is-one-of-the-iphone-ipad-coolest-tricks-its-only-getting-better (accessed 18 November 2021).

Tankenka (2016) *GPS Monster Scouter [Mobile Game]*. Osaka: Tankenka.

Vaughan-Nichols SJ (2009) Augmented reality: No longer a novelty? *Computer* 42(12): 19–22.

Wetzel R, McCall R, Braun A-K, et al. (2008) Guidelines for designing augmented reality games. In: *Proceedings of the 2008 FuturePlay conference*. Toronto, Canada: ACM. Available at: https://core.ac.uk/download/pdf/76998815.pdf (accessed 18 November 2021).

Winegarner B (2016) Forget Pokémon Go, there's another augmented reality game that's way better. Quartz. Available at: https://qz.com/732809/forget-pokemon-go-theres-another-augmented-reality-game-thats-way-better/ (accessed 18 November 2021).

Author biographies

Kati Alha (PhD) is a researcher and a university lecturer, teaching game studies in Tampere University, Finland. She works at the Centre of Excellence in Game Culture Studies, and has studied games from multiple perspectives since 2009, including research into free-to-play games, mobile games and location-based games.

Dale Leorke (PhD) is an independent researcher. His research focuses on the intersection of games, play and public space. He has published five books, among them *Location-based Gaming: Play in Public Space* (2018), *Games and Play in the Creative, Smart and Ecological City* (2020) and *The Library as Playground: How Games and Play are Reshaping Public Culture* (2022).

Elina Koskinen (MA) is a doctoral researcher at Game Research Lab at Tampere University, Finland. She has been doing research on free-to-play games, location-based games and ethics & game design. Her PhD work concentrates on memorable player experiences in Pokémon GO. Elina is an active volunteer in different games related associations, e.g. IGDA Finland and Finnish Game Jam organization.

Janne Paavilainen is a game developer and researcher. His research has focused on social, mobile, and free-to-play games with special interest in sociability, playability, and game experiences. His academic work has been mainly done in the Game Research Lab and in the Centre of Excellence in Game Culture Studies, Tampere University, Finland. Currently Janne works as a consultant for the game industry and academia.