Vladimir Geroimenko *Editor*

Augmented Reality Games II

The Gamification of Education, Medicine and Art

Springer

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This pioneering two-volume research monograph is dedicated to future generations of augmented reality game designers and players.

With sincere gratitude to the British University in Egypt (BUE), an excellent place to work, teach and write books.

Preface

This book is unique in two main respects: it is the first ever research monograph on the subject of Augmented Reality (AR) Games and also it has been published in two separate and rather substantial volumes. In Volume I, the phenomenon of the Pokémon GO game is analysed in theoretical, cultural and conceptual contexts, with emphasis on its nature and the educational use of the game. Volume II explores the most important and challenging issues that have been raised by the use of the Augmented Reality approach and technology in the gamification of education, health care, medicine and art.

The two-part monograph has been written by a team of 70 leading researchers, practitioners and artists distinguished by their specialist expertise, significant publications and ongoing projects. The books' co-authors are from 20 countries all around the world: Australia, Belgium, Brazil, Denmark, Egypt, Finland, Germany, Hungary, Italy, Malaysia, Netherlands, Romania, Slovenia, South Korea, Spain, Sweden, Switzerland, UAE, UK and USA.

The two comprehensive volumes provide a thorough and multi-faceted research into the emerging field of Augmented Reality Games and consider a wide range of its major issues: the concept and nature of Augmented Reality Games, the lessons learned from the rise of Pokémon GO, and the practical use of this novel type of games in education, health care, medicine, art and related fields. This is why these two books can be essential reading not only for researchers, practitioners, game developers and artists but also for graduate and undergraduate students, and all those interested in the rapidly developing area of AR Games.

It was difficult to make this two-volume book happen because research on Augmented Reality Games is still in its infancy, and there are therefore relatively few 'publishable' materials available. We owe a debt to our contributors who have managed to produce this two-part monograph in the face of these difficulties.

These two books can also be considered as part of a trilogy, a series of three pioneering monographs published by Springer on the same subject of Augmented Reality and with the same book editor:

- Augmented Reality Art: From an Emerging Technology to a Novel Creative Medium. Geroimenko, V. (Ed.), 1st Edition: Springer, 2014—314 p; 2nd Edition, Revised and Updated, Springer, 2018—384 p.
- Augmented Reality Games I: Understanding the Phenomenon of Pokémon GO. Geroimenko, V. (Ed.), Springer, 2019
- Augmented Reality Games II: The Gamification of Education, Medicine and Art. Geroimenko, V. (Ed.), Springer, 2019

The content of Volume II is arranged as follows. You can read chapters in sequence or randomly.

Chapter 1 'Educational Augmented Reality Games' argues that AR games have the potential to enable new forms of learning and transform the learning experience. However, it remains unclear how such AR games whose designs are based on diverse game genres can be used to leverage the conventional education process in the context of different theoretical paradigms and models used in learning. The chapter addresses these challenges by providing an analysis of game genres, learning paradigms, theories and models used in different AR games in the field of education. The authors present a number of previous studies of educational AR games, which are classified by year of publication, school subject, research method, game genres, AR systems, learning environment, learning paradigms and theories, target groups and study sample size. The classified data is analysed to identify how AR games designed based on diverse game genres can be used to benefit the educational process in the context of different theoretical paradigms and models used in learning.

Chapter 2 'Designing Educational Mobile Augmented Reality Games Using Motivators and Disturbance Factors' investigates mobile augmented reality (MAR) that has emerged as a mainstream technology to provide novel visualisation and interaction opportunities across application domains. The primary forte of MAR is its ability to bridge the real world with virtual worlds by bringing virtual elements onto a real-world view, and by adapting the experience according to the user's location and other context parameters. Research has shown that MAR possesses a multitude of affordances in the field of education. These affordances can be amplified in educational MAR games (EMARGs) due to the motivational value and the fun factor provided by intriguing game elements. However, there is a gap in research on design guidelines for EMARGs, especially regarding the connection to motivators and disturbance factors that may have positive and negative effects respectively on the learning experience. In this chapter, the authors present two MAR case studies (a treasure hunt and a story-driven adventure game) to illustrate their experiences in designing EMARGs. They conduct a qualitative analysis of the case studies based on questionnaire answers and interviews of 29 and 112 participants, respectively, to identify motivators (16, 20) and disturbance factors (11, 25) in the participants' gameplay experiences. Through an analysis of the motivators, disturbance factors and their design experiences, the authors proposed 24 design guidelines in 6 categories that can potentially strengthen motivators and diminish disturbance factors in MAR applications.

Chapter 3 ‘Augmented Imagination: Creating Immersive and Playful Reading Experiences’ deals with reading as a complex process that is changing dramatically during the ongoing evolution from purely physical books to digital ones. Between the two poles of physical and digital, there is an emerging field where physical is being augmented by digital and vice versa. In this chapter, the authors investigate physical and digital approaches to the phenomenon of book augmentation. Physical approaches do not embed any electronic elements into the book. On the contrary, in digital approaches, interactivity is supported by embedding electronic devices into the physical book, holding devices above the book or by placing electronic devices around the reader. First, the authors describe and analyse 10 augmented books that use different augmentation techniques (along the following three dimensions: the modalities being used, the type of content on offer and the impact of the augmentation on the reading flow). They then emphasise the need for further investigation of the ways for delivering multimodal and immersive content, in which the processes of reading the original text, interacting and consuming the digital content merge into one unified experience that does not disrupt the reading flow and enhances the sense of immersion in the story. Finally, the authors illustrate how we could move towards this vision of a unified augmented reading experience using different technologies, such as speech recognition systems, eye- and head-tracking systems, olfactory displays, smell synthesisers and digitally controlled food delivery systems.

Chapter 4 ‘Invisible Settlements: Discovering and Reconstructing the Ancient Built Spaces Through Gaming’ studies hidden historic settlements that still exist under layers of soil and debris, waiting to be discovered. Their discovery can precede the archaeological excavation through the use of ground radar for scanning and points-of-interest (POIs) for delineating their shape in space. Once discovered with the use of smartphones, these POIs display augmented information. If the presentation of the invisible settlement can be achieved as a playful activity of discovery, the impact on the player may have a stronger cultural, and possibly identity, value.

Chapter 5 ‘Explorations in Mixed Reality with Learning and Teaching Frameworks: Lessons from Ludus and the Vulcan Academy’ explores the design of mixed reality frameworks for learning and teaching at Griffith University, Gold Coast, Australia. Discipline areas from Pharmacy and Design have developed a series of experiential learning scenarios that help build rich frameworks in which to learn, teach and assess, using and testing multiple strategies in the process. Essential to teaching methods is the implementation of learning objectives as moderated by strategies of play-based learning. The learning scenarios range from developing mobile applications to impact upon spatial reasoning beyond the device frame, designing transformative experiences through student led content authoring of augmented game content, to immersion in a virtual pharmacy with access to augmented content through head mounted displays. Increased engagement is a key objective of the gamified learning experience, and the authors’ experiments seek to investigate the boundaries between educational theories as applied to mixed reality environments through active learning and inquiry-based instruction. The chapter demonstrates that play, through the use of mixed reality technologies, can benefit and prolong student engagement, but importantly that the student can have ownership of the experience. The technological frameworks are not just seen to have novelty but are effective tools for deeper and lasting levels of engagement.

Chapter 6 ‘Playful Ambient Augmented Reality Systems to Improve People’s Well-Being’ addresses the issues of intense stress, discomfort or sedentary behaviour as factors that have a negative impact on people’s well-being and efficiency. A number of prototypes have been developed to help people deal with these issues. In parallel, gamification techniques have been successfully used in applications that aim to improve people’s health by encouraging them to change their behaviour. The authors focus on the use of Ambient systems and/or Augmented Reality systems and discuss the potential of playful and gamified systems to improve people’s well-being. They first describe several prototypes for improving well-being. Then, they discuss the potential of gamification and projection-based AR systems in the context of well-being, and introduce the notion of playful projection-based ambient systems. The authors conclude by describing a scenario and discussing technical considerations for its implementation.

Chapter 7 ‘Augmented Reality Games for Health Promotion in Old Age’ looks at AR game concepts that can be used for health-related purposes. Physical activity is a key aspect for healthy ageing. Conceptual considerations and current research in the field of technology and ageing are examined in the chapter to recommend designs for augmented reality games for older adults. The authors explore relevant trends in augmented reality and possibilities to integrate this technology into individual health promotion. Research on the use of mobile devices and applications by older people, and older adults’ interest in using this technology for health-related purposes is thoroughly presented in the chapter. From this, the authors deduce older adults’ readiness to use augmented reality games on mobile devices in their everyday lives and for health promotion. Design recommendations include considerations of which technology is used by older people, how to create meaningful games, how to involve older adults’ social networks, issues of data security and the special requirements for designing health-related augmented reality games as a whole. The combination of empirical findings from gerontological and technical research groups allows the authors to discuss these issues in a broader perspective and define relevant factors for developing augmented reality games for older adults.

Chapter 8 ‘Gamification in Cognitive Assessment and Cognitive Training for Mild Cognitive Impairment’ begins with a statement that a most important aspect of gamification is its inherent ability to encourage engagement with a product or service. While this is often used as a marketing technique, it proved very worthwhile applying it to a medical domain. Good games or just some game properties challenge and encourage users to perform (sometimes unknowingly) to the best of their abilities and that is often important in (automatic) cognitive assessment. Furthermore, games often have the ability to maintain users’ motivation over a longer period of time, a very important aspect in sustained cognitive training. The chapter critically comments and looks at research and applications in the area of cognitive assessment and cognitive training for Mild Cognitive Impairment (MCI) from a gamification perspective.

Chapter 9 'The Healing App: Augmented Reality and Art for Pediatric Patients with Chronic Pain' starts with an assumption that training, live surgical guidance and therapy are already popular areas of AR in medicine. However, what if we also harnessed the freedom of augmented reality to influence pain management with art? In collaboration with artist Claudia Hart, the Montefiore Health System was creating a new project that explores the combined power of art and technology in a healthcare environment. By commissioning Claudia Hart for a specific area of a hospital, in a situation where she is an intimate part of the planning, a magical and meaningful space emerges that could directly affect overall patient experience and even the need for pain medications. The authors believe their work together in art, design and technology is the future of healthcare and patient environments.

Chapter 10 'The Gamification of Augmented Reality Art' discusses the merging of gamification and augmented reality-based art, its impact in terms of digital labour as well as examples of augmented reality that exhibit gamification or elements of it. Speculative design fictions of gamified augmented reality are examined to determine possible future outcomes of this genre. Finally, historical experiments in user interface design are mentioned to propose future solutions for augmented reality applications, artistic installations and gamification scenarios.

Chapter 11 'Unintended Consequence: Pervasive Games and Public Art' asks how Pervasive Games using Augmented Reality can contribute to a changing perception of Public Art through a playful exploration of place. By unintentionally discovering Art whilst playing games, new meanings are seen to emerge and are explored from new perspectives through the surprise of discovery and re-negotiation with art in public places. This chapter is a semiotic exploration, through analysis and interview of some of the signs and symbols of Public Art and particularly the ontological shifts arising from the re-contextualisation and revisitations of symbols in augmented frameworks. The analysis of semiotic change seeks to explore the shifting interpretations of Public Art afforded by playing games with augmented technologies. Pervasive Games such as Wayfinder Live, and even Pokémon GO and its precursors, unravel an evolving set of rich discourses in which to investigate the recursive correlations of Art and Place. The outcomes of this analysis of Pervasive Games reveal the ontological implications not of intentional design, but of the unintended consequence of playing Games through Art.

Chapter 12 'Defacing the 'Balloon Dog': Art, Algorithmic Culture and Augmented Reality' examines gamification through selected artworks that deploy augmented reality techniques. Gamification is approached as a form of 'algorithmic culture' in which algorithms can be, to varying degrees, both positively guiding or negatively coercing a user. After analysing examples of gamification in the mobile entertainment industry, such as Snapchat and Pokémon GO, examples from contemporary media art that blend augmented reality techniques with algorithmic structures and tendencies are investigated. This research considers AR as a processual entity, rather than a discrete form or technical medium. Its interfaces are not simply dynamically engaged across the physical and the digital, but entangled with social and cultural forces.

Chapter 13 'Circumpolar Gamifications in the Age of Global Warming: Ice Levels, Anxiety and the Anthropocene' looks at the representations of both culture and nature from the circumpolar north in mixed reality and videogames. This is explored through a historical analysis of videogames set in the Arctic, focusing mostly on Alaska, with a few works from media outside of mixed reality and videogames discussed. The chapter illustrates a history of games set in the Arctic, paired with how polar cultures are or are not accurately represented, what effects the global discussion on climate change has on these representations as well as the role of Indigenous sovereignty and justice. These issues are all compounded by a global anxiety associated with climate change/global warming, that leads to eschatological perseverations. The videogame 'Never Alone' is the quintessential example of how northern culture and environmental issues can be used in a videogame without the follies of vestigial colonialist thinking. Augmented reality works from the Dirigibles of Denali project by Nathan Shafer and Patrick Lichty are discussed in these new contexts, with an emphasis on biomes, anthromes and a new hybrid concept, the infome, which is a digital anthrome. Conclusions drawn are that Indigenous communities in the circumpolar north need to retain the control over their own infomes, which would include knowledge of their biomes and cultures, and how those are represented by the outside.

Lastly, we hope that the reader will not judge the books' editor and co-authors too harshly. We have accepted the challenge of being the first, and we have done our best to bring out this pioneering work on Augmented Reality Games. Just go ahead and read one or both of the volumes. We hope sincerely that you will enjoy it.

Cairo, Egypt Vladimir Geroimenko

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Part I
Augmented Reality Games in Education

Chapter 1
Educational Augmented Reality Games

Maheshya Weerasinghe, Aaron Quigley, Julie Ducasse, Klen Čopič Pucihar and Matjaž Kljun

Abstract Augmented Reality (AR) games, in the education sector, have the potential to enable new forms of learning and transform the learning experience. However, it remains unclear how these AR games whose designs are based on diverse game genres can be used to leverage the conventional education process in the context of different theoretical paradigms and models used in learning. This chapter addresses these challenges by providing an analysis of game genres, learning paradigms, theories and models used in different AR games in the field of education. Hence, we present a selected number of previous studies of AR games in the field of education, which are classified by year of publication, school subject, research method, game genres, AR systems, learning environment, learning paradigms and theories, target group(s) and study sample size. The classified data is analysed to identify how AR games designed based on diverse game genres can be used to benefit the educational process in the context of different theoretical paradigms and models used in learning.

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1.1 Introduction

The delivery and acquisition of knowledge and skills in schools or universities are undergoing constant change as the interplay between new forms of pedagogy, new technologies and new styles of education emerge. A prime example of this is when games, game-based learning and gamification are incorporated into the curriculum. Such developments are often motivated by a desire to improve student engagement, student-centered learning and enhance learning experiences.

Digital games are gaining increased visibility in education providing an enhanced experience in learning. Research has demonstrated games are effective with respect to learning and retention (Jan 2009; Pak 2011). Gamification has furthered the possibilities in raising engagement and motivation in educational applications with the use of game design elements and game principles in the teaching and learning contexts.

Within this context, interest in connecting physical and digital elements of a learning experience has emerged. Augmented Reality (AR) technology has the potential to mix virtual and real objects, allowing users to experience mixed content in various dimensions such as spatial, contextual and temporal. Amongst others, this creates an opportunity for exploring experiential student-centered learning rather than the typical educator-centered learning where users observe the educator.

However, prior to understanding AR-games for learning or more broadly digital games in education, it is important to first understand the theoretical underpinnings from education. A variety of theoretical frameworks and theories of learning can form the basis for understanding how, and where, AR-games might be incorporated into an educational context. This theoretical foundation is timely and important as today there are a plethora of research prototypes combining AR, digital games and gamification. These developments have fuelled the exploration of this approach in knowledge delivery and transfer. By introducing these foundations, we can better understand the challenges and issues, and reflect on these as we survey the AR-games for education already developed.

As a result, this chapter will analyse AR games for education through various variables such as subject focus, game genres, technology used, learning environment, learning paradigms, theories and activities, research methods used and target group(s). We first discuss learning paradigms, theories, and models that describe the educational concepts, frameworks, and practices used in teaching and learning. Secondly, we explore the digital games, their genres, and how gamification and games-based strategies might be used to sharpen the learning experience in the field of education. Next, in the method section, we explain how we identified and selected papers that describe AR games in educational settings and present some examples. In the fifth section, we categorize and analyse selected AR game studies according to the year of publication, school subject, research question or study aim, research method, game genre, AR system, learning environment, target group(s), learning paradigm and learning theories. Finally, based on these analyses, we explore the current status of AR games in education, focusing on future implementations.

1.2 Teaching and Learning Paradigms and Theories

When discussing AR games in education it is hard to overlook the teaching and learning paradigms and theories. Nevertheless, the educational games are always based on these and understanding them can clarify some game design decisions. Learning theories are conceptual frameworks that describe how people acquire, process, and retain knowledge during the learning process. They fall into one of several learning paradigms, including behaviourism, cognitivism, constructivism, and others. The wealth of scientific work and results in this field has expanded greatly during the 20th century but is far from being understood in its entirety. In this section we present a brief overview of the field.

Different theories are appropriate for different situations and learning outcomes. There is no single accepted definition of learning, since it depends on one's point of view or a learning paradigm. Most commonly accepted learning paradigms suggest that learning is:

- a visible change in one's behavior, which can be measured (Ashworth et al. 2004; Boeree 2000) (i.e. providing feedback in a game to learners and providing reinforcement to positively impact performance).
- the active process of acquisition (including insight, information processing, memory, perception) of new knowledge and developing adequate mental constructions (Ashworth et al. 2004; Innovative Learning 2011) (i.e. stimulating various regions of the brain and increase the number of consolidation processes through repetition and improve reflexes, promote critical thinking, and help people learn).
- an active, socially enhanced process of knowledge construction based on one's own subjective interpretation of the objective reality (Ashworth et al. 2004; University of Sydney 2011) (i.e. collaboratively and cooperatively engaging in a task in order to achieve a goal in a game).
- a natural desire of human beings, a mean of self-actualization and developing personal potentials (Ashworth et al. 2004; Simply Psychology 2015) (i.e. learning in a game through a cycle of concrete experiences, reflective observation, abstract conceptualization and active experimentation).
- the process of connecting to information sources containing actionable knowledge and maintaining those connections (Ashworth et al. 2004; Kop and Hill 2008) (i.e. leveraging game skills that are transferable across media, platforms and tools to expand students' learning networks).

Theories within the same paradigm share the same basic point of view (Ashworth et al. 2004). It has to be stressed that each of the paradigms has attracted both supporters and critics. Presenting all possible views is beyond the scope of this chapter and what follows is a brief overview of the paradigms mentioned above.

Behaviourism states that all behaviours are learned through the interactions with the external environment. Behaviourists do not attempt to analyse the inner processes of mind such as thoughts, feelings, or motivation. From behaviourist perspective, a learner starts off as a clear state and simply responds to environmental stimuli.

These responses can be shaped through positive and negative reinforcement (a reward for desired or a punishment for undesired behaviour), increasing or decreasing the probability of repeating the same behaviour (Ashworth et al. 2004; Boeree 2000). Behaviourist principles are commonly seen in learning tools including quizzes, discussions, and questions and answers, as well as sequenced skills-based learning such as AR enabled language learning. Such tools utilise reinforcement through immediate feedback and gamification. For example, feedback in the AR game EduPARK (Pombo et al. 2017) allows learners to monitor their process and respond accordingly by changing their learning behaviour.

Cognitivism is a learning paradigm focused on the inner mental processes of humans: how human brain perceives things, how does it make memories and creates new knowledge (Ashworth et al. 2004; Innovative Learning 2011). Cognitive approach to learning sees the learner as an active participant in the learning process, acquiring new knowledge and constructing mental constructions based on prior knowledge and experiences. Unlike behaviorism, it tries to understand the complex cognitive processes by searching for associations between learning and information processing, perceptions and memory. AR games can be designed to help stimulate various regions of the brain such as to improve reflexes, promote critical thinking, and help people learn different patterns of associations. For example, AR games designed based on cognitivism are helpful when used to learn a foreign language and memorize new material.

Constructivism is a learning paradigm claiming that learners construct their own knowledge of the world through experiencing things and reflecting on those experiences (Ashworth et al. 2004; University of Sydney 2011). Constructivism's approach to learning differs from behaviourism and cognitivism in that it perceives learning as an active, socially supported process of knowledge construction. As such, learner constructs their own subjective interpretation and meaning of what is being learnt of objective reality. AR games offer several opportunities for working with physical and conceptual materials to construct new knowledge. AR game-based constructivist activities might include taking photos, recording videos and/or sound, editing and integrating that perceptual information, across multiple sensory modalities, with the user's environment in real time. For example, AR game Leometry (Laine et al. 2016) is a collaborative AR application allowing students to construct 3D mathematical and geometrical models in a shared AR workspace, supporitng new dynamic opportunities for playful interactions to promote higher-level learning, and to help develop personal meanings is an example of the use of Constructivism.

Humanism defines learning as a natural human desire, based on self-actualization and development of personal potentials (Ashworth et al. 2004; Simply Psychology 2015). It emphasises the importance of every individual in that they are striving towards happiness through self-achievement while being responsible for their own actions. Individuals should also have a control over the learning process, which should be based on observing and exploring. The learning process is considered more important than the learning outcomes. Since the control is in the learner's hands, the role of the teacher is to encourage, motivate and provide reasons for embarking on the learning journey. AR games can be used to capture and curate experiences of individuals, and transform these experiences into knowledge. Such AR games can also be used to gather evidence from an experience and afterward to communicate, analyse and visualise the knowledge gained based on personal requirements. For example, AR game Table Mystery (Boletsis and McCallum 2013) helps to learn the elements of the periodic table, which is created through the transformation of experiences, is an example of the use of Humanism.

Connectivism claims that learning occurs not only in individual but also within and across networks. As such, learning resides also outside an individual such as within an organisation or web. The connections and the network of an individual are thus more important than their current state of knowledge. Connectivism is proposed as a learning paradigm for the digital age, which attempts to approach learning and knowledge in the context of technological development (Ashworth et al. 2004; Kop and Hill 2008). Connectivist learners share and communicate dynamic knowledge creation through networked interaction with machines and other people. The collaborative AR games, which are coupled with the resources available through connectivity, make connectivism an important paradigm for knowledge gathering. AR technology can help to provide the scaffolding for connectivist learning and provide the channels for interacting with dynamic sources of data. For example, AR game Electric Agents (Revelle et al. 2014) enables learners to learn vocabulary by interacting with a TV show in which learners collaborate through a mobile augmented reality experience, is an example of the use of Connectivism.

As mentioned, learning theories fall into one of the learning paradigms. Here we shortly describe each learning theory or model within each paradigm.

1.2.1 Models and Theories for Behaviourism and Cognitivism

Sign learning model presents learning as the acquisition of knowledge through meaningful behaviours (Tolman 1922). **Brain-based learning** model presents learning as a cognitive development process which emphasises how people learn differently as they grow, mature socially and emotionally, and cognitively (Jensen 2008).

1.2.2 Models and Theories for Constructivism

According to **Contextual learning** theory learning occurs only when students process new information or knowledge in such a way that it makes sense to them in their own frames of reference (their own inner worlds of memory, experience, and response) (Wikiversity 2017) [i.e. Astrid's steps (Nilsson et al. 2012)] while **Situated learning** theory argues that learning is not transmission of abstract and contextualized knowledge between individuals, but a social process within certain conditions which include activity, context and culture (Anderson et al. 1996) [i.e. Outbreak (Rosenbaum et al. 2007); Mad city Mystery (Squire and Jan 2007); Eco-

MOBILE (Kamarainen et al. 2013)]. The basic principle of **Scaffold of learning** is that the teachers or the instructors provide the support and scaffolding for the learner until learners adapt the knowledge into their own cognitive structure (Math Solutions 2016) [i.e. AmonPlanet (Hodhod 2014), Electric Agents (Revelle et al. 2014)]. **Case-based learning** model introduces learners who typically work in groups to a hypothetical situation (case) they are likely to face in real life. They are then encouraged to examine and discuss it (Williams 2005). **Simulation-based learning** strategy provides learners with an experience of working on a simplified simulated world or system. This approach is widely adopted in military and aviation to maximize training safety and minimize risk (Lateef 2010). **Goal-based learning model** combines case-based learning with learning by doing and defines a set of steps needed in order to accomplish a desired goal (Hubbard 2012) [i.e. Mystery at the Library (Fitz-Walter et al. 2012); (Hwang et al. 2016)]. **Problem-based learning** approach suggests that learning is more effective when learners are faced with a real-life practical problem they need to solve and empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem (Savery and Duffy 1995) [i.e. Parallel (de Sainte-Foy 2015); Leometry (Laine et al. 2016)]. **Challenge-based learning** is similar to problem-based learning, but with this model, learners formulate their challenges (Wikipedia 2012) [i.e. PasswARG (Eishita et al. 2014); UniRallye (Rogers et al. 2015)]. In **Enquiry-based learning** model learners are encouraged to use real-world examples; inquiry represents questioning that forwards curiosity in learners (Wikipedia 2016a) [i.e. Environmental Detectives (Squire and Klopfer 2007)]. **Incidental learning** model refers to the fact that people learn a lot without explicit intention to learn or without instruction, such as learning of new vocabulary through imitation and social interaction, learning social norms through playing games with other children, learning geography through traveling or surfing the web (Edutech wiki 2016).

1.2.3 Models and Theories for Humanism

Experiential learning model defines the process of learning as "learning through reflection on doing". According to the Experiential learning model, knowledge results from the combination of grasping and transforming experience (Wikipedia 2016b) [i.e. Furio et al. (2013a); Luostarinmäki Adventure (Viinikkala et al. 2014)]. **Passion-based learning** model facilitates learning by harnessing and focusing on the learner's passions as well as creating passion within the learners (Brown 2006).

In Table 1.1 we illustrate a brief comparison of learning paradigms including learning theories that fall into each based on (Ashworth et al. 2004).

Table 1.1 Comparison of learning paradigms (Ashworth et al. 2004)

	Behaviorism	Cognitivism	Constructivism	Humanism	Connectivism
Timeline	Since 1900s	Since 1960s	Since 1960s	Since 1970s	Since 2000s
What is learning	Development of desired behavior	Acquisition of new knowledge and developing adequate mental constructions	A mean which should help learner in self-actualization and development of personal potentials	Construction of new knowledge	Process of connection-forming
Control locus	Environment	Learner	Learner	Learner	Mostly learner but also environment
Role of learner	Passive, simply responding to external stimuli	Active and central to the process, he learns objective knowledge from external world	Active and discovery	Active, constructing his representation of knowledge using preferred learning styles	Knowledge acquisition in form of establishing connections to other nodes
Learning process	External supporting of desired or punishing of undesired behavior	An active process of acquiring and processing new information using prior knowledge and experience	Active learning through experience	Construction of subjective representation of knowledge based on prior knowledge and experience	Learning can also reside outside a person (within a database or an organization) and is focused on establishing connections
Critics	Ignores learner and his mental processes, depends exclusively on obvious behavior	Views knowledge as objective and external to the learner	More psychologically than experimentally grounded approach based on assumptions of free will and a system of human values which are generally believed to be true, yet sometimes discredited through counterexamples	There is little evidence for some constructivist views, and some even contradict known findings	A relatively new and according to some not fully developed theory

(continued)

Table 1.1 (continued)

	Behaviorism	Cognitivism	Constructivism	Humanism	Connectivism
Learning theories and models	Sign learning	Brain-based learning	Situated learning Contextual learning Scaffold of learning Collaborative learning Case-based learning Simulation-based learning Goal based learning Problem-based learning Challenge-based learning Inquiry-based learning Incidental learning	Experiential learning Passion-based learning	

1.3 Games, Gamification and Game-Based Learning

In this section, we explore the digital games and their genres. In the context of education, physical games have been used for years in the educator-centered setting where educators set up rules among students (Jan 2009).

One of the strengths of using games in learning is that it lays out situations that require reflection and decision making in order to solve problems. Unlike more traditional teaching methods, using games in teaching can acknowledge the capacity to capture the attention of students and ensure their full engagement. The motivating style of games turns the learning process into something dynamic and interesting, which is maintained as students progress to achieve objectives. Besides motivation and a playful approach, learning through games allows students to experience things in non-threatening scenarios and acquire knowledge through practice and social interaction both with the environment and their peers (Pak 2011).

With the advancement of technology, the digital games came to the forefront (Prensky 2004). Digital games present a structured interactive experience during which players must follow a set of rules and game stages to either achieve the aim of the game (win) or not (loose) (Schell 2014). Games are often classified into genres, which purport to define games in terms of having a common style or set of characteristics, such as gameplay, interaction, and objective as shown in Table 1.2. It needs to be stressed that other game genres might be found in the literature.

Table 1.2 Game genres (Wikipedia 2014)

Game genres	Description
Adventure games	Typically, the player is the hero of a story and in order to progress must solve riddles. The riddles can often involve manipulating and interacting with in-game objects, characters, etc.
Action games	Action games are represented by fast-paced events and movements, which often have to be performed reflexively
Simulation (immersive sim) games	Simulation games describe a diverse super-category of games, generally designed to closely simulate real world activities
Puzzle games	Puzzle games often require the player to solve puzzles or problems and can involve the exercise of logic, memory, pattern matching, reaction time, etc.
Strategy games	Strategy games are typically defined by a number of goals around resource collection, base and unit construction and engagement in combat with other players or computer opponents who also share similar goals
Role playing games	Role playing games are often characterized in terms of providing the player with flexibility in terms of character development, problem resolution, etc.
Treasure hunt games	Treasure hunt games encourage the player to search for hidden objects by following a trail of clues
Serious games	Serious games aim to simulate physical activities such as flying an aircraft

However, we have based our analysis on (Wikipedia 2014) since it covers all games in the analysed papers.

Different game genres can have different impact on different learners. Some learners may best learn through puzzle games, based on their abilities to process information (i.e. logical thinking, memory, pattern matching, reaction time, etc.) while others may best learn through role playing or simulation games. Also different game genres may appeal to different learning models. If games are used in the classroom or outside the classroom, the game genres should be selected to match the learning models (Rapeepisarn et al. 2008). Prensky (2003) emphasizes activities and learning techniques used in educational games and discusses how to combine gameplay and learning. He claims that educators can choose different learning activities according to particular types of content, and proposes the relationship between the learning content, learning activities and possible game style. Another research (Chong et al. 2005) shows the impact of learning styles on the effectiveness of games in education. The results show that the students' preferences of the games vary according to learning style. Furthermore, Rapeepisarn et al. (2008) propose a new conceptual model by comparing and matching learning styles, learning activities and game genres based on studies conducted by Prensky (2003) and Chong et al. (2005).

Table 1.3 Comparison of game, gamification and game-based learning

Game	Game-based learning	Gamification
The actual interactive experience	Uses games to meet learning objectives	Uses gaming elements such as points, levels, achievements, and badges to engage people
May or may not enhance our present level of awareness or knowledge	Learning is achieved by playing the game	People are motivated by external rewards

Besides distinguishing different game genres, it is also important to distinguish between already defined games, game-based learning and gamification. Game-based learning involves designing learning activities with game characteristics and game principles inherent within the learning activities themselves (Wikipedia 2014; Prensky 2003). Gamification, in contrast, is the integration of game principles and game-design elements such as points, leaderboards and badges into non-game contexts such as education and commerce, in order to increase engagement and motivation of the users (Deterding et al. 2011). While both gamification and game-based learning concepts promote engagement and sustained motivation in learning, the two have certain characteristics that make them unique (Karagiorgas and Niemann 2017). Table 1.3 shows the distinction between games, gamification, and game-based learning.

Hence, while games are for fun, game-based learning is a type of game play that has defined learning outcomes. Gamification on the other hand, is more than simply adding games to learning objectives. It utilizes the experience of fun along with intrinsic motivation and rewards to engage and captivate individual participants.

1.4 Method

In this section we explain how we identified papers that describe AR games in educational settings. We conducted a systematic search of available literature on Google Scholar, IEEE Xplore, and ACM Digital Library. We searched for the following phrases and their different combinations: “augmented reality”, “education”, “learning”, “game-based learning”, “gamification”, “edutainment”, “augmented reality games” and “AR games”.

During the search process we used inclusion and exclusion criteria defined upfront, which are presented in Table 1.4. In our search we solely focused on papers reporting on AR games (either real games, applications supporting game-based learning or applications using gamification principles as described in previous section) studied in the educational settings. Applications that were considered or described as fun but that did not use game mechanics were not included. We also excluded AR games

Table 1.4 Inclusion and exclusion criteria

Inclusion	Exclusion
Papers that reported using AR games for educational purposes (formal or informal)	Commercial applications available on Google Play or Apple App Store
Literature reviews focused on AR games development	Papers reporting on AR use in education without gaming components
Literature reviews discussing educational dimensions of AR games	Papers reporting on ideas or pilot studies without a description of the evaluation methodology

focused on education available on Google Play[1] and Apple App Store,[2] as well as articles describing the implementation of AR games only. We did not include articles without any study as well as articles that reported a short/small pilot study without a description of the evaluation methodology. Exceptionally, we included two studies (Santoso et al. 2012; Hodhod 2014) without a proper evaluation method as they were strongly designed upon both AR gaming and educational principles.

1.4.1 Game Examples

We have identified 30 papers describing AR games in educational settings based on the described method. In order to better understand the results and analysis section we have selected and described six games as illustrative examples of different genres based on different learning paradigms and using different learning theories in more details. The description also includes the rationale of our classification.

1.4.1.1 Outbreak @ The Institute

The game Outbreak @ The Institute (Rosenbaum et al. 2007) presents a simulation based game simulating the spread of an infectious disease across university campus. The players can take one of the several roles such as doctors, medical technicians, or public health experts and try to identify the source and to contain a disease outbreak that can spread among real and/or virtual characters based on a preselected disease model. As such, the game could be categorised also as a role-playing game but since the participants were in the class on medical technology and game was a part of the curriculum, we (as well as the authors of the game) categorised it as simulation. Moreover, players are given loosely defined tasks, limited amount of time, and it is on them to decide on goal states, which creates a realistic situation in which they must evaluate trade-offs and decide on a satisfactory balance.

[1]Google Play https://play.google.com/.

[2]Apple App store https://www.apple.com/ios/app-store/.

This study used authenticity of the system as a whole to frame the research, which is related to constructivism and situated learning. The findings suggest participants perceived the game as authentic. They demonstrated their personal embodiment in the game through verbal and physical reactions to the virtual disease, the shift from meta-level to person-level goals, seriousness and responsibility with which they treated their roles, showing an understanding of the interdependence of the roles and the importance of communication, and seeing that their actions had an effect on the outcome of the game in a realistic way. Participants thus constructed their own knowledge of the world in terms of their personal embodiment in the game, their experience playing different roles and the understanding of the dynamic model underlying the game.

1.4.1.2 Astrid's Steps

The Astrid Lindgren Landscape (Nilsson et al. 2012) is an outdoor mobile AR educational game aiming to enhance and augment the experience of a visit of a culturally significant place, the childhood home of the children's book author Astrid Lindgren. It allows players to learn about and explore the physical space through a treasure hunt game. Players activate content by moving between places and pointing their mobile devices at different markers and in different directions through various design concepts. The aim of the game was to visit a number of places of interest, and collect ingredients for a classic dish, which allows players to actively construct knowledge and create their ideas in such a way that it makes sense to them in their own frames of reference as opposed to simply absorbing information.

A set of eight design concepts (not all of them used in the final prototype) identified during the design stage are visible in Fig. 1.1. Leaving Traces allowed visitors to write notes and leave geographically tagged photos at specific places for others. The Time Machine allowed users to point the phone camera towards a scenery and see how it looked like in the past by moving the slider. The Show and Tell Guide was intended for a guide holding a visual marker while the rest of the group pointed their phone cameras to it in order to visualise content related to guide's explanation. The Interactive Map took advantage of a physical map with hidden information about interesting sites displayed when viewed through the mobile phone. Mythical Creatures from Astrid Lindgren's books could be visualised and taken photos of by looking at the landscape through a mobile phone. The Sidekick allowed the guide to carry a visual marker in order to dramatise a guided tour while visitors could see the sidekick when viewed through the phone. The Walking Quiz featured a treasure map showing user's position and where the questions or challenges are spatially placed. The Spatial Audiobook played stories of the author by pointing users' phones at specific artefacts.

In this study, the inquiry-based learning contexts were incorporated into contextual gaming scenarios for promoting students' learning performance. The main gaming interface enables players to learn in various gaming contexts based on the natural and cultural environment that supplies the content of learning.

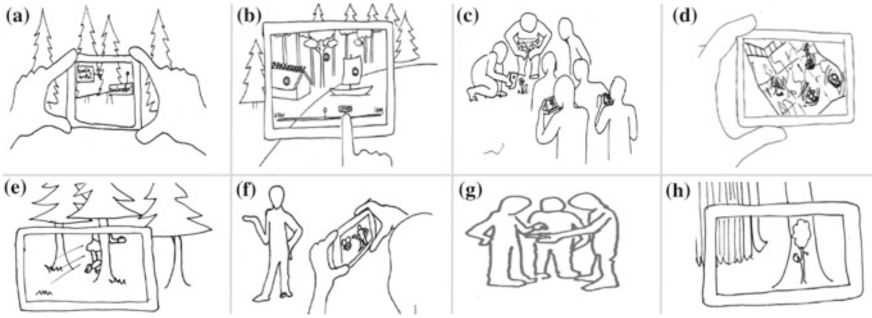

Fig. 1.1 The game design concepts: **a** leaving traces, **b** time machine, **c** show and tell guide, **d** interactive map, **e** mythical creatures, **f** sidekick, **g** walking quiz, and **h** spatial audiobook. Courtesy of (Nilsson et al. 2012)

1.4.1.3 Amon Planet

AmonPlanet (Hodhod 2014) is an AR game intended to teach computational thinking skills through a storytelling. For example, the story starts with an Bigaliens' invasion of a Zeomons' planet. Several of the Zeomons manage to escape and land on the player's back yard. Bigaliens followed them and try to capture them and challenge the player to attend a universal intellectual competition. The Zeomons agree to train the player to get them prepared. A series of activities are then provided. One such activity involves fractions. In order to understand that fractions can be represented as a subset, the learner is presented with a fraction and a number of food items. To fulfil this task the Zeomon will ask the learner to bring his favourite toy to the game to become a part of the virtual world. Next, the player needs to share a fraction of the sweets (e.g. 3/8 sweets) with his toy by clicking on 3 out of 8 pieces of sweets. If the answer is correct, the toy can give the player a balloon or jump up and down or fireworks will appear. If the answer is wrong, the sweets jump back to the original positions indicating the player has to try again. These pedagogical agents provide the support and scaffolding for the learner until learners adapt the knowledge into their own cognitive structure. Snapshots of the game are visible in Fig. 1.2.

The game is characterised as a role-playing game since it provides the player with flexibility in terms of character development, problem resolution, and by playing a

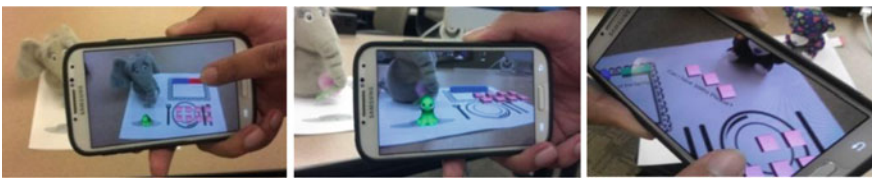

Fig. 1.2 Snapshots of AmonPlanet game. Courtesy of (Hodhod 2014)

role in the story. Through the intelligent tutoring components, the game also provides the necessary scaffolding essential for real knowledge acquisition.

1.4.1.4 Monster Adventure

The Luostarinmäki Adventure (Viinikkala et al. 2014) aims at presenting the daily life of a 19th century city. The player takes the role of Frans, a 23 year-old man from the countryside who comes to the city for the wedding of his cousin. As the player, Frans is unfamiliar with a 19th century city, and people he meets try to explain various aspects of city life (see Fig. 1.3). It is soon revealed that the wedding ring has been stolen from the groom. The game then takes a form of a detective story in which the player has to follow clues and find the thief and the ring to save the day.

The game is an adventure as the player is the hero of a story that needs to solve a mystery by solving various tasks. This game first immerses players in an experience and then encourages reflection about them in order to develop new skills, new attitudes, or new ways of thinking. It also describes the natural human desire, based on self-actualization and development of personal potentials which emphasises the humanistic behavior of learning.

Fig. 1.3 The player is presented with a snap of the past during the game. Courtesy of (Viinikkala et al. 2014)

1.5 Results and Analysis

Based on the described criteria, 30 papers from peer-reviewed journals and conferences were analysed. Each AR game and study reported was then categorized and classified along these criteria: year of publication, school subject, research question or study aim, research method, game genre, AR system (e.g. handheld, projector based, head-mount display), learning environment, learning paradigm and learning theories, target group(s) and learning activities. All AR games presented are also listed and summarised in Table 1.5. A more detailed table can be found in Appendix 1.

Table 1.5 Summary of AR games in education

Study	School subject	#	Game genre	Learning environment	Learning paradigm	Learning theories and models	Learning activities
Outbreak (Rosenbaum et al. 2007)	Biology (medicine)	21	Simulation	Outdoor (school garden)	Constructivism	Situated learning, Goal-based learning	Immersion, feedback, problem
Mad city Mystery (Squire and Jan 2007)	Biology (ecology)	28	Role play	Outdoor (sites around the university, near a lake)	Constructivism	Situated learning, Inquiry-based learning, Scaffold of learning	Imitation, practise, problem, creativity play
Environmental detectives (Squire and Klopfer 2007)	Biology (ecology)	76	Simulation	Outdoor/indoor (any)	Constructivism	Situated learning, Inquiry-based learning	Immersion, problem, creativity play
Astrid's steps (Nilsson et al. 2012)	Culture	20	Treasure hunt	Outdoor (in the woods)	Constructivism	Contextual learning, Inquiry-based learning	Problem, creativity play
Mystery at the library (Fitz-Walter et al. 2012)	Library education	7	Adventure	Indoor (library)	Constructivism	challenge based learning, Goal-based learning	Feedback, problem, creativity play
First colony (Echeverria et al. 2012)	Physics (Electronics)	45	Simulation	Indoor (classroom)	Constructivism	Collaborative learning	Immersion, work with others
Tangram AR (Santoso et al. 2012)	Math (spatial reasoning)	N/A	Puzzle	Indoor (school)	Constructivism	Challenge based learning, Goal-based learning	Feedback, problem, creativity play

(continued)

Table 1.5 (continued)

Study	School subject	#	Game genre	Learning environment	Learning paradigm	Learning theories and models	Learning activities
Thus, et al. (Furio et al. 2013a)	Biology (ecology)	79	Treasure hunt	Indoor (summer school)	Humanism	Experiential learning	Interact, practice
Thus, et al. (Furio et al. 2013b)	Psychology	234	Treasure hunt	Indoor (summer school)	Humanism	Experiential learning	Interact, practice
EcoMOBILE (Kamarainen et al. 2013)	Biology (ecology)	71	Simulation	Outdoor (lake)	Constructivism	Situated learning, Goal-based learning	Immersion, feedback, problem, creativity play
Table Mystery (Boletsis and McCallum 2013)	Chemistry	N/A	Adventure	Indoor (science center)	Humanism	Experiential learning	Interact, practice
Martinez et al. (Zarzuela and others 2013)	Biology (ecology Animals)	5	Puzzle	Indoor (any)	Constructivism	Challenge based learning, Goal-based learning	Feedback, problem, creativity play
ARMuseum (Chatzidimitris et al. 2013)	Chemistry	N/A	Treasure hunt	Indoor (museum)	Constructivism	Challenge based learning, Goal-based learning	Feedback, problem, creativity play
AmonPlanet (Hodhod 2014)	Mathematics (fractions)	N/A	Role play	Outdoor (any)	Constructivism	Scaffold of learning	Imitation, association, practise
Electric agents (Revelle et al. 2014)	Language literacy (vocabulary)	34	Action	Indoor (living room)	Constructivism Connectivism	Scaffold of learning, Collaborative Learning	Imitation, association, practise, work with others
PasswARG (Eishita et al. 2014)	Any	35	Treasure hunt	Indoor/outdoor	Constructivism	Challenge based learning, Goal-based learning	Feedback, problem, creativity play
REENACT (Blanco-Feŕandez et al. (2014)	History	61	Simulation	Indoor	Humanism	Experiential learning	Interact, practice
Luostarinmäki Adventure (Viinikkala et al. 2014)	History	56	Adventure	Outdoor (museum)	Humanism	Experiential learning	Interact, practice

(continued)

Table 1.5 (continued)

Study	School subject	#	Game genre	Learning environment	Learning paradigm	Learning theories and models	Learning activities
UniRallye (Rogers et al. 2015)	Navigation	30	Treasure hunt	Indoor (university campus)	Constructivism	Challenge based learning, Goal-based learning	Feedback, problem, creativity play
Parallel (from Sainte-Foy 2015)	Physics (electromagnetism)	160	Simulation	Indoor (school)	Constructivism	Problem based learning, Goal-based learning	Feedback, problem
Hwang et al. (Hwang et al 2016)	Biology (ecology)	57	Board, puzzle	Outdoor (butterfly garden)	Constructivism	Situated learning, Goal-based learning	Feedback, problem, creativity play
Leometry (Laine et al. 2016)	Mathematics (geometry)	61	Adventure	Indoor (school)	Constructivism	Problem based learning, Goal-based learning	Feedback, problem
Lin et al. (Lin et al. 2016)	Mathematics (geometry)	N/A	Puzzle	Indoor (school)	Constructivism	Challenge based learning, Goal-based learning	Feedback, problem, creativity play
AREEF (Oppermann et al. 2016)	Environment awareness	36	Action	Indoor (swimming pool)	Constructivism	Challenge based learning, Goal-based learning	Feedback, problem, creativity play
ARmatika (Young et al. 2016)	Mathematics (arithmetic)	30	Puzzle	Indoor (school)	Constructivism	Challenge based learning, Goal-based learning	Feedback, problem, creativity play
Calory battle AR (Laine and Suk 2016)	Physical exercise	29	Treasure hunt	Outdoor	Constructivism	Challenge based learning, Goal-based learning	Feedback, problem, creativity play
AR Ole Cierraojos (Tobar-Mu ~ noz et al. 2017)	Language literacy (reading comprehension)	51	Puzzle	Indoor (school)	Constructivism	Challenge based learning, Goal-based learning	Feedback, problem, creativity play

(continued)

Table 1.5 (continued)

Study	School subject	#	Game genre	Learning environment	Learning paradigm	Learning theories and models	Learning activities
EduPARK (Pombo et al. 2017)	Any	74	Treasure hunt	Outdoor (park)	Constructivism, behaviorism	Challenge based learning, Goal-based learning	Feedback, problem, creativity play
Hsu (Hsu 2017)	Language (English)	38	Puzzle	Indoor (school)	Constructivism	Situated learning, Task-based learning and Self-directed learning	Understand principle, graduated tasks
NatureAR (Alakarppa et al. 2017)	Biology	22	Treasure hunt	Outdoor (nature)	Constructivism	Challenge based learning, Goal-based learning	Feedback, problem, creativity play

1.5.1 Studies by Years

When sorting selected papers by year (see Fig. 1.4), we can observe an increase in the number of educational AR game studies from 2006 to 2013, while there is a drop in 2015. The increase might be related to the wide adoption of mobile handheld devices such as smartphones and tablet computers, and readily available AR libraries such as Vuforia,[3] both making it easier to develop and distribute AR application. With a recent release of Apple's ARKit[4] API and Google's ARCore[5] API we might be seeing further increase of AR games studied in educational environments.

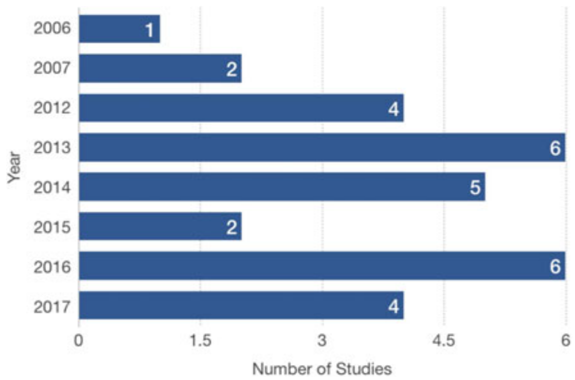

Fig. 1.4 Distribution of AR game studies by years

[3] Vuforia Software Development Kit https://www.vuforia.com/.

[4] Apple ARKit https://developer.apple.com/documentation/arkit.

[5] Google ARCore https://developers.google.com/ar/.

1.5.2 School Subjects

Looking at Table 1.6 we can see that AR games are used in a variety of school subjects. Biology (including ecology and medicine) is the leading field in this regard (30%). Taking all natural sciences into consideration along with physics (6.7%) and chemistry (6.7%), this branch of science is most often explored. Further division into topics reveal even more diversity: ecology (Squire and Jan 2007; Squire and Klopfer 2007; Furio et al. 2013a; Kamarainen et al. 2013; Hwang et al. 2016), electronics (Echeverria et al. 2012), electromagnetism (de Sainte-Foy 2015) and periodic table (Boletsis and McCallum 2013).

AR games are also used in mathematics (10%), history (10%) and language learning (10%). In addition to educational content described in school curricula, AR games are also employed for example in art (Rogers et al. 2015) and library education (Fitz-Walter et al. 2012). AR games are also employed in fields such as physical education (3.3%) and psychology (3.3%). Other studies cover 13.3% (library education, navigation and general content) (Fitz-Walter et al. 2012; Eishita et al. 2014; Rogers et al. 2015; Pombo et al. 2017). This finding shows that AR games can be employed in education and training of very diverse areas and cover various subjects from natural, social and other sciences.

1.5.3 Research Methods

A mix of qualitative and quantitative methods was used in 40% of the studies (see Appendix 1 and Fig. 1.5). Combining qualitative and quantitative methods is beneficial and allows for better understanding of AR games usage. This trend is also noticeable in Human-Computer Interaction (HCI) studies, since complementing subjective and objective methods can lead to better understanding of design problems

Table 1.6 AR Game studies by learning content

Learning content	Count (30)	%
Biology	9	30
Other	4	13.3
Mathematics	3	10
Culture and history	3	10
Language learning	3	10
Physics	2	6.7
Chemistry	2	6.7
Geometry	2	6.7
Physical education	1	3.3
Psychology	1	3.3

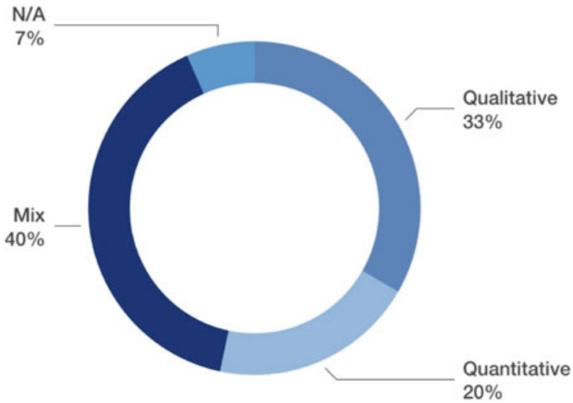

Fig. 1.5 AR Game studies by research methods

Table 1.7 Game genres used in AR games

Game genre	Count (30)	%
Treasure hunt	9	30
Puzzle	7	23.3
Simulation	6	20
Adventure	4	13.3
Role-playing	2	6.7
Action	2	6.7
Strategy	0	0

(Assila et al. 2014; Kjeldskov and Paay 2012). In our sample, qualitative only studies account for a third of all studies (33%) while quantitative only studies are reported by 20% of the papers. The remaining 7% are two papers without a study as explained in the Method section (Santoso et al. 2012; Hodhod 2014). These findings highlight the need for more quantitative studies or combination of both methods.

1.5.4 Game Genres

Among selected papers, the most common game genre is treasure hunt games (30%) and the least common is action games (6.7%) and role-playing games (6.7%) (Table 1.7). A considerable number of educational AR game studies also involved puzzle games and simulations games (23.3% and 20% respectively). Remaining game genre include adventure games (13.3%).

It has been pointed out by (Rapeepisarn et al. 2008) that game genres are not often considered when designing for a particular learning style. They also stress that different students have different styles of learning and that each student might have more than one style of learning. This means that in some learning situations, some students may prefer active engagement while others may prefer a more pragmatic learning approach. While game genres play an important role in game design, other factors such as pedagogy and literacy need to be taken into account as well.

1.5.5 Technologies Used

All selected AR games were developed for handheld devices such as PDAs in early studies, and later smartphones and tablet computers. The technology used is very dependent on what is currently available on the market and on the state-of-the-art in consumer electronics. This will change in the future when novel technologies will become available and socially acceptable (e.g. AR glasses) and when computational capabilities will increase. Currently, AR is positioned in the "Trough of disillusionment" phase in the Gartner Hype Cycle[6] for emerging technologies. Based on for example Google's investment in AR technologies in education[7] AR is likely to progress into the "Slope of enlightenment" phase in the near future, when technology becomes widespread and easily accessible. The example of Google might also contribute to a more widespread use of Head Mount Displays (HDM). Currently, educators can take advantage of BYOD concept (bring your own device), to reduce the cost of introducing AR games in the learning process.

1.5.6 Learning Environment

The majority of the educational AR game studies were conducted in indoor learning environments, i.e. in classrooms, museums, science centers, cultural centers, libraries, living rooms, swimming pools and at summer schools (60%) (Table 1.8). Majority of these indoor learning environments include more formal setups such as settings of the classrooms, museums, science centers, cultural centers and libraries. Some of indoor learning environments also include informal setups like settings of a living room or a swimming pool. A considerable number of educational AR game studies were also conducted in outdoor learning environments such as in gardens and parks (33.3%) and just a few studies were conducted in both indoor and outdoor learning environments (6.7%).

According to Table 1.9 the majority of AR game studies were conducted in indoor learning environments and have used a puzzle genre (6 games), which is a genre that can be easily implemented in indoor formal learning setup because it often requires players to sit and solve problems that can involve logic exercises, memory and pattern matching, etc. Among the games that were used outdoors, the treasure hunt games

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[6] Gartner Hype Cylce for emerging techhnologies 2018, https://www.gartner.com/smarterwithgartner/5-trends-emerge-in-gartner-hype-cycle-for-emerging-technologies-2018/.

[7] Google expeditions: https://edu.google.com/products/vr-ar/?modal_active=none.

Table 1.8 AR game studies by learning environment

Learning environment	Count (30)	%
Indoor	18	60
Outdoor	10	33.3
Indoor/Outdoor	2	6.7

Table 1.9 The number of AR games in relation to game genre, learning paradigm and theories

#	Game genre	Learning environment
6	Puzzle	Indoor
4	Treasure hunt	Indoor
3	Simulation	Indoor
3	Adventure	Indoor
2	Action	Indoor
4	Treasure hunt	Outdoor
2	Simulation	Outdoor
2	Role-playing	Outdoor
1	Puzzle	Outdoor
1	Adventure	Outdoor
1	Simulation	Outdoor/Indoor
1	Treasure hunt	Outdoor/Indoor

were mostly used as they encourage players to search for hidden objects in the environment by following a trail of clues.

1.5.7 Learning Paradigms, Theories and Activities

As seen in Table 1.5, we have categorised the majority of the AR games in constructivism and some in the humanism paradigm. This might suggest that behaviourism, cognitivism and connectivism are less explored learning paradigms in educational AR games. However, while each analysed prototype might focus mainly on one paradigm, we can find traces of other paradigms as well. For example in Electric Agents (Revelle et al. 2014), which is a transmedia action game to learn vocabulary by interacting with a TV show through AR and mobile device sensors, and EduPARK (Pombo et al. 2017), a treasure hunt AR game for a smart urban park.

According to Fig. 1.6, educational AR games were designed based on many learning theories and models. Challenge-based learning is the foremost model in this regard (43%). Educational AR games are often designed based on situated learning (20%) and experiential learning (17%). In addition to these models, educational AR games are also designed upon scaffolding (7%), problem-based 7%), collaborative (3%) and contextual (3%) learning models. The reason why challenge-based learning is mostly used in educational AR games may be related to the compensations of gamification and game-based learning.

The results from Table 1.5 shows that possible game genres for the situated learning can be simulation or role-playing games. And these game genres relate to the practice, immersion, and imitation learning activities. At the same time, it shows that the possible game genres for experiential learning can be adventure or treasure hunt games that relate to the practice and interaction learning activities. The same results can be found in (Rapeepisarn et al. 2008) study on relationship between learning techniques, learning activities and possible game genres.

We could not find any relation between game genres and learning paradigms (see Table 1.10) since for example we classified treasure hunt, simulation and adventure style games in both constructivism and humanism. The same is true for the relation between game genre and learning theories and for learning paradigms and theories in relation to learning environment.

1.5.8 Target Group(S)

Table 1.11 presents the distribution of educational AR game studies based on participants' age. The majority of the studies were conducted with primary school students (56.6%), followed by high school students (20%), and undergraduate students (6.7%).

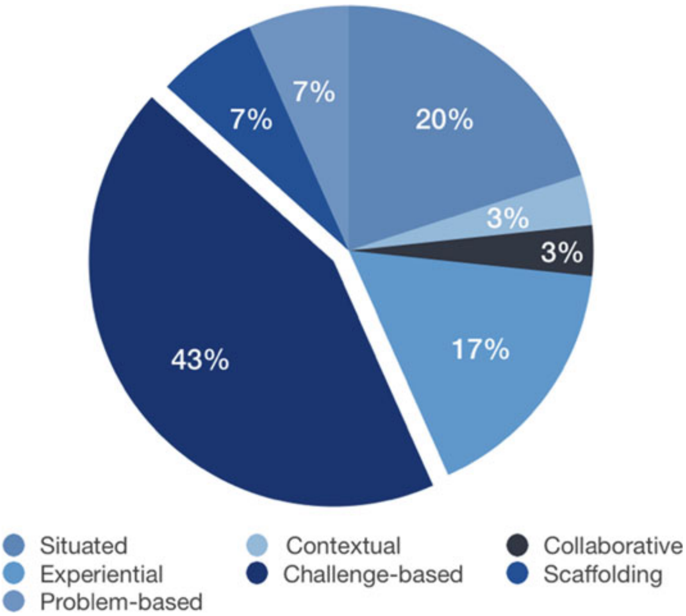

Fig. 1.6 AR game studies by learning theories

Table 1.10 The number of AR games in relation to game genre, learning paradigm and theories

#	Game genre	Learning paradigm	Learning theories
6	Treasure hunt	Constructivism	Challenge-based learning
2	Treasure hunt	Humanism	Experiential learning
1	Treasure hunt	Constructivism	Contextual learning
5	Puzzle	Constructivism	Challenge-based learning
2	Puzzle	Constructivism	Situated learning
3	Simulation	Constructivism	Situated learning
1	Simulation	Constructivism	Collaborative learning
1	Simulation	Constructivism	Problem based learning
1	Simulation	Humanism	Experiential learning
2	Adventure	Humanism	Experiential learning
2	Adventure	Constructivism	Goal-based learning
1	Role-playing	Constructivism	Situated learning
1	Role-playing	Constructivism	Scaffold of learning
1	Action	Constructivism	Scaffold of learning
1	Action	Constructivism	Challenge-based learning

Table 1.11 Target groups used in AR games

Target group	Count (30)	%
Primary school students	17	56.6
High school students	6	20
Educators	2	6.7
Any	2	6.7
Undergraduate students	2	6.7
Special education	1	3.3

The percentage of studies conducted with undergraduate students and teachers were the same (6.7%). The data also shows that AR game studies have a low percentage of students with special needs (3.3%).

Table 1.12 Sample size used in AR games

Min	Max	Mean	Median	Standard deviation
5	160	45	36	35

The results are not surprising since game-based learning might be more suitable for primary and secondary education. For example, the UNESCO report on “Games and Toys in the Teaching of Science and Technology” focuses entirely on primary and early secondary education (Lowe 1988).

We also found that the mean sample size in educational AR game studies was 45 participants (Table 1.12). The minimum sample size was 5 and maximum 160. The median value of the sample is 36 (standard deviation = 35). We can see that the majority of the presented papers have more than 30 participants. Only seven studies have less than 30 participants (21, 28, 20, 7, 5, 29, 22) and only two studies less than 20 participants. For five studies this information is not available. Table 1.5 has all the papers sorted by year and looking at the number of participants in each no pattern could be found.

1.6 Guidelines for Designing AR Games for Education

Here we present four design guidelines that emerged through our literature reveiw and should be applied as early as possible in the design and development of AR games intended for use in an educational context.

1.6.1 Design the Feedback in an Appropriate, Guided and Meaningful Manner

Feedback has been considered seriously in all of the analysed games (see Learning Activities row in Table 1.5). When designing for feedback in educational AR games, options should be considered in terms of the positive reinforcement, the timing of presentation, and of how the interpretation of feedback can help learners to build and enhance their mental models. Positive reinforcements and their timing influence the different aspects that the learner can consider in their mental model. For example, in the AR game EduPARK (Pombo et al. 2017) the virtual agent supports learners throughout the game by providing guidance about the path needed to be traversed, educational content relevant for answering questions (images, audio, videos, and augmented reality content), and feedback to given answers. Generic feedback or feedback which is not sensitive to the current learning context should be avoided as only meaningful feedback supports the learning process.

1.6.2 Create Collaborative Shared Experiences When Possible

Collaboration is a topic of several learning paradigms (e.g. constructivism and connectivism) and some AR games we have analysed have taken it into account. When a task or a learning activity is best handled through a group work AR games for education should allow learners to work together. Collaborative shared experiences provide a shared cognitive set of information between players and ensure that they build their own mental models to construct new knowledge. For example, Environmental Detectives (Squire and Klopfer 2007) engaged high school and university students in a real-world environmental consulting scenario. The scenario was built to immerse players in the practices of environmental engineers, giving them a "virtual practicum" experience, similar to working on an environmental research team. In the scenario players work in teams of two or three, and attempt to identify the contaminant, chart its path through the environment, and devise possible plans for remediation if necessary. The main focus of the game was on planning an effective investigation that balanced quantitative and qualitative data.

1.6.3 Use Elements from Real Environment to Enhance Experience

AR games do not have to focus exclusively on digital technology. For example, in the Astrid Lindgren Landscape (Nilsson et al. 2012) players need to use a real paper map where hidden information about interesting sites is displayed when viewed through the mobile phone. This concept can also be extended to include support for real elements such as cups, glasses and other objects within the game, for example using computer vision or radar (Yeo et al. 2018) to detect when users have collected such items.

In addition, in the Astrid Lindgren Landscape (Nilsson et al. 2012) game there are large distances between different AR elements, thus possibly leading to players becoming bored. This problem was partially avoided by ensuring that players make full use of the real world space. For example, selecting interesting routes in the environment, which can be used to increase the senses (e.g. dark streets leading to mystery locations), or leading players to have a coffee in a real café as part of the game (e.g. in location-based street games).

1.6.4 Design the Game Model as a Representative of the Real Phenomena

This is especially important in simulation-based games; however, it is an aspect that was considered in other games as well to make the experience as realistic and immersive as possible. To represent a real phenomenon of a learning context the game should be designed to model that phenomenon by including a set of aspects that characterize it. The learner builds their mental model by interacting with a process which executes the game model. If the game model is not representative of the real phenomenon, the experience will not help the learner to build a mental model in accordance with the real phenomenon [i.e. First Colony (Echeverria et al. 2012)]. In addition, representing the real phenomenon may influence the engagement of learners as realism is one of the characteristics of AR games that capture the attention [i.e. AREEF (Oppermann et al. 2016)].

By considering the feedback, collaborative opportunities, real world engagement and connection to real phenomena game designers and developers can enhance the engagement and pathways for adoption of AR games in education.

1.7 Conclusion and Discussion

This chapter examined thirty educational AR game studies that were presented in peer-reviewed journals and conferences. Selected studies were coded according to the following criteria: year of publication, school subject, research method, game genres, AR systems, learning environment, learning paradigms and theories, target group(s) and study sample size. Data was analysed to identify how AR games can be used to benefit the educational process in the context of different theoretical paradigms and models used in learning.

The number of educational AR game studies has increased over the years. It is foreseen that educational AR games will be more widespread in the future along with recent advancement of novel technologies.

Results reveal that AR educational games are used across diverse fields. Biology, mathematics, history and language learning are just some of the subjects, showing that a variety of fields are suitable for AR educational games. Nevertheless, the majority of studies focused on natural sciences, the area that can be easily enhanced with game components because it is often based on problem-solving tasks.

Furthermore, this review showed that the educational AR games have used various learning theories as a design principle, with challenge-based learning (constructivism paradigm) being the most common. Another interesting point is that AR games can be applied in any learning indoor and outdoor environment. Indeed, the use of AR games in appropriate settings enhances active and authentic learning in the real wold, creates an opportunity for exploring experiential student-centred learning rather than the typical educator-centred learning, and supports consolidation from working to long-term memory system through learning activities.

The results also revealed that the technology used is very dependent on what is currently available to the wider research community. While technology presents certain limitations, it is changing fast and handheld devices might soon be replaced by other technologies such as projections or head mounted displays.

One of the results revealed by our analysis is also the fact that AR games are not commonly used for teaching students with special needs. Games and gamified tasks are often used in rehabilitation or for maintaining or inhibiting certain conditions and diseases. This opens another interesting avenue for future developments.

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Appendix 1: AR Games in Education

https://docs.google.com/document/d/1-RsE1C-AoPOnnAe9FfDQaRG18HCLyB14QD31vfKmDes/edit?usp=sharing

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Chapter 2
Designing Educational Mobile Augmented Reality Games Using Motivators and Disturbance Factors

Teemu H. Laine and Haejung Suk

Abstract Mobile augmented reality (MAR) has emerged as a mainstream technology to provide novel visualization and interaction opportunities across application domains. The primary forte of MAR is its ability to bridge the real world with virtual worlds by bringing virtual elements onto a real-world view, and by adapting the experience according to the user's location and other context parameters. Research has shown that MAR possesses a multitude of affordances in the field of education. These affordances can be amplified in educational MAR games (EMARGs) due to the motivational value and the fun factor provided by intriguing game elements. However, there is a gap in research on design guidelines for EMARGs, especially regarding the connection to motivators and disturbance factors that may have positive and negative effects respectively on the learning experience. In this chapter, we first describe related background, and then present two MAR case studies—a treasure hunt and a story-driven adventure game—to illustrate our experiences in designing EMARGs. We conduct a qualitative analysis of the case studies based on questionnaire answers and interviews of 29 and 112 participants respectively, to identify motivators (16, 20) and disturbance factors (11, 25) in the participants' gameplay experiences. Through an analysis of the motivators, disturbance factors and our design experiences, we proposed 24 design guidelines in six categories that can potentially strengthen motivators and diminish disturbance factors in MAR applications.

2.1 Introduction

Augmented reality (AR) has come far since the 1990s when the term emerged, and the first AR applications were introduced. Today, thanks to the proliferation of powerful smartphones and tablet devices, mobile augmented reality (MAR) has become as a mainstream technology that provides intriguing visualization and interaction

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opportunities across application domains. MAR has been further popularized by hit applications, such as the Pokémon GO game, which captured the interest of millions of players around the world, both children and adults alike. The development of MAR applications has been accelerated further by easy-to-use toolkits and content editors that allow developers to create MAR experiences. Examples of well-known AR application development toolkits that support mobile devices include ARKit by Apple, the open source ARToolkit, and Vuforia SDK. Additionally, there are solutions, such as Aurasma and Blibbar, that allow a non-technical individual to create MAR experiences without programming.

Because MAR has become a popular concept in research as well as in business, the scope of its definitions has also widened. In this chapter, we adopt the following definition of MAR, as originally proposed in (Laine 2018):

> Mobile augmented reality is a type of augmented reality where a mobile device is used to display and interact with virtual content that are overlaid on top of a real-time camera feed of the real world.

An important implication of this definition is the explicit notion of a mobile device as the tool through which augmented reality experiences are provided. Consequently, given the multitude of sensors that one can nowadays find crammed inside mobile devices, MAR applications not only support the free traversal of the user between contexts, but these applications may also become aware of other aspects of the user's context (e.g. activity detection) and thereby provide increasingly personalized and context-sensitive experiences.

One area where MAR applications have been particularly effective is education. Much research has been conducted regarding MAR for educational and training purposes across disciplines (Lee 2012; Wu et al. 2013; Bacca et al. 2014; Dunleavy and Dede 2014; Radu 2014; Chen et al. 2016; Fotaris et al. 2017; Laine 2018), with a number of identified affordances that MAR can bring to pedagogical scenarios (Cheng and Tsai 2013; Wu et al. 2013; Dunleavy and Dede 2014; Nielsen et al. 2016; Akçayır and Akçayır 2017). Moreover, educational MAR games (EMARGs)—which are the focus of this chapter—have been found to be used with success across subject areas and age groups (Laine 2018). One of the core advantages of gamifying educational MAR experiences is the increased learner engagement that is propelled by the intrinsic motivators that games possess (Malone and Lepper 1987; Garris et al. 2002; Sweetser and Wyeth 2005; Ryan et al. 2006; Yee 2006; Fu et al. 2009). Yet these motivators are not to be taken for granted; their presence requires deeper design than merely adding game mechanics to an educational concept.

In this chapter, we seek to identify concrete design guidelines that can facilitate creation of engaging and motivating EMARGs. To this end, we present and analyze two EMARG case studies: (i) Calory Battle AR—a location-based treasure hunt game that promotes physical exercise and supports educational quizzes at waypoints, and (ii) Leometry—a story-driven game for learning basic geometry. Both games run on Android devices and have augmented reality features to increase player engagement and motivation. The details of these games have previously been described in (Laine and Suk 2016) and (Laine et al. 2016), respectively.

The analysis of the case studies will be conducted with help of two constructs inherently present in virtually any learning environment: *motivators* and *disturbance factors*. Motivators (e.g. fantasy, advancement, control, social interaction, curiosity) are a positive force that aid the learning process, whereas disturbance factors (e.g. technical bugs, overly difficult tasks, harassment by other students) act as a counterforce that may damage the learning experience. EMARG designers should strive to maximize the presence and the strength of motivators, whilst diminishing or completely eliminating disturbance factors. Following these objectives, after identifying motivators and disturbance factors in the two case studies, we propose design guidelines for creating future EMARGs.

2.2 Background

2.2.1 Motivators and Disturbance Factors

We approach the design of EMARGs from the perspectives of motivators and disturbance factors, which in most cases can be considered to represent the positive and the negative forces targeting at the learning process. Maximizing motivators and minimizing disturbance factors form the essence of technology integration from the learner's perspective (Laine 2012). In this section, we define these the terms in detail and give examples from the literature.

2.2.1.1 Motivators

An effective learning process requires that the learner is motivated to learn the topic at hand. Motivators can stem from various sources, both intrinsic and extrinsic, but here we define them in more general terms as follows:

> Motivator is a positive force that help learners become interested in the task at hand, and to maintain that interest throughout the learning process.

Many studies have been conducted on motivators in the context of games and play, with dozens of potential motivators identified (Malone and Lepper 1987; Garris et al. 2002; Sweetser and Wyeth 2005; Ryan et al. 2006; Yee 2006; Fu et al. 2009). Table 2.1 illustrates 38 motivators that were assembled by a previous literature review on motivators in educational mobile games (Nygren et al. 2018). It is noteworthy that the list is not exhaustive, and some overlapping exists among the motivators (e.g. Sociability, Socializing, Social interaction, Teamwork).

Table 2.1 Examples of motivators found in games (Nygren et al. 2018)

Motivator	Motivator	Motivator
Advancement (Malone and Lepper 1987)	*Discovery* (Yee 2006)	*Performance* (De Grove et al. 2014)
Agency (De Grove et al. 2014)	*Escapism* (Yee 2006; De Grove et al. 2014)	*Recognition* (Malone and Lepper 1987)
Autonomy (Ryan et al. 2006)	*Fantasy* (Malone and Lepper 1987; Garris et al. 2002)	*Relatedness* (Ryan et al. 2006)
Believability (De Grove et al. 2014)	*Feedback* (Sweetser and Wyeth 2005; Fu et al. 2009)	*Relationship* (Yee 2006)
Challenge (Malone and Lepper 1987; Garris et al. 2002; Sweetser and Wyeth 2005; Fu et al. 2009)	*Habit* (De Grove et al. 2014)	*Role-Playing* (Yee 2006)
Clear goals (Sweetser and Wyeth 2005; Fu et al. 2009)	*Immersion* (Sweetser and Wyeth 2005; Yee 2006; Fu et al. 2009)	*Rules/goals* (Garris et al. 2002)
Competition (Malone and Lepper 1987; Yee 2006)	*Involvement* (De Grove et al. 2014)	*Sensory stimuli* (Garris et al. 2002)
Competence (Ryan et al. 2006)	*Knowledge improvement* (Fu et al. 2009)	*Social interaction* (Sweetser and Wyeth 2005; Fu et al. 2009)
Concentration (Sweetser and Wyeth 2005; Fu et al. 2009)	*Mechanics* (Yee 2006)	*Sociability* (De Grove et al. 2014)
Control (Malone and Lepper 1987; Garris et al. 2002; Sweetser and Wyeth 2005; Fu et al. 2009)	*Moral self-reaction* (De Grove et al. 2014)	*Socializing* (Yee 2006)
Cooperation (Malone and Lepper 1987)	*Mystery* (Garris et al. 2002)	*Status* (De Grove et al. 2014)
Curiosity (Malone and Lepper 1987)	*Pastime* (De Grove et al. 2014)	*Teamwork* (Yee 2006)
Customization (Yee 2006)	*Player skills* (Sweetser and Wyeth 2005)	

2.2.1.2 Disturbance Factors

Whereas motivators facilitate the learning process, disturbance factors are those aspects of a learning environment that can hinder the learning process. More precisely, we define disturbance factor as follows:

> Disturbance factor is an element of a learning environment that has a negative effect on the learning process.

This definition views learning environment as a wide concept, comprising not only the learner, but also the teacher, the technology, the physical environment, other learners, and anything else that connects to the learning process. Hence, any element that disturbs the learning process within the learning environment can be considered a disturbance factor. Examples of disturbance factors that one might find in a learning environment comprising a learning game in a classroom are software bugs, overly complex user interfaces, too difficult tasks, repetitive game missions, disturbing classmates, and inadequate technical ability of the teacher. The disturbance factor concept also applies to informal learning environments. For example, in a forest-based environmental education application the weather conditions might cause disturbances to the learning process.

In contrast to positive motivators, disturbance factors are typically portrayed as a negative force that may damage or even prevent prospective motivators (e.g. network connection problems can damage the *social interaction* motivator in a multiplayer educational game). The goal of identifying and diminishing disturbance factors in a learning system is to increase the learner satisfaction and thereby to increase the learning effectiveness.

Although disturbance factors are often negative, research suggests that there also exist positive disturbance factors (Nygren et al. 2018) that may initially appear to disrupt the learning process, but can in some cases facilitate it. One example of a positive disturbance factor is learning content that conflicts with the learner's ideas, thus challenging the learner to think deeper. For example, Moreno and Myller (2008) proposed a programming visualization tool for learners that applies the concept of conflicting animations where the animation unexpectedly and intentionally does not match the code. As another example, emotion-provoking learning content (e.g. a dramatic story) can feel disturbing, but it can also make the experience more memorable. It is clear that special care must be taken when deliberately introducing disturbance factors in the learning content to avoid overdoing them.

2.2.2 Previous Work on MAR Design Guidelines

As the EMARG is a fairly new concept, little research has been conducted on identifying design guidelines for building effective and engaging EMARGs. However, since AR has been around for a significantly longer time, many useful MAR guidelines have been proposed to aid MAR application development. Table 2.2 summarizes previous studies that we discovered when conducting a literature search on MAR design guidelines. Because EMARG is an extension of MAR, these results are also applicable to aid EMARG development.

In the following sections, we complement these previous guidelines, best practices and lessons learned by conducting an in-depth qualitative analysis of motivators and disturbance factors on two case studies, and then use the results to formulate design guidelines for EMARGs.

Table 2.2 Previous research on MAR design guidelines

Study	Description	Source
Dirin and Laine (2018)	7 best practices for designing the user experience of MAR applications	Mixed-method user experience evaluations of two MAR applications (a marketing app and a virtual campus tour app)
Ganapathy (2013)	8 MAR user interface design guidelines, and discussion about other design aspects, such as usage scenarios, input modalities, and form factor	Researcher's own experiences and ideas
Kourouthanassis et al. (2015)	5 design principles and 12 supporting design practices for MAR application development	Literature survey on design principles and MAR applications; validation of the design principles by analyzing eight MAR applications
Laine (2018)	13 guidelines in 3 categories (pedagogy, augmented reality, gaming) for developing EMARGs	A systematic review of 31 EMARG studies and two case study EMARGs
Laine and Suk (2016)	11 success factors and 9 lessons learned for MAR exergame design	An analysis of the design process and a mixed-method evaluation of a MAR-based exergame
Shukri et al. (2017)	11 guidelines in four categories for developing MAR applications in tourism	A literature review on design guidelines and design principles
Wetzel et al. (2011)	26 guidelines in 5 categories for designing MAR games	Analysis of the researchers' previous projects and existing AR games

2.3 Research Questions and Method

2.3.1 Research Questions

As we described above, this chapter is based on the constructs of motivators and disturbance factors. Consequently, to guide this research, we devised the following research questions:

1. What disturbance factors can be identified in the case studies?
2. What motivators can be identified in the case studies?
3. What are the design guidelines that can be used to diminish disturbance factors and strengthen motivators in EMARGs?

Table 2.3 Participants of the case study evaluations

	N	Males	Females	Mean age (range)
Calory Battle AR				
Korea (elementary school students)	11	6	5	13 (13)
Korea (university students)	18	16	2	24 (21–33)
Total	29	22	7	
Leometry				
Finland (elementary school students)	51	42	9	11.77 (10–13)
Korea (elementary school students)	61	32	29	12 (12)
Total	112	74	38	

To answer the research questions, we employed a qualitative strategy, details of which are explained in the following sections.

2.3.2 *Participants*

The case study games—Calory Battle AR and Leometry—were designed to promote the user's interest in physical exercise and geometry, respectively. Table 2.3 shows the number of participants, gender distribution and ages for each case study. Most of the participants were elementary school students in Korea and in Finland. Additionally, in the evaluation of Calory Battle AR, we involved some university students. All Korean elementary school students in the same class have the same age as per the Korean age reckoning system, which considers a new-born baby one-year old.

2.3.3 *Data Collection and Analysis*

For both case studies, we analysed the data collected via questionnaires and semi-structured one-by-one interviews. These instruments collected both quantitative and qualitative data, with the purpose of capturing the participants' insights into the game and their experiences from various perspectives, such as likes, dislikes, features, learning/physical exercise, and problems. For the purpose of this chapter, we only used the following qualitative questionnaire and interview questions to identify motivators and disturbance factors:

Motivators:

– What did you like/enjoy about playing the game? (questionnaire)

– Which part of the game did you like? Why? (interview)
– What was good in the game? (interview)
– Did you find out anything surprising when you were playing the game? What was it? (questionnaire)

Disturbance factors:

– What did you dislike or what was difficult about playing the game? (questionnaire)
– Which part of the game did you dislike? Why? (interview)
– How would you make the game better? (questionnaire/interview)
– Did you have any problems while playing the game? (interview)

The data collection was conducted by students who assisted the authors in this study. Appropriate consents of participation were acquired before the data collections commenced. The collected data was anonymized before analysis for ensuring privacy.

The collected data was analyzed by the authors using a coding technique (Saldana 2016) whereby the open answers from the questionnaires and quotes from the interviews were assigned codes representing certain motivators or disturbance factors. The coding process was iterative. For example, an initial list of codes were created based on the previously known motivators (see Table 2.1), to which more codes (i.e. motivators) were added as necessary. The identified codes were then analyzed and combined further with our experiences of designing the case study games in order to form higher level design guidelines.

2.4 Case Studies

2.4.1 Calory Battle AR

Calory Battle AR is a location-based AR game with a goal to motivate people to become physically active through competitive and fast-paced game mechanics. The original design of the game has been published in (Laine and Suk 2016). In the beginning of the game, the player is shown a secret combination of four colors that must be memorized in order to be used later in the game challenges (Fig. 2.1, left). Then, a map is shown with AR markers placed around a geographical area, and a countdown timer that indicates the remaining time left (Fig. 2.1, middle). The player should carefully plan in which order they proceed to find the markers so as to minimize the time used. Then, after finding a marker, the player scans it with the mobile device's camera, and completes a challenge in order to clear the marker. There are currently two types of challenges: AR bomb defusing challenge and a location-sensitive multiple-choice quiz challenge. In the former, the player is shown a picture of a virtual "calory bomb" with a countdown timer of a few seconds (Fig. 2.1, top-right). The bomb is defused by poking the four colored fuses in the correct order using the defusing tool. The multiple-choice quiz challenge shows a question related

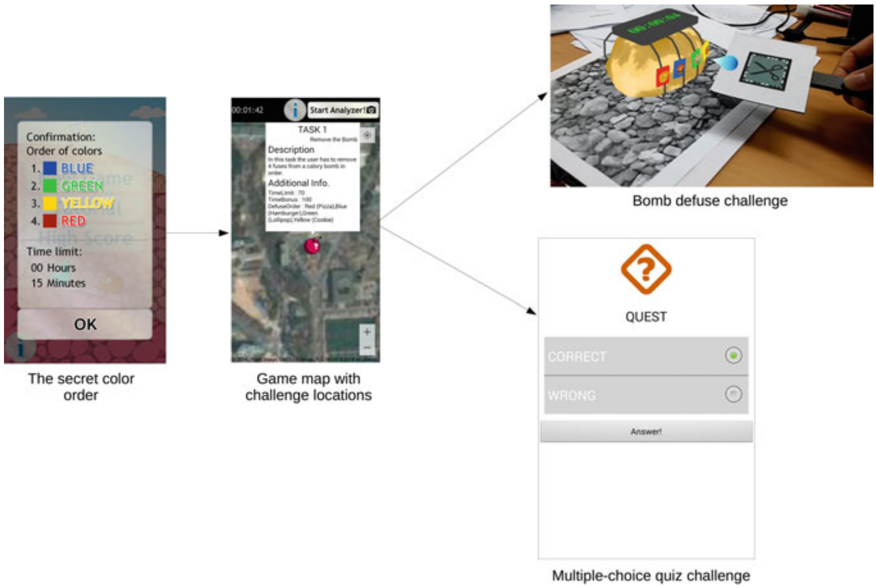

Fig. 2.1 Samples of Calory Battle AR screens

to a particular location and a few options, of which only one is correct (Fig. 2.1, bottom-right).

The game has a background story featuring the Dews and the Caloroids, which are characters representing the good and the evil in the game. The player's role is to help the Dews, who have a symbiotic relationship with us: they get their life force from our sweat and help us stay healthy by battling diseases. The Caloroids hate sweat and love calories, and they have deployed a series of "calory bombs" with other bluff challenges so as to damage our well-being. The game was originally aimed at children but it can be enjoyed by players of any age.

We also developed a web-based map editor which can be used to create custom game maps and publish them for players to download. For example, a parent could make a custom treasure hunt around a park to entertain kids during a picnic, or a teacher could make a map around a forest next to the school for a physical education class. The game clients have the ability to browse and search shared game maps, and download the selected maps to be played later.

2.4.2 Leometry

Leometry—a portmanteau of the words *leopard* and *geometry*—is a storytelling adventure game that aims to teach basic geometric shapes to elementary school students. The story takes the player on a journey with a mother leopard and her newborn cub, Senatla, on the African savannah. The story begins when the leopards escape from poachers and the player is asked to help them find a way back home. The road is filled with dangers, such as a river infested with crocodiles and hippos, and traps set by the poachers. The player's side-kick is a dung beetle named Dex who shows various geometry challenges to the players to solve in order to clear the obstacles. Dex also provides feedback and scaffolding hints to facilitate the learning process. Details of the development of Leometry and the results of a mixed-method formative evaluation are presented in (Laine et al. 2016).

Figure 2.2 illustrates some of the Leometry gameplay screens. Screen A shows a scrollable story screen, which can be a combination of text, pictures, and background sound. Screen B shows a virtual map of the first chapter of the story where the leopards have just escaped from the poachers and must now escape through three islands having shapes and challenges related to three basic geometric shapes (triangle, square, circle). Upon selecting an island, a series of learning challenges, such as the

Fig. 2.2 Samples of Leometry screens

one depicted in screen C, is presented for the player to solve. Feedback from Dex is illustrated in screen D. Screen E shows an AR map of the entire game, which thematically connects together the virtual maps (e.g. screen B). The player uses the AR map to select the next chapter or the story path. In addition to the AR map, we used AR to implement the poachers' traps; this is a boss challenge at the end of the game where the player must find and disarm a number of traps. The disarming technique is similar to that of the calory bombs described above: the player must poke the trap's pressure plates in a certain order in order to disarm it.

2.5 Results

In the following sections, we present the results of our data analysis. The results for the case studies are shown separately. For each game, we present the identified motivators and disturbance factors, which are then used to derive design guidelines in Sect. 2.6.

2.5.1 Calory Battle AR

2.5.1.1 Motivators

Table 2.4 lists 16 motivators that we identified by analyzing the qualitative questionnaire and interview data collected from the players of Calory Battle AR. The evidence column indicates supporting quotes from the players; we selected only the representative quotes because including all evidence would make the table very large. Moreover, some of the quotes appear multiple times as they identify more than one motivator.

It is important to notice that while some of the motivators are similar to those presented in Table 2.1, there are several motivators (e.g. AR content, AR interaction, navigation, nostalgia, physical movement) that are specific for the location-based exergame genre. Moreover, we distinguished the altruism motivator from fantasy (i.e. the background story) because not all stories assign the role of altruistic helper to the player.

Table 2.4 Motivators identified in Calory Battle AR

Motivator	Evidence
Achievement	[I liked] the achievement when I removed the bomb (male, 21)
Altruism	Sorry Dew that I couldn't save you (male, 21)

(continued)

Table 2.4 (continued)

Motivator	Evidence
AR content	The virtual bomb was wonderful (male, 21) Augmented reality is amazing (male, 27) Bomb's appearance on the screen and the process of defusing the bomb are exciting (male, 25)
AR interaction	[I liked] finding bombs and cutting the wires (male, 13) [I liked] defusing the bomb (female, 13) Bomb's appearance on the screen and the process of defusing the bomb are exciting (male, 25) [I liked] when I found bombs and defused them (male, 23)
Believability	I felt like finding a real bomb (male, 13)
Control	[I liked] finding bomb on my own (male, 13)
Discovery	Finding bomb on my own and running was fun (male, 13) [I liked] finding together with a friend (male, 13) [I liked] when I found bombs and defused them (male, 23)
Fantasy	Sorry Dew that I couldn't save you (male, 21) Dew, it is good that you do not burst when Caloroids burst (male, 21)
Fun	Finding bomb on my own and running was fun (male, 13) It is fun to find with my friend (female, 13) The process of finding a bomb is fun (male, 29)
Navigation	Finding bombs, finding locations on the map was fun (male, 25) Like a treasure hunt, finding bombs with a map is fun (male, 21) Finding the way was fun (male, 26)
Nostalgia	When I found the bomb hidden in the Yulgok hall, I recalled treasure hunting that I played when I was young (male, 26)
Physical movement	[I liksed] running to find bombs (male, 26) [I liked] that fact that my body has to move (male, 24) When I run the feeling is good (male, 27)
Teamwork	[I liked] finding together with a friend (male, 13) It is fun to find with my friend (female, 13) [I liked] running with a friend (male, undisclosed) Playing with a friend is fun and fresh (male, 23) [I liked] playing in a team, it feels like treasure hunting (male, 33)
Technology	[I liked] using the mobile phone and using the surrounding environment (male, 21)
Tension	[I liked] the thrill and tension (female, 13) [I liked] running and defusing in a limited time (male, 30)
Thrill	[I liked] the thrill and tension (female, 13)

2.5.1.2 Disturbance Factors

The disturbance factors (11) that were extracted from the data of the Calory Battle AR players are presented in Table 2.5 together with relevant evidence. ZPD stands for Vygotsky's Zone of Proximal Development, which is used to describe appropriateness of the challenge level of learning tasks. Like above, we only included representative quotes from the players. The results suggest that the game suffers from several disturbance factors that may affect the experience. For example, interaction with the AR bombs (i.e. poking the bomb fuses with the rod) was considered tricky by several players, as it requires a good amount of precision. This disturbance factor could be diminished by using an in-game tutorial, as one player suggested, that would allow players to practice AR interaction before starting the game. Graphical representation, especially the resolution of the game map, also received some criticism. Finally, one player commented that the game should show the current location on the map. This feature actually exists, but perhaps the icon indicating the current location is not sufficiently clear.

Table 2.5 Disturbance factors identified in Calory Battle AR

Disturbance factor	Evidence
Beyond ZPD	Bombs were hard to find (male, 13) It is too hard for beginners (male, 24)
Cognitive load	Allow seeing the color sequence again (female, 21) The color sequence gets confused when running (male, 27) Remembering the color order [was difficult] (male, undisclosed)
Inappropriate graphics	I don't know why the shape [of the defuser] is a water drop. It would be better to change the shape to be more sharp (male, 26)
Inconvenient AR interaction	Cutting the fuse was difficult (male, 13) It is difficult to defuse a bomb with the stick (male, 13) When defusing the bomb control is not good (male, 25) When defusing the bomb, the line is not cutting (male, 21) When the bomb is on the ground, it is hard to push the fuse exactly. It would be better if the fuse would be a little higher (male, 21) One time the recognition was not good and the bomb exploded (male, 26)
Lack of customization	I want to change the image of my location (male, 24) It would be better to allow choosing the time and see the color sequence later again, I forgot it often (male, 24)
Lack of realism	Design bombs to be more realistic (female, 13) The bomb is viewed with the camera, so it would be good to use a real picture [of the bomb] (male, 26)

(continued)

Table 2.5 (continued)

Disturbance factor	Evidence
Lack of time	Please extend time and reduce the number of bombs (female, 13) Time is too short (female, 31) I worried that I cannot complete the game in time, and I found it hard to find the bombs. It would be good if the game was longer. (male, 24)
Lack of tutorial	It would be good to teach how to use the defuser (male, 23) What is Dew? (female, 24)
Navigation	It will be good if it lets me know my current location (male, 21) Finding the way was difficult (female, 13) Bomb locations are a little bit different with the map (male, 21)
Physical movement	It is hard to run (female, 13) Running was difficult (female, 13) Friends ran faster than me, I was exhausted (female, 13) [I disliked] that I had to run (male, 13)
Quality of graphics	If the icon for defusing the bomb would be bigger, it would be better (male, 30) Increase the map resolution (male, 21) Map resolution is not good so it is hard to follow the map (male, 21) It would be good if the map would be clearer (male, 24)

2.5.2 Leometry

2.5.2.1 Motivators

Our analysis of the Leometry data collected by questionnaires and interviews from Finland and Korea revealed 20 motivators that are listed in Table 2.6 with supporting evidence samples. Some of these motivators are similar to those in Table 2.1, and there also exists correspondence between many of these motivators and the motivators identified for Calory Battle AR in Table 2.4. Commonly reported motivators include challenge, fantasy, fun and usefulness, which directly reflect the Leometry's genre as a story-driven game with mathematical challenges. We were somewhat surprised that many students saw the presence of mathematics in the game as an asset that made the game interesting to them. Moreover, novelty of the game was seen as a motivator by some students, as they probably had not played a game like Leometry before.

2.5.2.2 Disturbance Factors

The players in Finland and in Korea reported various things that they did not like or that they would improve in Leometry. A synthesis of these comments is presented in

Table 2.6 Motivators identified in Leometry

Motivator	Evidence
Achievement	[I liked] when I succeeded (male, 12)
Advancement	It was interesting when I solve a question and go next step (female, 12) I feel some satisfaction when I clear the stage and go to next stage (female, 12)
Adventure	[I liked] the adventure (male, 11) While I play this game, it feels like an adventure (male, 12)
Altruism	[I liked] helping the leopards (female, 11) It was good that the game is related to math and helping animals (female, 12)
Appearance	Good story and nice graphics (male, 12)
AR content	It was very interesting when I took the camera close to the marker, something would come out (female, 12) [I liked] the camera function (female, 12) Finding hidden things by using the smartphone was the most fun part of the game (female, 12)
AR interaction	[I liked] disarming the trap (male, 12)
Challenge	[I liked] the questions (male, 12) This game made me think many times because the questions were difficult, but it was fun (male, 12) Solving the mathematical questions was interesting (female, 11) I wanted keep trying to solve the problems when I selected the correct answer (female, 12)
Clear goals	Instructions were clear and tasks were nice (female, 11)
Competence	[I liked] when I answered a correct answer (female, 12) I wanted keep trying to solve the problems when I selected the correct answer (female, 12)
Fantasy	[I liked] the animals in the game (female, 11) The leopard was so cute (male, 12) The story was interesting (male, 12) The story with the leopards was interesting, and I can use math in a fun way (female, 12)
Feedback	It was interesting. I can review the problem what I solved previously (female, 12)
Fun	The gameplay was fun (female, 11) The game story and math quizzes were not boring. It made me have fun (female, 12) This game helps understand math and people can play with a lot of fun (female, 12)
Immersion	You collected the devices from us too early (female, 12) It could be better if there is no ‘Game Over’ (male, 12)

(continued)

Table 2.6 (continued)

Motivator	Evidence
Novelty	[I liked it] because it was a new experience (male, 12) Until this time, there have been no other games like this (male,12) I was really enjoying this game because I have never seen this kind of game before (male, 12)
Relaxation	It solved my stress (male, 12)
Surprise	It was very interesting when I took the camera close to the marker, something would come out (female, 12) I was excited when the figure comes out (female, 12)
Teamwork	I was excited when the figure comes out (female, 12) It was interesting that I can play the game with other friends (female, 12)
Technology	Playing with a smartphone was interesting (female, 12)
Usefulness	It was interesting. Good story and it teaches math! (male, 12) I was happy because I could learn math by playing the game (male, 12) Good thing is that it can raise interest towards studying mathematics (male, 12)

Table 2.7 as 25 identified disturbance factors. Similar to the case of motivators, some of these disturbance factors also correlate with those identified in the Calory Battle AR evaluation. Some of the disturbance factors are problems in the game implementation (e.g. Language errors, technical faults, lack of technical performance), some relate to pedagogical design (e.g. below/beyond ZPD, lack of scaffolding, unclear instructions, monotony), some are about usability (e.g. inconvenient (AR) interaction, lack of control, inappropriate sounds), and some can be thought of stemming from the differences in players' preferences (e.g. disturbing content, inappropriate graphics, lack of competition, unfairness, too short, and wrong age group. Finally, some of the identified disturbance factors can in some situations be thought to be positive rather than negative. For example, the disturbance factors conflicting content, disturbing content, and lack of time can stimulate the player's thinking process when applied responsibly.

2.6 Guidelines for Designing EMARGs

After identifying the motivators and the disturbance factors presented above, we analyzed them in conjunction with our experiences and observations as supervisors of the design processes of the case study games. The goal of this process was to combine the insights of the players with our knowledge and experience, which were then distilled into reusable design suggestions for future EMARG designers. As a result of this process, in Table 2.8 we propose 24 design guidelines divided into six categories. For each guideline, we identify which motivators the guideline helps strengthening, and which disturbance factor it helps diminishing.

Table 2.7 Disturbance factors identified in Leometry

Disturbance factor	Evidence
Below ZPD	It was really easy (male, 12) Some tasks were really easy (male, 12)
Beyond ZPD	Questions need to become more easier than now (male, 12) The questions difficulty were going harder and harder. Maybe younger children couldn't solve it well (female, 12)
Conflicting content	Square is a part of the rectangle. But in this game, this rule is not considered (female, 12) There was an error that said 'wrong' when I chose the correct answer. When I clicked confirm again, it said 'correct' (male, 12)
Language errors	Fix the typos (male, 12) There was a typo in "to beginning" (male, 12)
Disturbing content	I was sad when the leopard died (female, 12)
Inappropriate content	I didn't like the triangles (male, 12) There were no guns. It should have war, and there should be more animals when you do the tasks (male, 10) Please make more interesting questions (female, 12)
Inconvenient AR interaction	The trap disarming did not work well when I pressed each color button (female, 12) The accuracy is not good enough (male, 12) I couldn't play the game because it didn't work when I selected the map. Fix the error where the map doesn't react to input (female, 12)
Inconvenient interaction	It could be better if this game have big size button (female, 12) Fix the crashing bug and the buttons that didn't work by touching. Make the buttons bigger (female, 12)
Lack of access	I can't play this game all the time. It would be nice if I could play this game when I want it (female, 12)
Lack of competition	It would be nice to be able to compete against others (female, 11)
Lack of control	It would be nice to control the leopard (male, 11)
Lack of customization	It should be possible to choose the music (male, 12) It could be better if I can change the animals (male, 12)
Lack of realism	Improve graphics to more realistic (male, 12) Everything is good except there is no body for leopard (male, 12)
Lack of scaffolding	It should give more hints and the hints should be clearer (male, 11) Give more hints if the question is difficult (male, 12)

(continued)

Table 2.7 (continued)

Disturbance factor	Evidence
Inappropriate sounds	Music was too loud (male, 12)
Lack of technical performance	Loading took too much time (female, 11) So much lagging existed (female, 12) The game was stopped for a short time continuously (male, 12) There was too much lagging (male, 12)
Lack of time	[I disliked] the lack of time (male, 12) You collected the devices from us too early (female, 12)
Monotony	I want other animals, not leopard (female, 12) It could be better if there were more animals (male, 12) I want to see other questions in other subjects, not math. And I want play with other animals (female, 12)
Unfairness	I couldn't clear all stages because I chose a wrong answer. That was sad. (female, 12) It was little bit annoying that I need to solve it all again if I choose the wrong answer at the last step (female, 12) [I disliked] going back to the start position if I didn't get any score (female, 12)
Quality of graphics	It needs better graphics and better playability (male, 13) Graphics should be better and the bugs should be removed (male, 12)
Technical faults	The game didn't work in the second island (male, 12) Fix the crashing bug and the buttons that didn't work by touching (female, 12)
Too educational	[I disliked] calculating the numbers. Add some kind of playable content, not related to math (female, 12)
Too short	[I disliked] when the game is over (female, 12) It could be better if there is no 'Game Over' (male, 12)
Unclear instructions	It should give more hints and the hints should be clearer (male, 11) It was hard to understand the questions (male, 21)
Wrong age group	It should have war. Too childish game! (male, 10)

2.7 Discussion

The 24 identified guidelines are not comprehensive but they certainly give a good starting point for designing EMARGs and other MAR applications. There also exist many other design guidelines, such as the ones listed in Table 2.2, as well as guidelines specifically targeted at designing educational applications (Beale and Sharples 2002; Mak and Nathan-Roberts 2017) and games (Chou 2015; Schell 2015). We invite the readers interested in EMARG design to review existing guideline publications and combine a set of guidelines that works the best for the intended scenario.

Table 2.8 Guidelines for strengthening motivators and diminishing disturbance factors in EMARGs

Guideline	Disturbance factor (DF), Motivator (M)
Gameplay	
Provide opportunities for competition and collaboration, and allow the player to choose their preferred gameplay mode	Competition (M), Teamwork (M)
Encourage world exploration by physical movement; however, make sure that the extent of movement matches with the requirements of the pedagogical setting (e.g. available time, safety requirements) and provide per-player customization option of the amount of required movement	Physical movement (DF), Physical movement (M)
If the game requires physical movement, allow players to use navigational skills but provide appropriate level of guidance if they cannot find the place (e.g. analysis of movement patterns)	Navigation (DF), Navigation (M)
Avoid repeating similar content and game activities for a long time (even if the player repeatedly makes a mistake), and try to surprise the player occasionally	Monotony (DF), Surprise (M)
Nurture engagement through tension (e.g. timed tasks, limited resources) but ensure that the overall experience leaves the player relaxed.	Immersion (M), Tension (M), Thrill (M), Relaxation (M)
Provide a way for the player to find hidden and/or surprising things to proceed in the game.	Discovery (M), Surprise (M)
Scaffolding and progress	
Allow the player practice AR interaction before playing the game for the first time	Inconvenient AR interaction (DF), Inconvenient interaction (DF), AR Interaction (M), AR Content (M)
Provide an in-game tutorial on the essential game features, as well as contextual and personalized scaffolding hints (e.g. based on the player's location and their skill level) to the player	Lack of scaffolding (DF), Lack of tutorial (DF), Unclear instructions (DF), Feedback (M)
Provide clear instructions on the game's objectives and on reaching those objectives.	Unclear instructions (DF), Advancement (M)
Show the progress of the gameplay to the player by for example points, trophies, and milestones	Feedback (M), Achievement (M), Advancement (M)
Customization and control	
Allow customization of gameplay experience by the player and by the teacher (e.g. story creation, challenge creation, changing preferences). This can be done with a dedicated story editor, for example	Lack of control (DF), Lack of customization (DF), Control (M), Technology (M), Fantasy (M)

(continued)

Table 2.8 (continued)

Guideline	Disturbance factor (DF), Motivator (M)
Allow the player to control and manipulate the game world, including characters and interactable game objects	Lack of control (DF), Control (M)
Pedagogy	
Detect the player's skill level and adjust the difficulty of challenges and other parts of the game content so that the player can stay in the ZPD	Below ZPD (DF), Beyond ZPD (DF), Wrong age group (DF), Challenge (M)
Avoid overemphasizing pedagogy at the expense of watering down the fun factor of gameplay; strive for seamless integration of learning content and game mechanics	Too educational (DF), Fun(M)
Ensure that a game session length complies with the intended pedagogical setting (e.g. a classroom) and allow continuing the gameplay at a later time	Lack of time (DF), Too short (DF), Lack of access (DF)
Be fair when the player makes a mistake; use a constructive carrot rather than a stick	Unfairness (DF)
Nurture understanding of the player on how the game and the pedagogical content can be of use in the real world (i.e. real-world relevance). The relevance of AR content to the real world context is especially of importance	Usefulness (M), AR Content (M)
Provide challenges that do not rely too much on remembering facts, but understanding them. If cognitive load is necessary, allow dividing it among team members, for example	Cognitive load (DF), Teamwork (M)
Provide positive disturbances (e.g. disturbing content, conflicting content) to challenge the player's ideas and make them think deeper	Disturbing content (DF), Conflicting content (DF)
Immersion and fantasy	
Provide a sufficient level of realism, fantasy and immersion to help achieving suspension of disbelief (Brown 2012)	Lack of realism (DF), Quality of graphics (DF), Technical faults (DF), Lack of technical performance (DF), Believability (M), Fantasy (M), Fun (M), Immersion (M), AR Content (M)
Give the player a chance of becoming a "hero", thus feeding achievement, altruism and fantasy	Achievement (M), Altruism (M), Fantasy (M)
Provide a well-written story (or another structure) that connects together various game components and helps immersing the player in the experience. If possible, connect the story to something that the player already knows	Lack of Control Fantasy (M), Immersion (M), Nostalgia (M)

(continued)

Table 2.8 (continued)

Guideline	Disturbance factor (DF), Motivator (M)
Media and technology	
Utilize rich media content that facilitates immersion in the game experience, but use mock-up testing with end-users to ensure that the media used in the game are appealing and acceptable	Inappropriate graphics (DF), Quality of graphics (DF), Inappropriate sounds (DF), Appearance (M), AR content (M)
Apply state-of-the-art technologies to implement the game, but also create and execute plans for technical and usability tests to ensure that the technology and the game content work in most situations	Technical faults (DF), Lack of technical performance (DF), Language errors (DF), Technology (M), Novelty (M), AR content (M)

Using a fairly straightforward iterative analysis approach on the collected qualitative data, we were able to identify rich sets of motivators and disturbance factors from both Calory Battle AR and Leometry. Yet the numbers of identified motivators and disturbance factors for Leometry were higher than those identified for Calory Battle AR. A possible reason for this is that the number of participants in the Leometry evaluation (112) was significantly higher than that in the Calory Battle AR evaluation (29). Moreover, Leometry has a richer set of features than Calory Battle AR, which directly translates to more possibilities of errors.

It is interesting that an aspect that is a motivator to one player, can be a disturbance factor to another player. For example, physical movement and navigation features were both praised and blamed by the players of Calory Battle AR, thus revoking the idea that one game design could fit all player types. Another aspect that supports this notion is that some of the Calory Battle AR players considered the bombs to be realistic, whereas others requested to have even more realistic bombs. This connects to the concept of suspension of disbelief (Brown 2012) that manifests itself in gaming as the player's immersion in the gameplay by voluntarily putting aside the laws of physics, logic and other real-world ideas that could shatter the foundations of the imaginary game world. Indeed, one of the major challenges of any game designer is to achieve suspension of disbelief among the players. We believe that strengthening motivators and diminishing disturbance factors using appropriate design guidelines is a potential approach to achieve this.

Becoming aware of various disturbance factors and following related EMARG guidelines to avoid them does not guarantee disturbance-free learning experiences. There always exist a possibility for disturbance factors that cannot be controlled by the designer. For example, harsh environmental conditions, harassment by other players, and unexpected technical faults cannot be fully prepared for. Moreover, there can also be emergent disturbance factors that are not known of until the game is in use. Designers are therefore recommended to employ an iterative design-implementation-evaluation processes—preferably with end-user involvement in all phases—that allows such emergent disturbances to be identified and tackled early.

2.8 Conclusions

The main contribution of this chapter was to provide a set of 24 guidelines in six categories that EMARG designers, and MAR designers in general, can utilize to facilitate their design processes. The guidelines can also help designers to avoid certain pitfalls and apply good design practices. We achieved this contribution through answering the three related research questions via a qualitative analysis of data from two case study EMARGs. The results can be of interest not only to EMARG designers but also other individuals involved in a game's lifecycle, including but not limited to developers, evaluators, researchers, teachers, and of course students as end users.

In the process of writing this chapter, we were reminded of the old fact that design is a difficult topic to handle objectively. Unlike science, design is largely based on creativity and the designer's interpretation of the available facts (e.g. requirements) and supporting guidelines. Thus, when two independent designers use the same set of design guidelines, they most likely come up with different results. Yet fundamental similarities are likely to exist in these designs, especially if they were drawn from the same set of guidelines.

Another contribution of this chapter was the use of motivators and disturbance factors as tools to evaluate the case studies and to subsequently devise the design guidelines. Similar to design processes, coming up with the design guidelines presented in Table 2.8 was affected by our subjective, tacit experience in designing and evaluating the two EMARGs. If the same task would be given to another researcher, the results would most likely differ. Yet the process by which the guidelines were extracted—that is, identifying the motivators and disturbance factors and then analyzing them—provides a common ground for guideline derivation. Therefore, we believe that the proposed method can be used in the future to create design guidelines for MARs and other applications, or to simply evaluate what worked and what did not work.

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Chapter 3
Augmented Imagination: Creating Immersive and Playful Reading Experiences

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Abstract Reading is a complex process that is changing dramatically during the ongoing evolution from purely physical books to digital ones. Between the two poles of physical and digital, there is an emerging field where physical is being augmented by digital and vice versa. In this chapter, we investigate physical and digital approaches to the book augmentation. Physical approaches do not embed any electronic elements into the book. On the contrary, in digital approaches interactivity is supported by embedding electronic devices into the physical book, holding devices above the book or by placing electronic devices around the reader. Firstly, we describe and analyse 10 augmented books that use different augmentation techniques (along the following three dimensions: the modalities being used, the type of content on offer, and the impact of the augmentation on the reading flow). We then emphasise the need for further investigation of the ways for delivering multimodal and immersive content, in which the processes of reading the original text, interacting and consuming the digital content merge into one unified experience that does not disrupt the reading flow and enhances the sense of immersion in the story. Finally, we illustrate how we could move towards this vision of a unified augmented reading experience using different technologies, such as: speech recognition systems, eye- and head-tracking

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systems, olfactory displays, smell synthesizers and digitally-controlled food delivery systems.

3.1 Introduction

People consume more and more digital information through rapidly and constantly changing technologies. These changes also have an effect on the way people read (Baron 2017). However, it appears that reading comprehension skills have not significantly improved since 2009 (OECD 2015), showing that the potential of new technologies to improve reading experience and reading skills remains largely underutilized.

We believe that if new mediums are to replace or complement traditional printed books, they could and should also be used to enhance the reading experience and reading skills. More precisely, we believe that technology, if well implemented, can be used to:

(1) engage readers—for example, by providing interesting and relevant content using different sensory modalities;
(2) make experiences more meaningful—for example, by providing readers with appropriate additional content.

In this chapter, we discuss to what extent we can enhance reading experience using digital technology. In particular, we focus on how technology can be used to augment users' imagination without interfering with the reading flow. To do so, we first introduce the concepts of reading, reading experience and imagination. We then define two main approaches for book augmentation (physical vs. digital approaches) and introduce a set of criteria for the augmentation of books. After this, we illustrate different digital-augmentation techniques by describing 10 augmented books. In the fourth section, we analyse these books according to the sensorial modalities that they involve, their impact on the reading flow, and their augmented content. Finally, based on these analyses, we explore the design space of augmented books, focusing on future implementations.

3.1.1 What Is Reading?

Reading is a complex activity that can serve various goals. While some people read books for entertainment only, others read books to gather new knowledge and enhance their abilities (OECD 2000; Bown 2001). Depending on the reader's intention, the term 'reading' may therefore cover different concepts.

From a pedagogical perspective, reading is "the process of constructing meaning from written text. It is a complex skill requiring the coordination of a number of interrelated sources of information" (Frankel et al. 2016). From a literary perspective, reading refers to an activity that establishes a link "between the reader's mind and the universe described by the author in the text" (Ramirez Leyva 2009).

In fact, it is possible to distinguish between at least two types of reading, namely: active and ludic reading. Active reading is practiced by people who read because they need to (e.g. to study and acquire new knowledge) and requires that readers have critical thinking abilities, are able to construct new meanings, and are capable of applying acquired information and a particular meaning to a specific context. Active reading is particularly useful for learning purposes (Schilit et al. 1998) and relies on different techniques, such as underlining important notions or writing marginal notes. Active learning can also be facilitated by the use of illustrations or highlighted sections, which can trigger complementary research. On the other hand, reading for entertainment, also referred to as "ludic reading", can be considered as a "play activity" of which the main goal is to immerse the reader into the story or into a pleasurable, fun experience (Nell 1988; Hupfeld et al. 2013). Emotions, imagination and narrative play an important role on the reader's experience of immersion.

Reading is associated with several benefits. For example, reading enables people to expand their vocabulary (Hargrave and Sénéchal 2000), and to improve their reading comprehension skills. This can, in turn, positively impact the reader's ability to communicate efficiently, as well as their ability to acquire and generate knowledge (Snow and Sweet 2003). In addition, previous research showed that reading reduces the risk of mental diseases (Pennebaker and Seagal 1999). Altogether, these studies highlight the fact that reading is very important for the development and prosperity of societies. However, despite the mentioned benefits, results from the 2015 PISA test (a worldwide-recognized evaluation in reading, science and mathematics) have shown that at least 40% of students from countries that belong to The Organization for Economic Co-operation and Development (OECD) group are below the PISA average in reading comprehension (OECD 2015). These reading scores are actually an indicator of human development and economic growth of a country.

3.1.2 Reading Experience and Imagination

Imagination can be seen as a mental process that is fed through information obtained by our senses (Pelaprat and Cole 2011). More precisely, in reading, imagination "involves the power of reproducing images stored in memory under the suggestion of associated language or of recombining former experiences to create new images that vitalize and animate the text" (Sadoski et al. 1990). In other words, during reading, the visual stimuli (i.e. the text) is converted into streams of information and meaning that result in "new concepts, realities and generate ideas" (Vygotsky 2004; Marzo 2016). The reading experience is therefore influenced by our language, our knowledge and our previous experiences.

For instance, readers may have never seen the Mississippi river but know from experience or by research how a river looks like. They construct their own mental image of the Mississippi river in their mind by combining their past experiences of rivers with elements from the text that they are reading (e.g. adjectives, verbs, etc.). Their mental image of the Mississippi river may end up being very different from the real Mississippi river, but also from other readers' mental images. Hence, the reading process results in a new personalized "reality".

Many studies pointed out that a good reading experience can have significant positive impacts, such as involving new readers, engaging readers, and enabling readers to understand abstract or complex topics (Sprecken et al. 2000; Obaid et al. 2016; Nation 2017). The use of imagination also enables people to improve their comprehension and creativity skills and to have more fun when reading (Sadoski et al. 1990; Usherwood and Toyne 2002; Vygotsky 2004; Woolley 2014). Berns et al. also showed that reading fictional novels could result in "significant alterations" in the brain, which affect "networks associated with short-term changes" (Berns et al. 2013).

Even though books predominantly convey the story through text, many of them also complement text with supplementary material (e.g. illustrations) or using different narrative styles or colours, etc. These elements are designed to enhance the reader's imagination and, consequently, create a more immersive reading experience. Supplementary materials are particularly important when the reader has problems with language or reading skills, a common situation for children who are learning how to read. Digital technology offers a new medium through which complementary materials could be served to the reader, in order to enhance their reading experience and imagination.

3.1.3 Existing Approaches for Augmented Books

Reading experience can be designed and improved by enhancing the story that is being told or by providing the reader with additional content that complements the story. In this chapter, we focus on the ludic reading coupled with the latter. We also make the distinction between two approaches that can be used to do so, namely: physical and digital approaches.

Physical approaches do not rely on any electronic devices to provide complementary materials. Instead, they rely on the physical aspects of the book, such as the printed content or the book itself. Examples of supplementary materials implemented through physical approaches include, but are not limited to, illustrations, games, the action of handling a book and physical modification of the book (e.g. scratching, folding parts of the book—see Fig. 3.1). Tap the Magic Tree[1] is one example of a book that is augmented using a physical approach. It is a printed book that provides instructions which guide the reader through different steps. The reader must follow these instructions in the appropriate order to complete the story. The instructions include touching, shaking or jiggling the book. Each action enables the reader to

[1]Tap the Magic Tree by Christie Matheson: https://www.harpercollins.com/9780062274465/tap-the-magic-tree-board-book/.

Fig. 3.1 Augmented physical books. Top left: a magnet-based dress-up book where the reader dresses up the book characters based on the context. Top right: a pop-up book with characters and additional objects on the side, which the reader can move within the pop-up scene and from page to page. Bottom left: a book with figurines and a playing mat representing the living areas of the main character's house. Bottom right: a sound book where the reader presses buttons on the right edge of the book and plays sounds based on the page they are on

reveal the content of the following page. For example, the reader is asked to touch each bud of the tree before turning the page. On the following page there is a picture of the tree with flowers instead of buds.

Digital approaches consist of embedding electronic devices in the book itself, replacing the book and/or adding external technology to the book. Some examples of this approach are: sound books (Fig. 3.1 bottom right), Electronic Popables (interactive pop-up books that integrate flexible paper-based electronics, allowing readers to turn lights on and off in the pop-up designs (Qi and Buechley 2010) and e-books (digital documents that contain the electronic version of a printed book, and that are accessible with electronics devices only, such as computers, mobile phones, e-readers) (Li et al. 2016). Another technique is to augment the book with hyperlinks (e.g. through QR codes), which enable the reader to access additional content (e.g. a video or augmented-reality content).

In this chapter, we will focus on digital approaches. We are particularly interested in how these can be used to augment the reading experience and imagination of the reader. We use the term "augment" to describe the enhancement, amplification and increased immersion of the reading experience and reader's imagination. We do not use the term "augment" to describe augmented reality technology, although it may be used as a tool to augment reading experience and imagination.

3.1.4 Regarding Ludic Reading Flow

It is important to note that the techniques used to augment the book have different impacts on the reading flow. While some of them do not interfere with it, others may disrupt it—for example when the reader must switch between the book and another electronic device, such as smartphone. If the technology is used to enhance the reading experience, then it should not interfere with the reading flow. Therefore, we propose that the (ludic) reading experience is "augmented" only if the following criteria are met: (1) the content is tightly tied to the story; (2) the interactive technique that enables the reader to consume the content is seamless and unobtrusive (i.e. it does not require the reader's focus of attention); (3) the interactivity does not interrupt the storytelling narrative and the reading flow. In other words, the supplementary content needs to be consumed as part of a hybrid experience that combines both the reading of the printed material and the (passive or active) interaction with the digital content. This creates one unified medium through which the story is being told.

If reading and interaction are experienced separately, then the reader is faced with a segmented experience: the complementary content interrupts the reading flow and is consumed in a disconnected way. We refer to these approaches as the "hypermediation" (Park et al. 2010) of reading experience. In fact, in these situations, the system only creates hyperlinks between different mediums (e.g. text, video and sounds) and diverts the readers' focus of attention from one medium to another, which disrupts the reading experience and is likely to reduce the feeling of being immersed into the story.

3.2 Augmented Books

When mentioning reading in this chapter we always refer to ludic reading. In order to better understand how well current systems support the augmentation of reading experience, we first review a set of prototypes that attempt to do so. Instead of providing an exhaustive list of prototypes, we chose to focus on illustrative examples, which are presented and discussed in more detail. The goal is to identify the missing gaps in knowledge and examine the design space of hybrid reading experience to offer ideas for future developments.

Different augmentation techniques have been used within the digital approach. Some use a physical book in combination with external devices such as speakers, ambient lights or smartphones (in particular for Augmented Reality-based books); others rely on tablets only (i.e. they do not require any physical books) (Hallmark; Back et al. 2001; Weerasinghe and Quigley 2018)

The most common type of augmented books are books that embed buttons which can trigger particular sounds or music (see Fig. 3.1 bottom right). These books are particularly interesting for children who do not know how to read yet. Some even allow users to record their own voices. For example, Hallmark Cards Inc. released the *Recordable StoryBook*[2], which is a storybook that allows users to record voices over a printed-paper book with an integrated sound recorder. This system supports two main interactions: the recording of reading the story and playing the recording of the story. To record the story, the user simply reads aloud while pressing the record button; to play the story, the user must flip pages. The idea aims to strengthen relationships between family members by integrating an "emotional" value into the reading experience (e.g. a grandparent's voice recorded for grandchildren to listen to while flipping the pages of the book). See Fig. 3.2 for a schematic representation of the Recordable StoryBook.

Although the use of buttons is interesting, it is also very limiting in terms of input. An alternative with additional input device, such as a pen or the reader's finger, is *LeapPad* (Gray et al. 2009; LeapFrog 2018), a book and pen system intended to be used by children (see Fig. 3.3 for schematic representation). It is composed of a dedicated case in which users must insert a LeapFrog proprietary-book, with which they can interact using a dedicated pen that is tracked by the system. When touching a word or an image, the reader can listen to the corresponding content, read by a voice synthesizer. They can also play the whole story by pressing a button embedded in the case. Furthermore, LeapPad also supports self-assessment: the reader can answer a questionnaire by touching the right answers in the book.

Instead of focusing on the book only, several projects investigated the use of external devices and stimuli to enhance the reading experience. For example, *Listen Reader* (Back et al. 2001) combines music, sounds and projected graphics to create a special and multimodal atmosphere around the reader, who is sitting on a comfortable sofa (see Fig. 3.4 for schematic representation). The system combines RFID technology and Electric Field Sensing in order to identify the page that is being read and continually measures the distance between the hand and the book. This enables the system to augment printed text and images with sounds that are related to the content of the page being read and that are continuously played in the background. Whenever the user's fingers touch a different part of the page, a new sound is played in a loop until the user turns the page or touches another element. The sounds are mixed via fade-in and fade-out effects in order to avoid silence and to maintain the reading flow. This system was one of the first to implement page tagging, therefore

[2]StoryBook by Hallmark Inc.: https://www.hallmark.com/gifts/books/recordable-storybooks/.

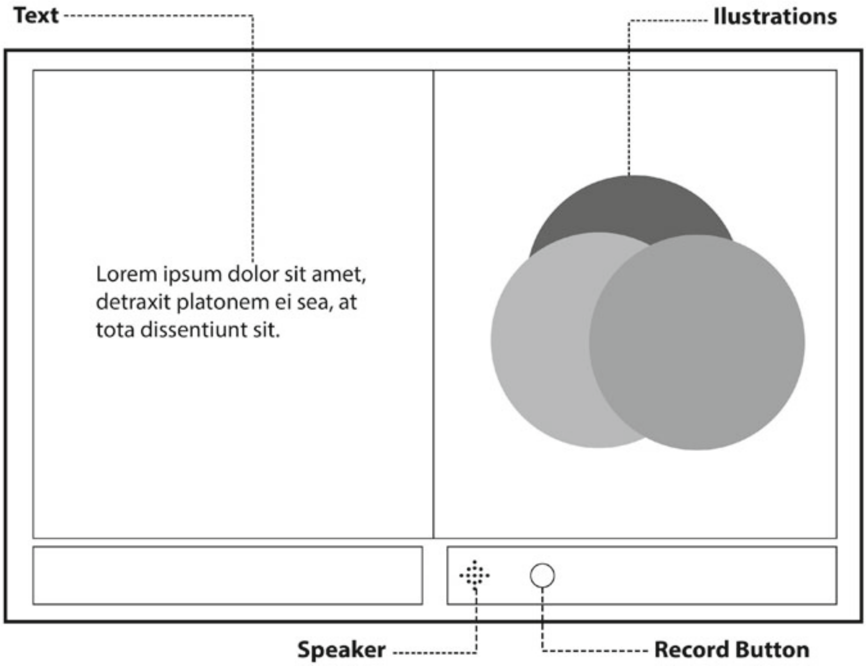

Fig. 3.2 A schematic representation of the recordable storybook

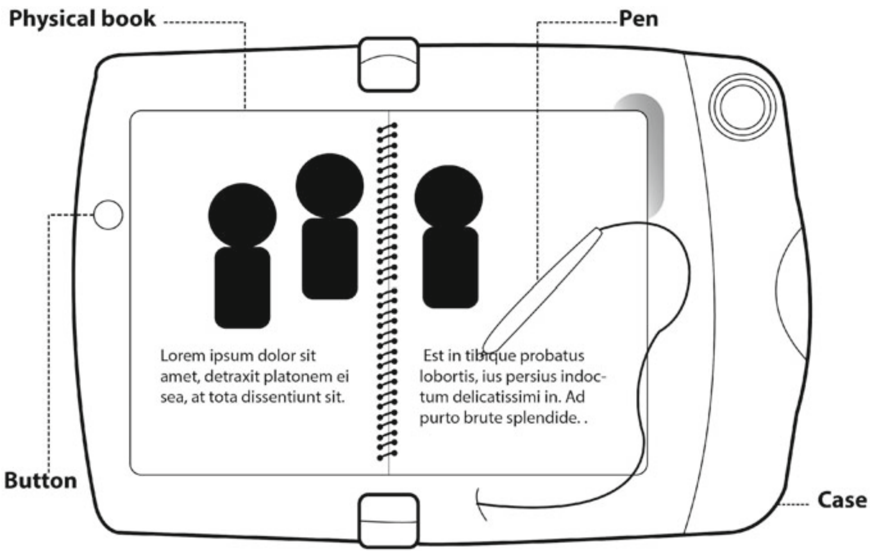

Fig. 3.3 A schematic representation of pen and book system similar to LeapPad

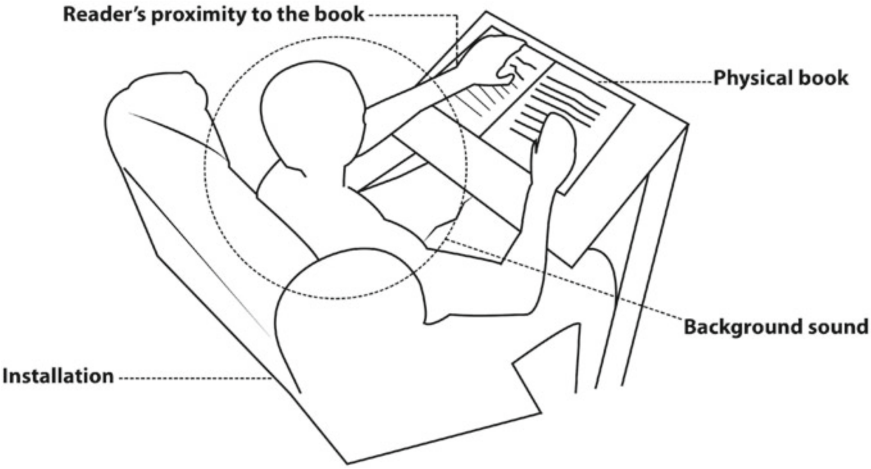

Fig. 3.4 A schematic representation of a system that augments ludic reading in a similar way to Listen Reader

enabling the direct mapping of feedback with the user's action without requiring an interactive pen or an external tracking system. The system was presented in a museum as part of a 6-months exhibit that was attended by more than 350,000 visitors. The authors observed that "the average time spent at a Listen Reader was much longer" than expected. They also observed that the augmented book triggered "social reading", with several visitors sitting on the same chair and listening to the sounds.

Another example of a digital augmentation through an external device is the *Sensory book* (see Fig. 3.5 for schematic representation) (Heibeck et al. 2013). The prototype combines a physical book with a wearable device composed of (1) a book-case with tagged printed sheets and 150 LED-lights that are distributed along the book cover with an integrated speaker box; (2) a wearable vest with an attached heating device, a vibration motor and a compression system. Multimodal feedback is provided to the reader depending on the page being read, in order to reflect the mood of the characters and to enhance the reader's empathy with the protagonist of the story.

Given the availability and accessibility of smartphones and computers in our society, a number of augmented books based on additional displays have been developed. These devices can be used as a display inside the book, alongside the book, or even above the book (when used as see-through displays).

For example, *PhoneBook* (Maki 2010) is a hybrid book that uses an iPhone *inside* a picture book and that is intended to be used by children who do not know how to read yet. It was developed for the Mobile Art Lab in Japan[3] in 2009 with the goal of connecting parents and children through the use of mobile phones and books. To use this hybrid book, one needs to insert an iPhone in the middle of a book. While

[3]PhoneBook by Mobile Art: https://www.mobileart.jp/phonebook.html.

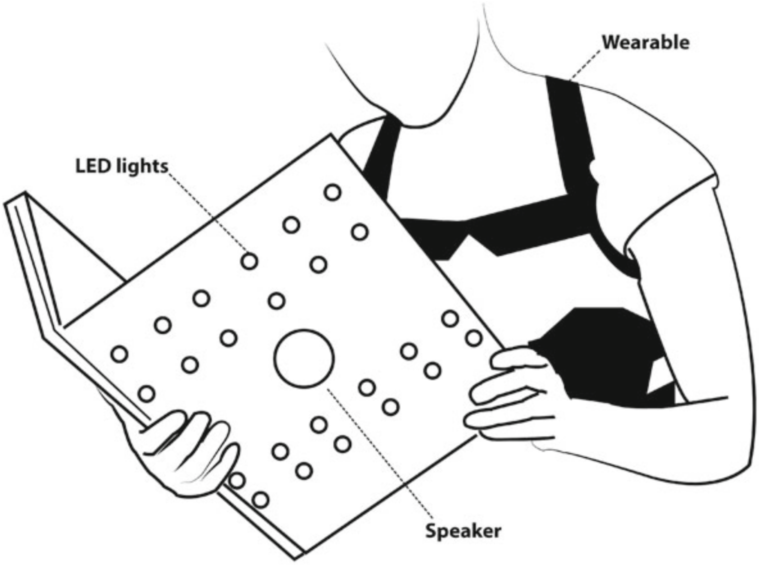

Fig. 3.5 A schematic representation of a system that augments ludic reading in a similar way to Sensory book

parents are reading the story, kids can interact with the current screen animation by touching or tilting the book. Sounds, visual feedback and parent-guiding instructions are provided depending on the user's actions with the smartphone.

Blink (Kelaidis 2008) stands for book and link. This system places an external device next to the book. Each page of the book is preprogrammed with conductive ink circuits connected to key words, text or images. Once the user presses a printed-hyperlink, the integrated wireless module sends a Bluetooth signal to a computer or a mobile device and shows the content related to the integrated hyperlink as can be seen in Fig. 3.6.

BobriVoz (Kljun et al. 2019) is an example of a printed comic book that is augmented with video content displayed on the user's smartphone, which must be held *above* the book (see Fig. 3.7). The videos are integrated into marked frames of the comic book. When scanning the pages with the smartphone, users can unlock multimedia content that is related to the story. Marker-based Augmented Reality is one of the most common approaches in integrating digital content in printed books with a variety of examples: World of Fairy Tales (Edgar Arts 2016) Penguin books (The Drum 2012) some Marvel Comics (Hutchings 2012), and the Finnish Walt Disney comic book as seen in Fig. 3.8.

See-through displays can also be used to augment physical books with 3D elements. For example, *MagicBook* (Jin and Wen 2001) uses glasses as a video see-through display to present 3D pop-up elements. When looking through the glasses, the user sees augmented content projected on top of the printed book (see Fig. 3.9 for

Fig. 3.6 Picture of the Blink system in action (Courtesy of Manolis Kelaidis. http://manokel.com/blink/)

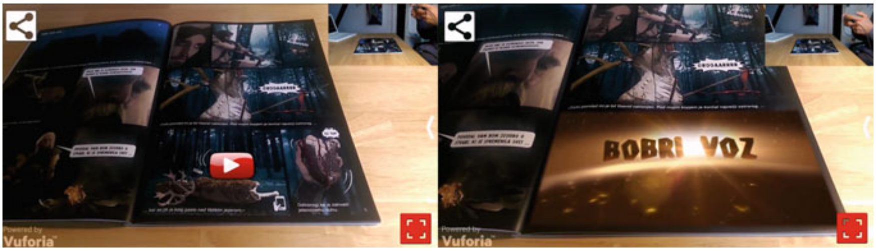

Fig. 3.7 AR comic book Bobri Voz. Videos are integrated into the comic book. The reader views the video through a smartphone's screen as visible in right top corners on both left and right side. The user sees a play button (left) and when the button is pressed a video starts playing (right)

a schematic representation). Users can also move through the view by zooming in, which results in an immersive experience. The content mainly includes 3D objects and animations. The MagicBook prototype also allows several users to read and explore the book (including the augmented content) at the same time. For example, if two users are seeing the same scene in the same book they can look at each other in the scene via an avatar-based representation.

The *Augmented Reality Coloring Book* (Clark and Dunser 2012) uses a similar technique, but it also allows users to customize the 3D elements. It is an educational colouring book that augments printed content by generating a 3D-model using the colouring book as a texture map (see Fig. 3.10). Children are first asked to colour a sketch in the book. Then, they can use a handheld AR system, which scans the

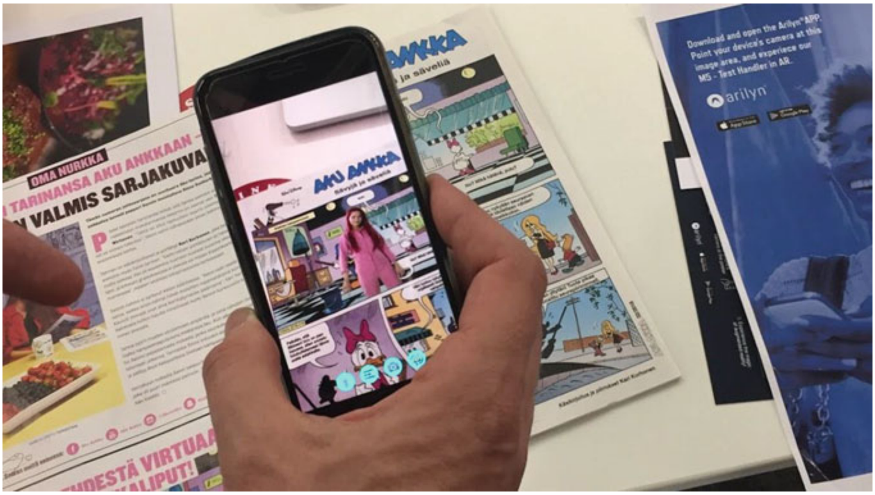

Fig. 3.8 Another example of viewing digital content within a comic book frame through a smartphone's screen (see-through display) using a marker-based system (Marty Swant. Sanni surprises readers of Aku Ankka magazine. Adweek, September 21, 2018, https://www.adweek.com/digital/to-promote-her-upcoming-show-this-finnish-pop-star-appeared-as-an-ar-cartoon-in-a-donald-duck-comic-book/)

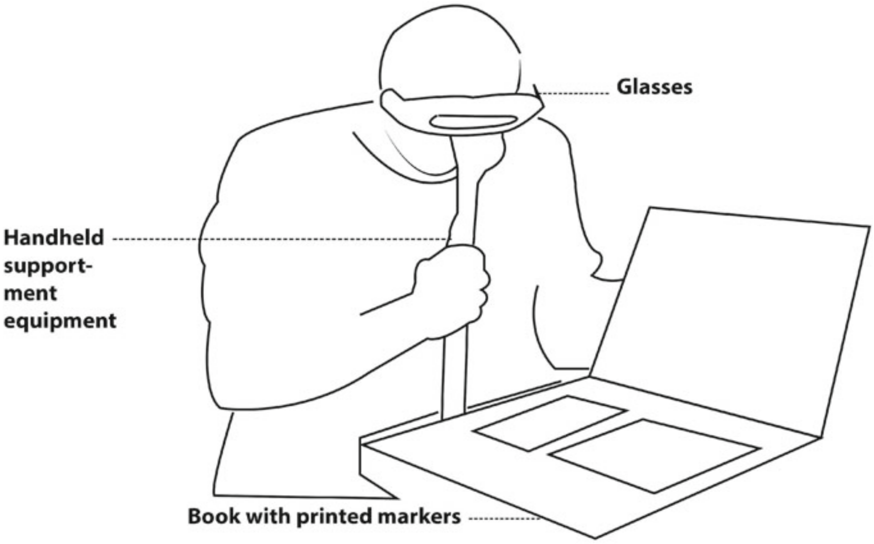

Fig. 3.9 Schematic representation of the MagicBook. The user sees the augmentation by looking at the book though video see-through glasses

Fig. 3.10 Screen grabs of Augmented Reality Coloring Book (courtesy of HITLab NZ). Coloured 2D sketch is used for texturing 3D models

coloured book as a texture map and displays it on a digital screen as a coloured 3D model of the drawing.

Finally, some augmented books are purely digital and do not rely on any element of physical books. This is the case with augmented e-books, that are becoming more and more common. *PopOut!* (LoudCrow Interactive 2010) is an interesting example as it includes a large variety of interaction techniques. It is a digital book for tablet computers that uses a combination of background sounds, speech synthesis and animated sequences to improve the reading experience. The book allows users to read the story or to listen to it. It also enables them to manipulate the content of the book, e.g. by resizing the images and text, dragging and dropping elements, watching animations and simulating page turning as in a physical book.

3.3 Analysis

In this section, we will review described projects and analyse them based on the sensing modality they attempt to augment, their impact on the reading flow and the type of content.

3.3.1 Analysis of Sensing Modalities

We perceive our world through five basic senses, namely: hearing, sight, touch, taste and smell. Our bodies have specific organs associated with each sense that detect and send information to the brain. Even though all of these sensory modalities cumulatively curate our perceptions of reality, they do not have the same influence on the final interpretation our brain curates. According to Thomas Politzer (Politzer 2018), 80–85% of our perception, learning, and cognition activities are mediated through vision. However, this comes at a cost of higher processing demands on our brain when compared to hearing. Amongst others, this is demonstrated by the faster reaction time to auditory stimuli compared to visual stimuli (Jain et al. 2015).

As highlighted in Fig. 3.11, all but one of the prototypes use the sense of hearing to enhance the reading experience, and three out of ten prototypes rely solely on this modality. These systems predominantly play recorded sounds, ambient music or recorded voice messages. The second most represented sense is sight; examples of visual augmentations include videos, projections and ambient lights. Only one prototype delivers additional content through the sense of touch, whereas taste and smell were not used at all. Figure 3.11 also shows that all but three presented prototypes use more than one sensory modality to augment the book, highlighting the importance of multimodal techniques when digitally augmenting books.

Reading is heavily dependent on our vision as one needs to continuously follow the pattern of text in order to decode these patterns into words, sentences and meanings. It is very easy to break this flow and interrupt the reading experience, especially if the augmentation requires direct focus of attention of the user for the purpose of accessing the content (e.g. tapping "play" to trigger audio) or consuming the content (e.g. interacting with 3D content while looking through the phone camera). This is not the case when other modalities are used, such as: touch, sound or smell. These

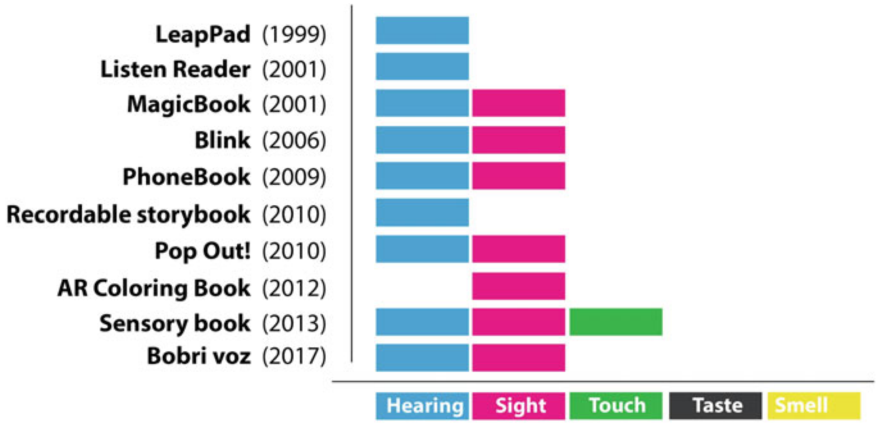

Fig. 3.11 Classification of reviewed augmented books based on augmentation of senses

could very easily be perceived in parallel with the visual activity of reading, making them more appropriate for the purpose of augmented reading experience. For this reason the dominance of sound modality over vision does not come to us as a surprise, particularly as sound is a common modality that we use to augment visual experience in mediums such as movies or video games. The lack of examples that utilize other sensory channels, such as touch, taste and smell, could be attributed to the fact that these senses are more difficult to augment, particularly when one wants to augment them in an unobtrusive way.

3.3.2 Analysis Based on Content Type

Another aspect to analyse is the content that is provided to the reader in order to augment the book. Examples include, but are not limited to: videos, lighting, animations, 3D models, sound effects and music. Choosing the type of content to deliver is crucial as some elements and modalities could potentially affect the reading experience in a negative way, causing distraction, interruption or confusion. In the worst case, inappropriate content could demotivate readers and cause them to give up reading.

Therefore, depending on the type of reading (active vs. ludic) and on the context of reading, the additional content being delivered may serve different purposes. Here, we will simply identify whether the additional content is duplication or augmentation of the text being read. We use the term 'duplication' to refer to situations where the additional content is a summary, repetition or description of the elements already present in the book. For example, if a reader touches the word 'cow' in a book, the duplicated content would be the playing of the sound 'cow'. We use the term 'augmentation' to refer to situations where the additional content extends or complements the elements already present in the book. For example, if a reader touches the word 'cow' in a book, one augmented content would be the playing of the mooing of a cow.

The content analysis is presented in Fig. 3.12 and shows whether the analysed augmented book uses duplicated or augmented content. As we can see, duplication is mainly used by prototypes supporting active reading (LeapPad and AR Coloring Book). In fact, active reading requires repetition and reinforcement to enable readers to efficiently learn new concepts. However, the BobriVoz comic book, which is intended for ludic reading, also used duplication of content as a way to augment the book. A study of BobriVoz conducted in-the-wild showed that when facing duplication some readers tend to look for augmented pages only, skipping the ones that do not display interactive elements and defying the purpose of the hybrid medium. The readers likely found the digital content more attractive or did not want to read/watch the same parts of the story twice (Kljun et al. 2019). Therefore, when supporting ludic reading, duplication techniques should be used carefully in order not to devalue the reading of the physical book and not to create interruptions in the reading flow (e.g. when skipping pages to look for multimedia content).

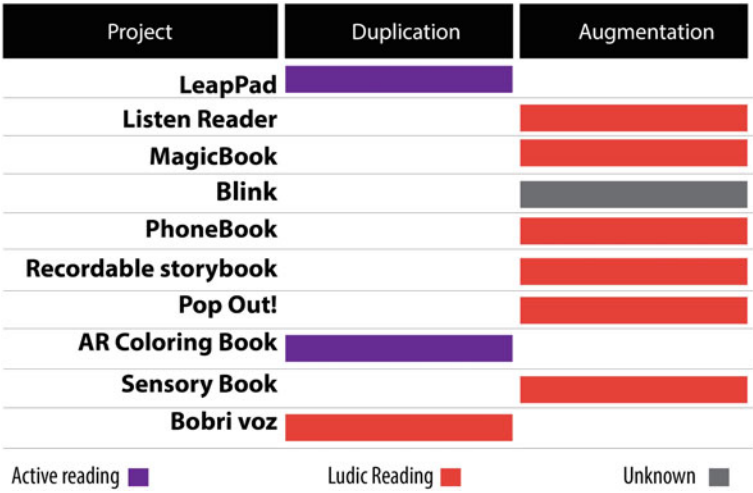

Fig. 3.12 Augmented content analysis identified whether the additional content is duplication or augmentation

3.3.3 Reading Flow Analysis

A good reading experience of any book, whether augmented or not, must engage and absorb readers into the story. Inappropriate use of technology or poor design may have a negative impact on the reading flow and reading experience. To better understand how the reading flow is affected when integrating digital content into the reading experience we propose the Reading Flow Continuum. On one side of the continuum we have continuous reading experience whereas on the other side one can find segmented reading experience.

The mapping of prototypes onto the reading flow continuum was done by two authors of this chapter individually. The results were compared and aligned through discussions. The results of this activity can be seen in Fig. 3.13.

In the figure above we can observe that projects, such as Bobrivoz, AR Coloring book, MagicBook and PopOut book are located closer to the segmented reading experience because they force readers to suspend the act of reading in order to trigger augmentations (e.g. scan a mark, press a button, hold 3D glasses in front of the user's eyes). Moreover, additional content presented in these prototypes pulls the attention of readers towards the augmentation (e.g. watch a video, see a 3D model). Projects such as Listen Reader, Sensory Book, Recordable StoryBook and LeapPad are listed towards the continuous reading end of the continuum because here the interaction with the book (e.g. flipping the page, following text in the book with the interactive pen) triggers appropriate digital augmentations. The key feature of such systems is that they do not take the attention away from the reading activity.

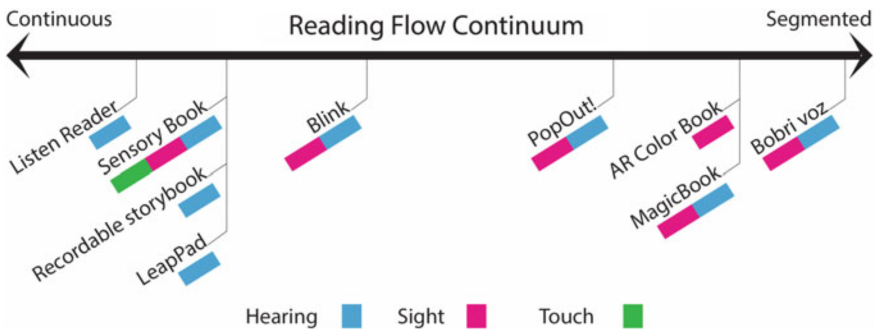

Fig. 3.13 Reading flow analysis identifying the extent to which additional content promotes segmented over continuous reading experience

We predict that projects that are listed within the left side of the continuum (continuous reading) tend to be more immersive and are better for creating augmented atmosphere. For instance, Listen Reader is set up as an installation using a sofa and a spotlight; Sensory book implements a wearable that tries to recreate an environment and atmosphere though ambient lighting, tactile stimuli and sound. It is also worth mentioning that augmentation systems that support continuous reading experiences do not rely on videos because they require focus of attention, but rather relate to ambient light effects or scene setting changes that happen in the periphery of users' attention.

3.4 Exploring the Design Space of Interaction Techniques

In previous section, we analysed a number of augmented books according to three dimensions: the senses involved in the augmentation, the reading flow and the type of additional content. We highlighted that currently-used interaction techniques mainly depend on touch input, often interrupt the reading flow, and are mainly used to trigger audio and visual augmentation. In this section, we explore the design space of interaction techniques, focusing on: (i) different ways to trigger additional content without disrupting the reading flow and (ii) the use of alternative senses, such as taste, smell and touch to create multimodal and immersive reading experiences.

Fig. 3.14 Sound augmentation based on speech recognition

3.4.1 Investigating Speech Recognition and Eye/Head Tracking Interaction Methods

3.4.1.1 Speech Recognition

Speech recognition technology is now widespread, for example to interact with mobile devices or with in-car systems. Speech recognition can also be used to identify the user's current activity and environment (Laput et al. 2018). This technology could be used for immersive "reading-aloud" experiences. For example, the user's mobile phone could identify which section the user is reading and trigger additional content (such as 3D sounds or ambient sounds) that directly maps to the story being read (see Fig. 3.14). Reading aloud often happens when parents read to children—which has been shown to provide several benefits (Hutton et al. 2015; Merga 2018)—or when children read aloud when learning how to read.

A similar approach would be to display specific footage only if the user is reading aloud some parts of the text. The system would be based on subtitles, but unlike traditional movies, reading the subtitles aloud triggers the video, animation or sound (see Fig. 3.15).

In both of the above cases, the reader would not be required to perform a specific action such as pressing a button or holding a phone—reading and interacting would be perceived as a unified and continuous experience. The limitation of this approach is that reading aloud could interfere with the augmented sounds being played by the video, hence it would be interesting to see how well such a system would be accepted, especially in the group of users who are learning how to read.

3.4.1.2 Eye and Head Tracking

Eye and head trackers can be used as "input" devices and have been already used to enhance reading experience (Biedert et al. 2010; Campagna et al. 2014). For example, the user's gaze position can be used to display smart footnotes or to automatically

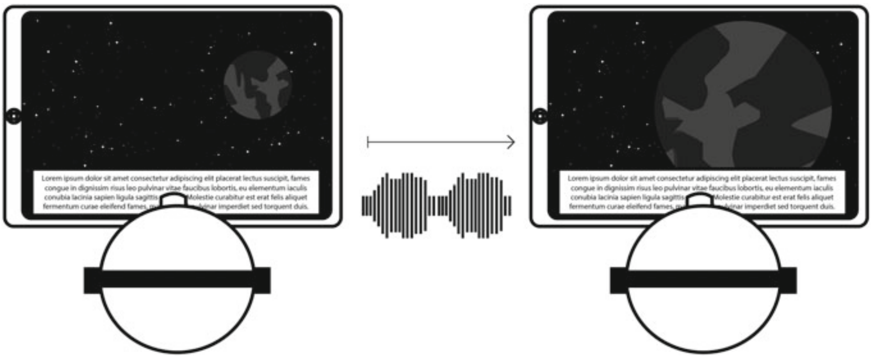

Fig. 3.15 Visual augmentation based on speech recognition. The user reads a paragraph aloud which triggers video animation

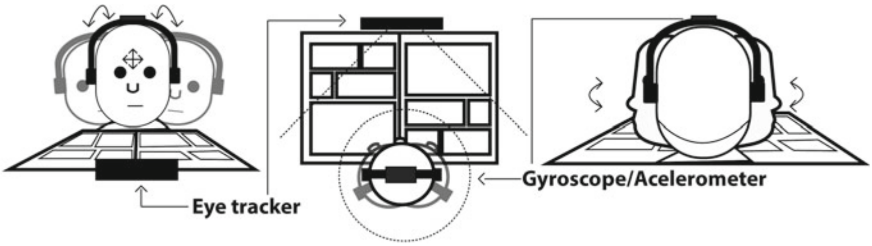

Fig. 3.16 Sound augmentation using head tracking and/or eye tracking. Based on the orientation of the user's head or eye position the audio is being played

scroll down a webpage, a feature which was commercially available in Amazon Fire phones. In the context of reading, eye and head tracking could be used to unobtrusively detect what section the reader is looking at, and display additional content accordingly (see Fig. 3.16 for schematic representation).

3.4.1.3 Bio-feedback

Physiological sensors can be used to measure the heart rate, blood pressure or even brain activity, therefore providing insights on the reader's emotional state, such as their mood or even their imagination (McGrady and Horner 1999; Peper et al. 2015). Such data could be used to infer the reader's level of arousal and accordingly adapt the content being delivered. For example, if the reader does not seem to react to a particular stimulus, the system could use another sensory modality. Interestingly, Nishimoto et al. (2011) proposed a model that is able to provide visual reconstructions of movies based on the users' brain activity. In the future such a technique could support the development of augmentations based on the user's imagination; the user

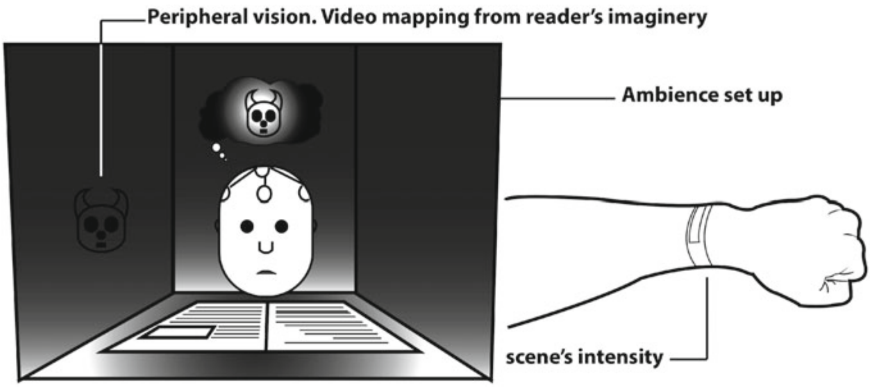

Fig. 3.17 Augmented imagination using physiological sensors (e.g. EEG and heart rate)

would be able to author the additional content by mentally visualizing different images such as natural landscapes (see Fig. 3.17 for a schematic representation).

3.4.2 Providing Multimodal Content

Augmented books mainly rely on audio and visual feedback to enhance the reading experience and make it more immersive. However, the senses of smell, touch and taste could also be used as a way to augment the content in a non-distracting way.

3.4.2.1 Augmenting Books with Olfactive Feedback

Augmented books could rely on the sense of smell using Odour Olfactory Displays (OOD), for example. These electronic devices generate scented air by blending odours. There is evidence that implementing OOD while reading can facilitate learning and that it does not disturb the reader's attention (Bordegoni et al. 2017). This technology could be used to augment the sense of smell in ludic reading, by creating special odour-based atmospheres (e.g. scented candles, fireplace smells) or by associating each character with a specific odour that will represent his/her perfume (see Fig. 3.18).

3.4.2.2 Augmenting Books with Tactile Feedback

Augmented books could also rely on the augmentation of the sense of touch. For example, Mediable (Fitzgerald and Ishii 2018) is a mobile surface that modifies its form to represent geometric shapes, volume and textures. It was designed to enable

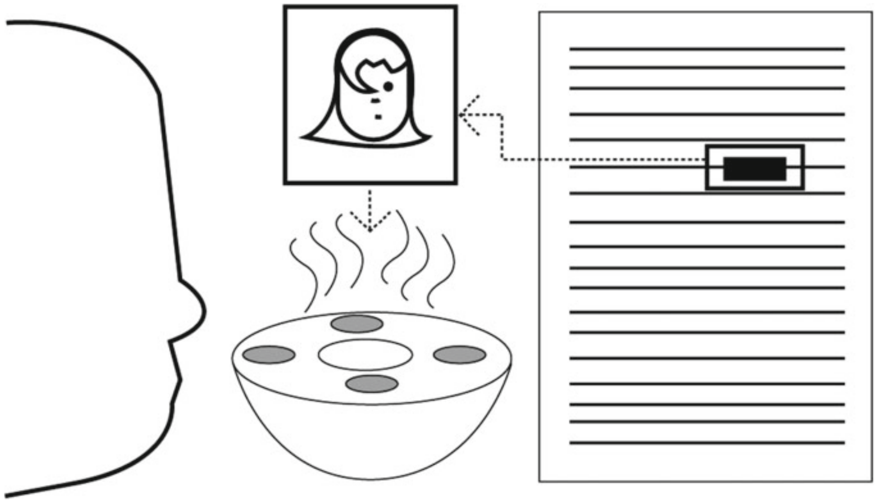

Fig. 3.18 Augmenting imagination with smell. As soon as the reader reads about a new character entering the room the perfume associated with this character is presented to the reader

tactile interaction within virtual reality. Mediable-like surfaces could be attached to backrests of chairs, on the table or even in the cover of the book to provide readers with a tactile experience that links to the story (see Fig. 3.19). Similarly, vibrator motors could be added, as it is already the case in video games (Narumi et al. 2011).

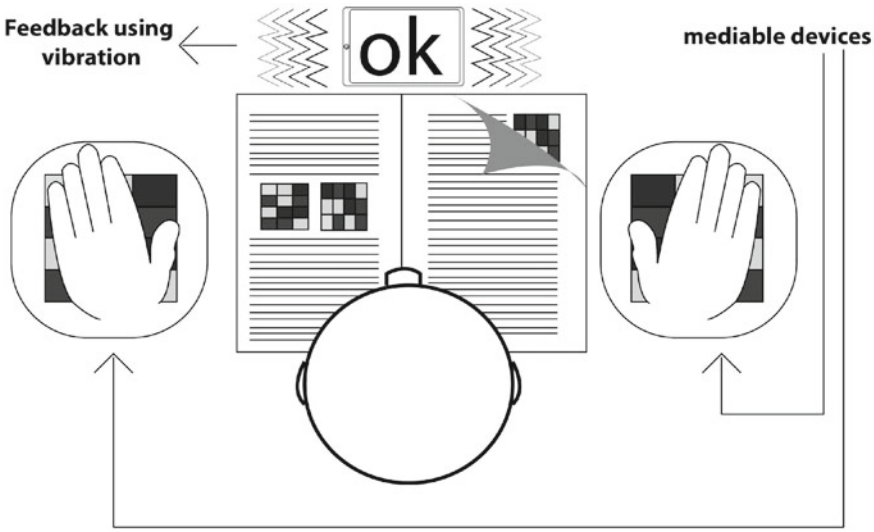

Fig. 3.19 Augmenting the reading experience through smell and touch stimuli

3.4.2.3 Augmenting Books with Taste Stimuli

Finally, the sense of taste could also be augmented using a digital flavour synthesiser, in order to augment books that are dedicated to food and/or cooking. Digital flavour synthesizers are experimental devices that let users feel different flavours through electric stimulus on their tongues. For example, Ranasinghe et al. (2014) proposed the design of a Bluetooth device in the form of a small capsule (similar to a small candy) that can digitally augment flavours. Another example is a contactless food delivery system based on acoustic levitation of food morsels proposed by Vi et al. (Narumi et al. 2011). Irrespective of these recent advances in technology and the fact that digital flavour synthesisers offer interesting possibilities for reading augmentation, they currently face many technological challenges before they become unobtrusive and practical.

3.5 Conclusion

Reading is a complex process affected by various parameters such as the reader's motivation, age, environment, and a medium being used (e.g. a purely physical book or a digital book). People read for various purposes; for example to acquire new knowledge, to communicate or simply for entertainment. When designing augmented books, one needs to take the purpose of reading into account. This is particularly important when designing augmented books for ludic reading where it is crucial to create "an environment in which real and virtual objects harmonically coexist" (Hincapie et al. 2011).

In this chapter, we identified physical and digital approaches as the two main approaches to augment books. Physical approaches do not embed any electronic elements into the book. This is not the case for digital approaches where interactivity is supported by embedding electronic devices into the physical book, holding devices above the book, or by placing electronic devices around the reader. We described and analysed ten augmented books that use different augmentation techniques, along three dimensions: the modalities being used, the type of content on offer, and the impact of the augmentation on the reading flow. We highlight the need to further investigate ways to deliver multimodal and immersive content so that the processes of reading the original text, interacting and consuming the digital content merge into one unified experience that does not disrupt the reading flow and enhances the sense of immersion into the story. We also illustrated how we could move towards this vision of a unified augmented reading experience using different technologies such as: speech recognition systems, eye- and head-tracking systems, olfactory displays, smell synthesisers and digitally-controlled food delivery systems.

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Chapter 4
Invisible Settlements: Discovering and Reconstructing the Ancient Built Spaces Through Gaming

Dragoş Gheorghiu and Livia Ştefan

Abstract Throughout the world, settlements invisible to the contemporary eye exist hidden under layers of soil and debris, waiting to be discovered. Their discovery can precede the archaeological excavation through the use of ground radar for scanning and points-of-interest (POIs) for delineating their shape in space. Once discovered with the use of smartphones, these POIs display augmented information. If the presentation of the invisible settlement can be achieved as a playful activity of discovery, the impact on the player may have a stronger cultural, and possibly identity, value.

4.1 Introduction

> **Motto** Does your journey take place only in the past?
>
> All this so that Marco Polo could explain or imagine explaining or be imagined explaining or succeed finally in explaining to himself that what he sought was always something lying ahead, and even if it was a matter of the past it was a past that changed gradually as he advanced on his journey, because the traveler's past changes according to the route he has followed: not the immediate past, that is, to which each day that goes by adds a day, but the more remote past. Arriving at each new city, the traveller finds again a past of his that he did not know he had: the foreignness of what you no longer are or no longer possess lies in wait for you in foreign, unpossessed places. (Calvino 1997, p. 24)

A great part of the material past remains invisible, hidden underground or under palimpsests consisting of successive layers of construction in time. Ground radar scanning reveals these submerged architectures to archaeologists, but the broader public remains unaware of their existence.

The creation of an awareness of the past through the discovery of these invisible settlements can be achieved using computer-mediated reality "class of technologies"

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(Milgram and Kishino 1994), i.e. Virtual Reality (VR) or Augmented Reality (AR) in a geographical context.

AR-enabled mobile (MAR) devices have become accessible to the general public via sophisticated smartphones and tablet PCs.

By positioning points-of-interest (POIs) on the archaeological remains either excavated or scanned with a ground radar, a user possessing a mobile device can discover these POIs and visualize augmented information, showing the utilization of these spaces in everyday life, in the past. Areas displaying a succession of POIs could allow the contemporary visitor a coherent journey through the invisible settlement immersed underground.

If the presentation of the invisible settlement can be achieved as a playful activity of discovery, the impact on user may have a stronger cultural, and possibly identity building value.

Several interactive games have been developed using MAR (Schmalstieg 2005). *Conquar* was the first MAR game developed on the Layar commercial platform (Conquar 2011). Recent experiences with the MAR exergame (i.e. exercise-game) Pokémon GO (Giddings 2016; Zsila et al. 2017) have shown strong levels of engagement being achieved among children, youngsters and adults. Recent studies have also shown the usefulness of this type of game based on the discovery, acquisition of "artefacts" and the accumulation of scores, in bringing archaeology closer to the public, especially children (Bond 2016).

The authors possess previous experience in this field, having proposed in 2013 an *Archaeology at home* educational game similar to the Pokémon GO game of 2016, and having worked for the past six years on the subject of cultural palimpsests. The results obtained with this game (Gheorghiu and Ştefan 2013b) as well as with other similar applications (Gheorghiu and Ştefan 2012; Gheorghiu and Ştefan 2013a; Gheorghiu et al. 2014) have led the authors to expand their research with another, more elaborate, MAR game in the field of archaeology and education.

The current research objective was to design a MAR game, an application built on the Layar AR platform with two levels of discovery and user engagement with a game play with two layers similar to the process of the archaeological unearthing.

The present chapter outlines the theoretical background of the research, the game concept, rules, digital content, gameplay and on-line solution developed, as well as a discussion, and the conclusions of the cultural implications of the game.

4.2 The Potential of AR in Archaeology

Eve (2012) states that AR in archaeology "provide(s) a timely way to combine the strengths of a computer-based approach (reproducibility, experimentation, computer reconstruction) with archaeological phenomenology (embodied experience in the field)". Authors (Trapp et al. 2012; Papadoupolos and Kefalaki 2010) performed researches on using MAR applications to visualize and associate archaeological information in real contexts.

State-of-the-art simulated revivals of ancient places, e.g. Pompeii, have been performed by means of character reconstructions and animations in AR (Archeoguide 2018; ARCO 2018; Papagiannakis and Magnenat-Thalmann 2007), interactive storytelling (Hermon 2008), re-enactments (Gheorghiu and Ştefan 2012; Gheorghiu et al. 2014) or MAR games (Schmalstieg 2005; Maiorescu and Sabou 2013; Jasink et al. 2017).

4.3 Educational Video Games

A game is defined as a "playful way of interacting with people or objects with the aim of achieving a goal" (Kafai 2006). "Playability" was best defined by Huizinga (1955) as "a voluntary and absorbing interaction done for its own sake". The design of a game is an interdisciplinary activity that considers different factors, educational, aesthetic, social or cultural (Ştefan and Moldoveanu 2013).

Several game genres exist, e.g. adventure games, shooting, strategy, role-playing, and simulation games (Prensky 2001; Amory 2007; Gee 2003).

Educational games or "serious games" were first introduced as a game genre by Abt (1970) and the definition given by Zyda (2005) was adopted by the Serious Games Institute (SGI 2018). Djaouti et al. (2011) discuss the historical origins of serious games and their purposes before the 2000s.

An early study of creating games for cultural heritage is performed by Anderson et al. (2009). Liritzis et al. (2015, p. 325) state that "games with virtual worlds have been developed with an intention to be used in education, impelling users to increasingly participate, much like the games at their free time".

4.3.1 Game Design

Game design is team work that requires imagination, design, aesthetics and communication skills, and the designer's personal experience, with the purpose of producing a "meaningful play" (Salen and Zimmerman 2004).

Weilguny (2006, p. 18) has identified several characteristics that a good game must possess, among which: *playability*, i.e. "the amount of satisfaction a player gets out of interacting with a game" or "parameters that are hard to define, like fun, challenge"; *emotional appeal*: the capability of the game to stimulate player's emotions by means of virtual and physical surroundings; *interactivity*: the capability of the game to respond to the user's actions and to allow the player a degree of freedom within the limits of the game storyline. The game designer has to fine tune a balance between the player's freedom of choice and the pre-defined storyline (Weilguny 2006). This balance is sometimes performed with Artificial Intelligence (AI). Another characteristic is the *player's contribution*: a player adds his/her own contribution to the game, by using his/her skills, taking decisions, handling the interface, by means of his/her concentration and attention (Weilguny 2006).

In multi-player games, specific concepts are used, e.g. associating multiple players in guilds to achieve the goals of the game (Loiseau et al. 2013) or role-playing (Granström 2013).

4.3.2 MAR Game Design

MAR game design follows the same principles as regular games (Kafai 2006), by combining elements of classical computer games with the MAR technology to create an entertaining experience for the player (Kafai 2006; Schmalstieg 2005; Wagner and Schmalstieg 2007).

MAR games as a new genre are discussed by Ştefan and Moldoveanu (2013), covering the following topics: (1) enhanced perception in a mixed-reality environment; (2) the sense of immersion; (3) player-oriented and dynamic environments, according to the device orientation and movement; (4) point-and-click interfaces and natural (gesture-based) human-computer interactions; (5) context-awareness; (6) support of user mobility; (7) stimulation of the users' motivation.

Complex AR games can leverage AI such as software agents (Barakonyi et al. 2005; Litzlbauer et al. 2006).

4.3.3 The Pokémon GO Phenomenon

In 2013, the authors developed a discovery MAR game for educating children in the local archaeological heritage of Vadastra, a South Romanian village (Gheorghiu and Ştefan 2013b). The game was named *Shards hunting* and challenged children to discover ancient pottery on the village's premises and then rebuild the objects using the augmented information under the form of archaeological images.

The children were eager to discover forms and objects and were engaged in the process of discovery of shards and artefacts from the past. The game employed geographic points-of-interest (POIs), which confined its usage to outdoor/on-site environments. The game had no rules or levels, just a playable design and the requirement for the users to be situated within a defined geographic area, presenting similarities with the 2016 Pokémon GO version.

Pokémon was launched in Japan in 1997. It was designed as a video game, and afterwards, upon its success, evolved as a mobile application and a MAR application. The Pokémon series began with the *Pocket Monsters Red* and *Pocket Monsters Green*. When these games series became popular, the international *Pokémon Red and Blue* was released.

Pokémon comprises 7 generations with different series, from GO to Gold, Sapphire, Rubin (Pokémon Core Series 2018).

A timeline of its evolution is presented by Webster (2017). The Pokémon was franchised since the 7th generation on November 18, 2016 with Pokémon Sun and Moon on the Nintendo 3D stations. The Pokémon game evolution is similar to that of complex video games.

Zsila et al. (2017) analyse the phenomenon of the Pokémon GO which, starting in 2016, "became the most popular game in the history of smartphone games and was among the first games to feature geo-located AR elements" (p. 1). Zsila et al. (2017) conducted research to understand the motivations underlying Pokémon GO use and to measure these motivations.

According to Walker et al. (2017), "Pokémon Go is a prime example of the power of AR" (p. 2). The Pokémon GO game is based on author "Satoshi Tajiri's childhood love for finding insects" (Walker et al. 2017, p. 4). The game was first developed in 1999 for Nintendo play stations, when "Tajiri noted that kids increasingly play inside their homes due to urbanization and have forgotten about outdoor games" (Walker et al. 2017, p. 1). The modern version of the Niantic Pokémon GO is a geo-located MAR game, based on GPS and the local time and environment to generate and place new Pokémon "creatures" on the user's premises, i.e. "in a park, more bugs and grass appear. If close to water, more Pokémons that are native to water will appear. If it is night, more ghosts will appear" (Walker et al. 2017, p. 1).

The Pokémon GO game was a phenomenon as it showed a successful case of using MAR to reach the mass users and to engage them in an interactive and very dynamic game. From an implementation point-of-view it is as complex as a video game, i.e. uses Artificial Intelligence and gamification tools. Even though its ultimate purpose seems to be to stimulate people to perform physical exercise and explore natural surroundings, some sources reveal that the game also has a crowd-sourcing component, and the company is collecting location data from the gamers, to map public spaces, such as parks and plazas (Pokémon GO crowd-sourcing 2018).

4.3.4 Archaeological Games

Most known archaeological games fall within the category of video games that can be played on desktop stations, such as *Tomb Raider*, *Civilization* or the *Indiana Jones* series. These are complex games with storylines, multi-characters, etc., which are known and played even by archaeologists.

The *Magazine of the Society for American Archaeology* (2016) dedicated a special issue to the topic of video-games in archaeology. According to Morgan (2016, p. 9): "*Archaeologists who study video games illustrate the energy and creative potential within this interdisciplinary space, with research that investigates the history and materiality of archaeological games as artefacts, including the literal excavation of video game cartridges and other gaming material culture, the critique of archaeological content in video games, the use of gaming strategies to query past landscapes, collaboration with gaming studios and gamers to create archaeology-based games, and the creation of video games by archaeologists*."

A survey made by Mol et al. (2016, p. 11) showed that "[*a*]*rchaeologists enjoy a variety of genres, with strategy games and massively multiplayer online role-playing games (MMORPGs) being the most popular. Exploration (68%), the story (66%), and game characters (38%) are the three most important aspects of video games that attract archaeologists. Respondents listed more "historical" (171) than "archaeological" (91) games*."

For mobile devices the most popular applications in archaeology are the virtual guides (Vlahakis et al. 2002; Papagiannakis et al. 2005), virtual tours or visualizations of 3D reconstructions of archaeological sites or artefacts using Unity3D gaming engines in combination with AR tools such as Vuforia or Layar (Deliyannis and Papaioannou 2014; Kyriakou and Hermon 2016; Quattrini et al. 2016). The research purpose was focused on the reconstruction and integration of the content in the world (Quattrini et al. 2016) or on allowing users to physically interact with the content (Kyriakou and Hermon 2016) or in developing frameworks for rapid prototyping (Deliyannis and Papaioannou 2014).

In a recent survey, the authors (Bekele et al. 2018) concluded that most of the outdoor AR applications in archaeology are designed for exhibitions, exploration and education.

MAR technologies for the creation of edutainment or gaming applications with archaeological topics are numerous and very recent (Deliyannis and Papaioannou 2017). They were developed as research projects and hence did not achieve a public impact similar to that of Pokémon GO (Bond 2016).

The game proposed by the authors offers players the opportunity to have access to two types of archaeology: one dealing with the understanding of the process of building, and one, post-processual, that involves the phenomenological experience (see Tilley 1994; 2004) of the spaces discovered.

4.4 Invisible Settlements—Awareness of the Past by Playing

The creation of an awareness of the past through the discovery of invisible settlements can represent an archaeological and educational exercise able to define the identity of a place and community. At the same time, this type of approach continues the artistic experience introduced by the psychogeographers (Coverley 2010, p. 9ff) Guy Debord (1992) and Iain Sinclair (1997).

The possibility to gradually discover fragments of ancient settlements over which the application user may have passed without being aware of them, is an exciting aspect of this archaeological discovery game.

The game interactivity with the site creates an emotional response in the user, whose contribution to the game lies in the ability to efficiently use the application to discover the hidden archaeological and architectural pieces.

The game starts with an identification of the points-of-interest (POIs) positioned on the archaeological remains either excavated or scanned with a ground radar. The search to approach them with the users' smartphones implies a process of discovery similar to the one followed by an archaeologist who analyses a site. Once discovered, these POIs will display augmented information which is offered to the user gradually and is related to the architectural structures of the past settlements under the form of 3D architectural reconstructions.

In the first level, the player/discoverer will search for architectural fragments which collected and accumulated will compose a complete ancient house. By continuing to play the game, the player will collect several 3D reconstructions of houses, which will define a settlement. In the second level, the player/discoverer will search for fragments of a settlement under the form of partial 3D video tours. When all these fragments are collected, the user will have a complete immersive experience by visualizing the full 3D video tour of the settlement populated with real characters dressed in historical costumes that are scanned in 3D.

The gradual increase of the user's level of interest occurs through the process of reconstruction of the invisible settlement that the user performs through the archaeological search, followed by the experience of the built space.

The MAR game proposed is designed to achieve the following three features of a game according to Weilguny (2006):

Playability: the archaeological discovery game with different levels of difficulty and complexity of the digital content. The game design started by defining the interest areas by a succession of POIs defined in such a way as to allow the contemporary user a coherent journey into the Past and a ludic awareness of the invisible settlement immersed underground;

Emotional appeal: the curiosity and imagination are stimulated by the game design;

Interactivity: the players can create snap-shots they can share on Facebook or on their own smartphones, and can switch between the AR view and the mapping view of the application.

4.4.1 The Rules of the Game

The *first rule* is for the user to register in this game. Each user will collect points associated with POIs.

To do this, the *second rule* of the game is that the users must be at a distance of no more than 50 m from a POI, at which point augmented information can be triggered. These rules will allow users to "collect" the pieces discovered by sharing them into a user-associated folder. Like any game, there is a bonus/reward associated with the level: the user who collects all the pieces in this "puzzle" will be rewarded with the image or movie of the fully reconstructed house.

4.4.2 The Game Design

In the present case study, the game unfolds in a locality that overlaps a prehistoric site, ***the first level (L1)*** invites the player to discover fragments of a prehistoric house, starting from details to complex configurations. This level is in turn organized on five sub-categories, and has the role of stimulating the interest to discover and the ability to consistently combine series of data, such as the reconstruction of a prehistoric house.

The role of the game is to educate and to inform, so the game concept was designed to allow for the bonus to be viewed not only by those who collect all the pieces from all five sub-categories, but also by those who collect the pieces from at least one category. The reward is the image of a fully built prehistoric house.

The ***second level (L2)*** has the role of immersing the user throughout the prehistoric settlement overlapped by the contemporary village, the operation being possible through the discovery of five POIs containing five fragments of a 3D spatial reconstruction of the settlement. When the user discovers all five architectural structures of the prehistoric settlement, the reward will be the immersion of the user in a virtual tour through a 3D virtual settlement, populated with human characters, performing different tasks specific to the epoch.

The connection between the two levels is achieved by meeting the requirement of the following rule: the user has to collect two or more fully built houses within L1 to be able to enter L2 (a settlement encompasses several houses). This action is made possible by the user moving to another group of POIs (Fig. 4.1).

The collection of an artefact on any of the levels is registered in the game by a user's click operation on the POI.

4.5 DomusAR: A Location-Based MAR Puzzle for House Reconstruction

The first game level named '**domusAR**' was designed and experimented, with the purpose of helping people understand the local history by discovering and receiving explanations, for example, on local prehistoric households and their artefacts in the village Vădastra, Olt County, Romania.

The augmentations are triggered by the geographic location of the users within the defined interest/archaeological area, and are associated to different POIs. The user must be located within a range of maximum 50 m from the defined POIs, ideally at a range of 20 m, to be able to visualize the augmentations, i.e. image puzzle/fragments. The search range is configurable by the user in a configuration page which is open when the application is launched. The main role of this range is to limit the number of POIs which can be detected, but also to allow the user to obtain a good representation of the mixed reality, i.e. the reconstructed information overlapped on the present remains.

Fig. 4.1 POIs marking prehistoric houses in the Vădastra village

These characteristics differentiate a location-based MAR application from a vision MAR one, in which the augmentation is triggered by a static image.

4.5.1 Game Description

The game offers **five mini-puzzle** levels that can be selected from the game starting page (Table 4.1): wooden joints (Fig. 4.2), wattle-and-daub walls (Fig. 4.3), house decoration, ceramic vases, and human characters, presenting five levels in increasing logical order to build the house. The player can select one category at a time, or all at once, which gives the game a greater degree of complexity due to the fact that the POIs may overlap and the user has to make a greater effort to achieve the goal. Each mini-puzzle level identified in the table below has a gameplay score equal to the number of pieces it contains to complete the puzzle.

4.5.2 Game Objective

The game objective is to find the pieces that fit a digital or real model, in the present case, parts of prehistoric house and archaeological artefacts. The first level of the

Table 4.1 The mini-puzzle levels needed to discover a prehistoric house

Mini-puzzle levels	Gameplay score
1. Wooden joints	4 artefacts/4 points
2. Watle-and-daub walls	7 artefacts/7 points
3. House decoration	1 artefact/1 point
4. Ceramic vases	2 artefacts/2 points
5. Human characters	3 artefacts/3 points

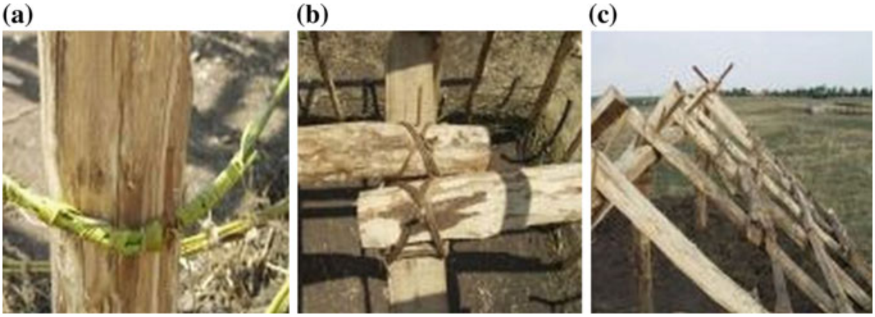

Fig. 4.2 **domusAR**: **a**–**c** the pieces for the "wooden joints" (the reconstruction of a Chalcolithic house in Vădastra village by D. Gheorghiu)

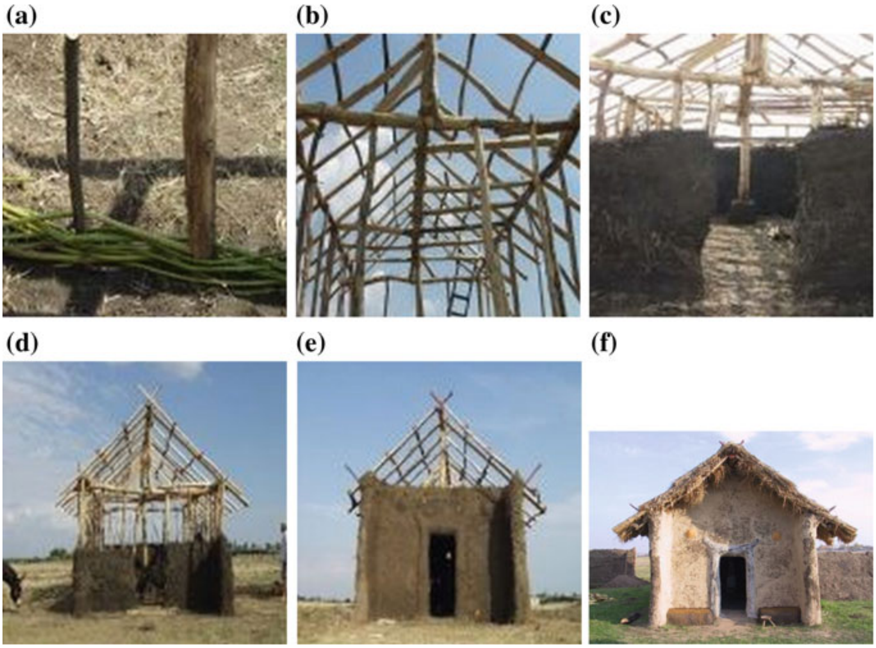

Fig. 4.3 **domusAR**: **a**–**e** the pieces for the "wattle-and-daub walls"; **f** the whole house (the reconstruction of a Chalcolithic house in Vădastra village by D. Gheorghiu)

game ends when all the pieces are found and registered. The educational goal is to help a user understand how a prehistoric house is built and decorated.

4.6 UrbanAR: A Location-Based MAR Puzzle for Settlement Reconstruction

In a second stage, another game level was added, as a new AR layer, labelled "urbanAR", to emphasize that complex forms of spatial organization, including the urban ones, are considered.

4.6.1 Game Description

The augmentations of each defined POI are triggered by the geographic location of the players within the selected archaeological area, inside a range of maximum 50 m radius. Within this sensitive area, the augmentations will be visible and overlapped on the live image of the contemporary landscape. The augmentations are video fragments of a 3D virtual tour, representing the reconstructed prehistoric settlement.

4.6.2 Game Objective

At this game level, users have to discover five fragments of a 3D reconstruction of a prehistoric settlement. The educational purpose is for the observer to understand the general form of the settlement and its internal organization, as well as providing an immersion and experiences of the ancient built spaces (Fig. 4.4).

Fig. 4.4 urbanAR: three video-fragments for the 3D reconstruction of the settlement

4.7 Game Design Methodology

To create the game "mechanics", the geo-POIs were distributed within the defined archaeological site in the village of Vădastra. The design followed the subsequent stages:

- the five mini-puzzle pieces and the relevant images/pieces were defined;
- a description of the game purpose and rules was provided;
- for each puzzle a text indication was created for users to know how many pieces were to be found;
- a settings page was defined, to select the POI search range, the game levels and the categories in each level as radio buttons. The range can be configured up to 50 m, and it is set by default at five meters;
- a version of the game was given, such that the users will know if a continuation of the game were to be developed; in the present case it is v1.0;
- to allow users to collect puzzle-pieces and gain points associated with their user accounts, an authentication process was implemented, based on Open Authentication (OAuth) technology.

The MAR application was developed on the Layar AR platform (Layar 2018), a free platform for geo-AR layers. The POI definitions and content are defined and stored in a MySQL database, while the application itself can be customized using php and JavaScript programming languages.

4.8 Game Development

For the development of the game, two geo-AR layers possessing images and 3D videos as augmentations were created on the Layar AR platform (Layar 2018) under the name of *ARcheo*.

The application started from the online Layar developer platform where the application's tags and metadata (e.g. application category, interest, version) were introduced, to register the application and facilitate its search in the Layar ecosystem (Fig. 4.5). In the present case, the tags are "education, archaeology, discovery, game, puzzle", and the category "Architecture and Buildings". The Layar online platform also allows pre-defined interface elements (POI icons, colours) to be customized.

To develop the Layar MAR application, it is necessary to create a MySQL database and a web service (Layar architecture 2018) responsible for fetching the content according to the defined contexts. Although the Layar site is well documented with application samples, an IT expertise is needed to understand and customize the two components, i.e. the POIs database and the web service. The database contains all the application's content and logic (e.g. actions, interactions).

After a test of the application (Fig. 4.6), the Layar Platform allows the publication of a MAR application, called "layer", so that it can be found by users in the Layar application catalogue (Fig. 4.7).

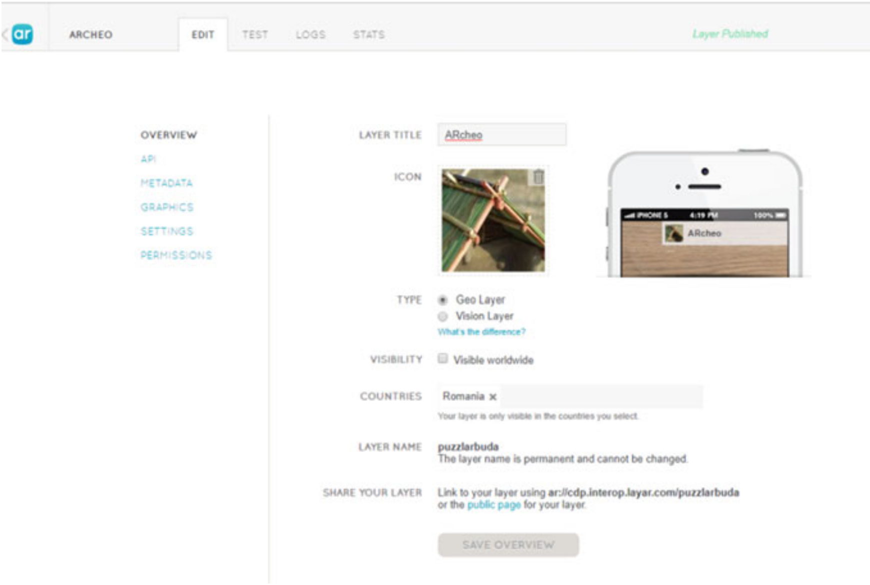

Fig. 4.5 The *ARcheo* page on the Layar development website

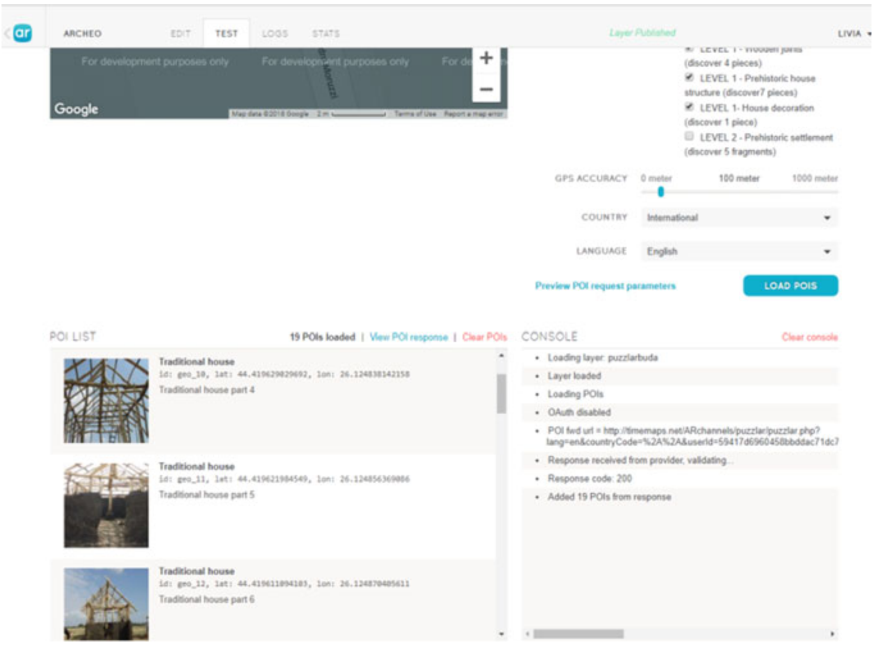

Fig. 4.6 The *ARcheo* test page on the Layar website

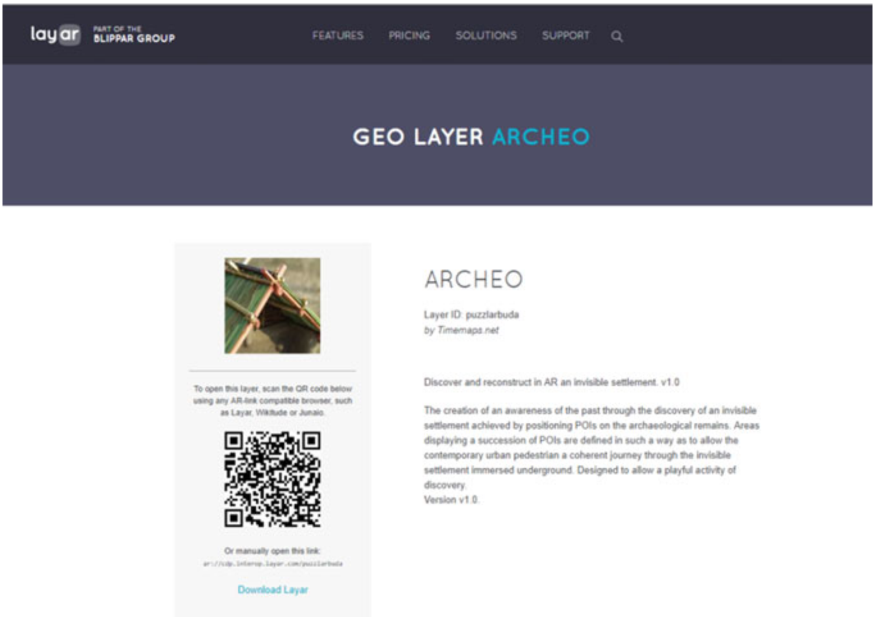

Fig. 4.7 The *ARcheo* page on the Layar application catalogue

In order to access the game, it is necessary to install the Layar AR platform on a mobile phone and to search for the two layers in the Geo and Vision category. For Vision, the camera will turn on, and for Geo, the GPS receiver will be activated, i.e. identifying the location (Fig. 4.8). The game *ARcheo* uses a simple gameplay, the main objective being to discover and understand the local heritage in an attractive way, actively involving users and stimulating their imagination (Fig. 4.9).

The game play is open, allowing an iterative development, i.e. content can be developed with other puzzles related to the interior of the house, other household objects or characters. This ensures the users' motivation to return/check if a new version has appeared. In the current version the level of difficulty is chosen by the players through the filters which allow the selection of a puzzle or a combination of puzzles.

The use of the Layar platform allowed the development of an ambitious geo AR application. It is a mature platform that uses the Android operating system to deliver AR applications with attractive interface elements, multi-media content, content sharing, inter-layer links, interactions or "actions". Each POI can be represented with a customized icon and a "billboard" containing descriptive text.

Fig. 4.8 The *ARcheo* MAR application on smartphone

4.9 Lessons Learned and Future Work

The Layar platform offers a combination of rapid development, by means of its online platform, application samples, and custom development. For the prototype the content used (under the form of reconstructions and videos) was retrieved from the Vădastra archaeological site, as well from the Time Maps project (www.timemaps.net).

In a future version, different layers could be created for each puzzle, conditionally allowing players to advance from one level to another, after finishing the previous level. The content may also be diversified, e.g. with audio, video and 3D, to create a more immersive gaming environment. Story-boards and content management are required to support the design and development of the game with a more complex game play and mechanics, avatars, levels, objectives, etc.

Fig. 4.9 Searching POIs within the Vădastra site, together with local children

4.10 Conclusions

The archaeological *ARcheo* game does not only involve a ludic activity, but also an artistic and intellectual one, acting at the level of emotions. Ancient invisible settlements have excited not only the imagination of archaeologists, but also of writers, to cite only the book of poetic archaeology, *Invisible Cities* (1997) by Italo Calvino, used as the motto for the present text.

The game described would like to be an art product, a metaphor for the archaeological process of discovery of the fragments of an invisible whole, which is unfolding gradually, to reveal the ancient hidden settlement.

Although the text describes a simple case of the utilisation of the game within a small village community, the game can be used with great efficacy in urban areas to carry out an urban archaeological research, and, moreover, a pshychogeographical research. It is well known that psychogeography was an art movement initiated at the middle of the last century (see Stein and Niederland 1989), and represents "[the] study of the specific effects of the geographical environment, consciously organized or not, on the emotions and behaviour of individuals" (Coverley 2010, p. 93).

In this perspective, the game could be seen as a form of *situationism*, a concept meaning not only the creation of different situations (see Guy Debord in Knabb 1981), but also the conscious situation of the player into a certain place in space and time.

Fig. 4.10 Real character dressed in prehistoric costume, scanned in 3D

The player-performer moves within a contemporary space, being guided by the material forms and spatial organizations from the Past. The player's walking traces spatial diagrams from the past that appear gradually like the erased writing emerging from a palimpsest.

It is desirable that the play function as a rural or urban work of psychogeography, to allow the walker access not only to the ancient architectural know-how, but also to spatial and emotional experiences through the contact with the objects and the people from the Past. This is the reason why real characters dressed in ancient costumes were scanned in 3D and introduced into the reconstructed spaces, to animate and humanize them (Fig. 4.10).

In this way, the *ARcheo* game would act upon the emotions of the individuals, becoming a significant contribution to the realm of psychogeography.

We conclude with Michel de Certeau's (1988) assertion: "Every story is a travel story, a spatial experience" (p. 115).

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Chapter 5
Explorations in Mixed Reality with Learning and Teaching Frameworks: Lessons from Ludus and the Vulcan Academy

Gary Grant, Daniel Della-Bosca, Dale Patterson, Shane Prenzler and Scott Roberts

Abstract Implementations of mixed reality technologies for teaching and learning are becoming increasingly common, however it is depth of experience that should be the goal of pedagogical design. This chapter explores the design of mixed reality frameworks for learning and teaching at Griffith University, Gold Coast, Australia. Discipline areas from Pharmacy and Design have developed a series of experiential learning scenarios that help build rich frameworks in which to learn, teach and assess, using and testing multiple strategies in the process. Essential to teaching methods is the implementation of learning objectives as moderated by strategies of play-based learning. The learning scenarios range from developing mobile applications to impact upon spatial reasoning beyond the device frame, designing transformative experiences through student led content authoring of augmented game content, to immersion in a virtual pharmacy with access to augmented content through head mounted displays. Increased engagement is a key objective of the gamified learning experience, and our experiments seek to investigate the boundaries between educational theories as applied to mixed reality environments through active learning and inquiry-based instruction. Our findings demonstrate that play, through the

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use of mixed reality technologies, can benefit and prolong student engagement, but importantly that the student can have ownership of the experience. The technological frameworks are not just seen to have novelty but are effective tools for deeper and lasting levels of engagement.

5.1 Introduction

We want what science fiction promises. We were captivated long ago by visions of a holodeck on the starship *Enterprise* and of the immersive holographic interfaces of the *Vulcan Academy*, and we are now entranced by the idea of a whole virtual planet for learning called Ludus, described in Ready Player One (Cline 2011). Through a series of experiments, we are beginning to build those experiences, so that we can change the way we teach, and our students, change the ways that they learn. The teaching and learning frameworks described, all address common pedagogical goals, and that is for a gamified experience within the classroom.

On Ludus 'every school is a grand palace of learning' (Cline 2011). And learning can be tailored to use any type of simulation and visualisation imaginable. We may not yet have access to virtual realms that could easily be mistaken for reality but we can augment and mix realities using available technologies to contribute to improved learning outcomes. This chapter outlines a series of case studies within the schools of Health and Design at Griffith University in Australia. Our needs are to impact upon an interaction student's development of spatial reasoning, to test user experience for design students, to challenge the compositional structures of the frame and to accelerate learning for a pharmacy student. The individual objectives may differ but the experiences that we are creating are similar in their technological mediation of reality.

The overarching theme for us are the imperatives of play-based learning. We have some quite serious things for our students to learn but if they are playing, discovering, for themselves the experience is meaningful and skills are more likely to be retained.

Ready Player One has a great gaming hero in the form of Warren Robinett, the creator of the Atari game *Adventure*. In that game, he created the first *Easter Egg*, a device not necessary to achieve an outcome but available for the pure joy of discovery. Warren Robinett went on to become one of the principal developers of head mounted displays for NASA and in 1991 described the concept of computer graphic representations superimposed onto the real world (Robinett 1991), a set of technologies that we now refer to as Augmented Reality (Caudell and Mizell 1992). Most of Robinett's forecasts of the uses of augmented realities are just coming to fruition. Some have yet to take hold such as the grand idea of real space graphic databases to overlay onto the world (Robinett 1991), but in small ways the present assets, for these future databases are being constructed.

It is evident that technologies utilising augmented realties, have practical purposes as Robinett, Caudell and Mizell suggested nearly three decades ago. In education, however, the design of learning and teaching frameworks utilising virtual, augmented and mixed reality frameworks have the potential to reach beyond the prosaic, and to afford new ways of understanding to affect ontological change. Terry Winograd and Fernando Flores summarise that 'the creation of a new device or systematic domain can have far-reaching significance—it can create new ways of being that previously did not exist and a framework for actions that would not have previously made sense' (Winograd and Flores 1987). Designing for the affordances of virtual, augmented and mixed realities is our challenge, and we meet that challenge through the experimentation with and the implementation of ludic strategies with our students. This is not to state that all of our teaching frameworks are gamified, rather a series of explorations or discoveries negotiated with our students. The game experience is influential to curriculum design and the use of mediating technologies in the learning and teaching environment.

Crucial to the students experience is the mediation of 'Presence' (Lombard and Ditton 1997; Weibel and Wissmath 2011). Theresa Lombard and Matthew Ditton define Presence as a 'perceptual illusion of nonmediation' (Lombard and Ditton 1997). To contextualise this phenomenological concern, Samuel Taylor Coleridge similarly, 200 years ago, coined the phrase 'Willing Suspension of Disbelief' (Coleridge 1817). Coleridge's term is the more poetic of course, whilst Lombard and Ditton's is clear to us in its use of contemporary intellectual grammar. There is no distinction except for Coleridge's claim that his poems, as a counterpoint to those of William Wordsworth, could extend the senses of the reader beyond the realities understood by the audience into imaginary realms. Wordsworth, in his endeavours on the other hand, 'would excite a feeling analogous to the supernatural, by awakening the mind's attention from the lethargy of custom' (Coleridge 1817). In writing of his and Wordsworth's endeavors, Coleridge essentially wrote of the idea of presence, and the perceptual illusion of nonmediation in aesthetic terms, ideas understood in the language of the time. Terms that are essentially relative to human experience and made relevant by the use of (media) language devices of the time.

In a short introduction to this chapter an intentional thread has been woven, loosely connecting Poets, Computer Programmers, Academics, Novelists and Screenwriters of Science Fiction. The premise is that all of course explore the multifaceted ideas of presence in either intellectual or aesthetic paradigms. We share the desire for ontological significance, we desire to find meaning in our world by extending our senses beyond it, even by attempting to escape it sometimes. Virtual, Augmented and Mixed realities in an educational paradigm permits this discourse to exist and flourish in an environment where, our students learn to enquire whilst navigating new mediums for communication, collaboration and instruction. There is essentially nothing new about our new technologies, and new mediums for expression. In some manner we can understand them in much the same way as we can negotiate literature, or poetry or film. Winograd and Flores are correct in their ontological position, however, the 'new' mediations of presence do create new ways of being and permit new frameworks for actions. In the classroom these frameworks are rapidly affording educators and students alike new ways of enjoying the experiences. It is this enjoyment that is crucial, the discovery of *Easter Eggs* is an analogy for the personal discoveries in any learning process. Lombard and Ditton write, ‘the most prominent psychological impact of presence is enjoyment and delight’ (Lombard and Ditton 1997).

5.2 The Augmentation of Learning

The development of immersive learning environments, like those displayed in the holodeck of the Starship Enterprise, are needed to create foundation knowledge that connects the learner to the workplace. High resolution panoramic imagery and modelling of virtual environments have allowed for detailed presentation and representation of workplaces. The resolution of these virtual environments is high enough to view tools and resources contained within them. These tools and resources represent countless markers from which interactive and engaging learning objects can be launched. The potential exists to tailor learning to the requirement of the learner and develop authentic self-paced learning. Multiple users inside the virtual environment can actively engage in specific learning opportunities depending on which markers they engage with. These environments provide the learner with a safe virtual environment to develop skills contextual to the relevant workplace. Gamification of the virtual and augmented learning environments provide the impact required to maximise the learning opportunities presented by these disruptive technologies. Gamification includes the elements and thinking of games in activities that are not specifically games (Kiryakova et al. 2018). The value of gamification in learning and training is well established (Dichev and Dicheva 2017; Erenli 2012; Gressick and Langston 2017; Kiryakova et al. 2018; Martí-Parreño et al. 2016 and Nevin et al. 2014). The use of AR presents an easy, sustainable option to gamify guided activities inside virtual environments, including features of challenges and tasks, scores, levels, badges, and rankings provide the gamified context to the learning (Kiryakova et al. 2018). These features can easily be connected to marker linked AR-tasks, thereby providing the learner with a gamified learning and training experience. The virtual environments, markers, objects, relevant educational and learning theory, interactive/active learning or training tasks, and elements of gamification are therefore important components. This chapter draws upon the experiences of the authors and outlines achievable options for educators with little background in developing applications to produce tailored learning and training in AR games.

Augmented Reality represents a powerful productivity and educational tool in pharmacy and the broader health care setting. AR promises to bridge the gap between knowledge and practice (Zhu et al. 2015). In pharmacy, head mounted displays (HMDs) coupled with AR tools offer potential support to the dispensing process and provision of clinical services (Fox and Felkey 2013). Other suggested applications for AR in pharmacy include: first-person perspective procedural skills education and training, facilitation of ‘telementoring’, remote collaboration, real-time risk management, creation of visual records to document and verify episodes of care; tailored health care educational experiences to accommodate patient needs and health literacy; inventory tracking and management; medication checking prior to dispensing;

and timely access to in field of view patient and drug information (Fox and Felkey 2013). Despite the promise, little published evidence currently exists on the feasibility, acceptability, and outcomes associated with the use of AR specifically in pharmacy. This has formed the basis for our research into AR applications for pharmacy learning and teaching and application to clinical pharmacy practice.

The first case at Griffith University for the use of AR in pharmacy education related to its integration with the projection of a virtual clinical workplace on a purpose-built large projection display wall. The primary aim of this work was to provide associations between the learning and teaching and authentic clinical workplaces. High resolution panoramic images of clinical workplace settings were professionally captured at multiple levels and positions throughout the workplace. Workplaces captured included ambulances, hospital wards, treatment rooms, clinical laboratories, hospital pharmacies, and community pharmacies Fig. 5.1.

The panoramic images provide authentic, high-fidelity environments with a resolution sufficient to allow students to read information on medicines stocked in the facilities and use handheld scanners to scan their bar codes for product checking. Virtual tours of the captured clinical settings were generated using *Tourweaver 7* (*Easypano*) allowing users to move through facilities to locate medicines and equipment relevant to the specific learning objectives of the lesson. Students are seamlessly warped within and between clinical workplaces in a risk-free environment. The virtual clinical environments themselves assisted with group-based discussion and facilitated the development of inquiry-based learning activities. However, there remained a need to facilitate students to actively participate in self-paced learning off the projected virtual clinical environments. Initial work focussed on the addition of multiple embedded QR codes or as clickable hotspots linked to active learning.

Fig. 5.1 Example panoramic image of community pharmacy workplace and linked AR activities (Image courtesy of the author)

Following this, the projected medicine containers or equipment located in the virtual environments were set as the markers for identification. AR objects and active learning tools included animated mechanisms of drug action, access to relevant drug information, access to simulated learning activities, and links formative online assessments developed using *iSpring Suite 9.3* and *Adobe Captivate* (e.g., multiple choice questions, extended matching questions, drag and drop activities, and digital crossword puzzles). Proprietary pharmaceutical products were also captured using the Iconasys Medium Photography Turntable, *LumiPad 360 Photography Lighting System, Medium 360 Acrylic Riser*, *and Shutter Stream 360* software to generate the image shown in Fig. 5.2. These high-resolution rotatable images allow for more detailed, interactive exploration of medications.

The AR applications were initially developed using *Metaio Creator 4* and delivered on iOS and android-based devices using the *Junaio AR* mobile browser. Equivalent experiences are currently being developed using ARKit 2. Particular attention was devoted towards development of activities, which facilitated group involvement and used achievement unlocking to gamify activities. AR provided the means to allow multiple users to interact at different positions across the projected virtual environment. It provided the capacity to individualise the student learning experience, catering for varying levels of foundation knowledge, and learning needs. Although the captured panoramic images provided a powerful tool to promote active learning, AR provided a doorway to unlimited learning opportunities. AR has the potential as a tool to combine learning in practice (Zhu et al. 2015).

Work at the Griffith school of pharmacy is now focused on using the potential of AR to provide context sensitive procedural skills education and training. In particular, our work has since focused on the framework for developing and assessing

Fig. 5.2 Example pharmaceutical product captured using the iconasys system (Image courtesy of the author)

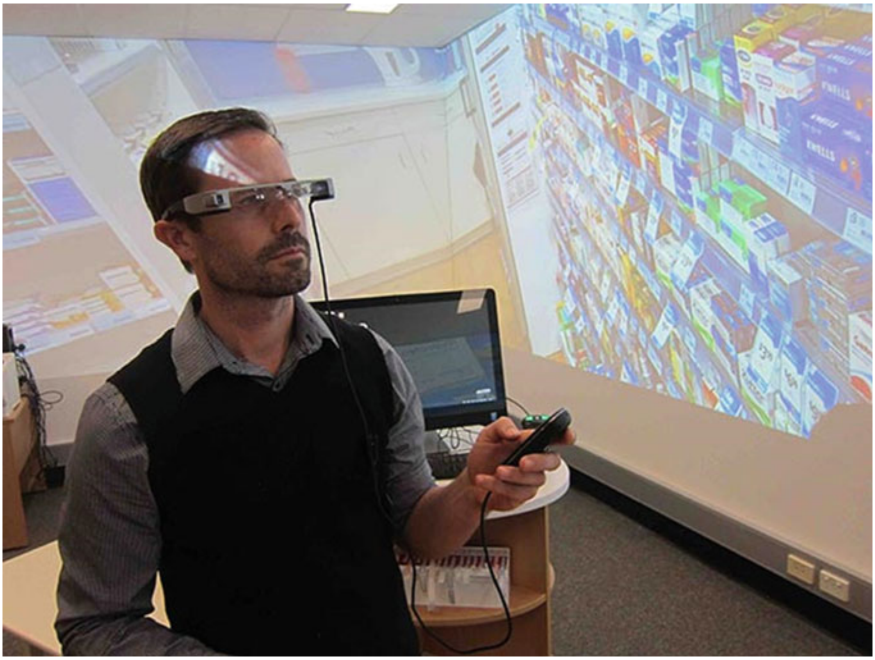

Fig. 5.3 Virtual pharmacy at Griffith University (Epson Australia 2017)

AR applications for the provision of pharmacy services to standardise and enhance productivity.

AR coupled with an HMD such as the *Epson BT-300 Smart Glasses* is entertaining and visibly engaging (see Fig. 5.3). However, our experiences with the use of AR in health care education highlighted a need to adopt a suitable framework for the design and iterative development of these practical education tools. In addition, there was a need to assess the acceptance of this technology-enhanced learning practice.

5.3 The Mobile Augmented Reality Education Design Framework

The mobile augmented reality education (MARE) design framework was identified by the research team as an appropriate model for the rational planning, design, and re-design of our AR pharmacy applications. The MARE framework, which was built using a conceptual framework analysis method, was proposed by Zhu et al. (2015).

The AR function layer is the design object and the foundation and outcome layers provide the support to meet the design aim. These layers map required key concepts, which include: activities, assessment, environment, objectives, materials, and personal paradigm. As outlined by Zhu et al. (2015), implementing the MARE framework requires several steps, which include: defining the educational outcome; defining the personal paradigm, characterising the learning environment, and designing the learning activities. The three main layers to MARE include: foundation; outcomes; and function. These layers provide the hierarchical structures for the content objects. The MARE framework in essence attempts to meet all the components of functional conceptualism, which includes: goals; values; functions; and situations, Zhu et al. (2015). We have successfully applied the framework to the development of an AR HMD warfarin counselling guide that steps the pharmacist through the correct, documented procedure (see Fig. 5.4). The tool provides context sensitive counselling advice by considering and incorporating foundation, function, and outcome in its design. At this stage, our evaluation of the developed tool has primarily focused on user acceptance of developed AR applications delivered using HMDs.

Educational outcomes of using the HMD-AR warfarin counselling guide may become a reality if it is repurposed in the future. When considering the layers of the MARE framework used for its development, the heavy use of learning theories incorporated aid any potential use as a leaning tool. The outcome level helps to understand which abilities learners can gather from the framework as well as contributing to the functional layer. Expected abilities of the learner, leaning objectives and the learning assessments being conducted influence the function and foundation layers of MARE. The function layer of MARE incorporates the learner's personal paradigm, learning assets, learning activities and the learner's environment to inform how healthcare learning could be achieved with the designed framework. Learning materials and activities need to be considered alongside the learning objectives and the learner's personal paradigm and the AR environment. Both the learning activities

Fig. 5.4 HMD-AR warfarin counselling guide use

and the learning environment should be grounded in learning theory which makes up the foundation layer. The cycles of synthesis and re-synthesis and the revising of the conceptual framework made necessary with the use of CFAM, in turn allowed grounded development of the foundation layer (Zhu et al. 2015).

The foundation layer depends mainly on available learning theories and gives reason to why the developed educational framework can be used for healthcare education. Learning theories are the foundation for the development of learning environment, activities and materials used for the educational framework. Each learning theory also casts a different view on learning itself. The original MARE contained three learning theories which were applicable to the AR environment in the original study regarding the judicious prescribing of antibiotics by general practitioners. These learning theories included experiential learning, situated learning and transformative learning (Zhu et al. 2015). Further research led to the discovery of other learning theories which have previously been used in healthcare education utilising AR, including cognitive information processing theory (CIPT) and dual coding theory (DCT) (Bitter 2014). Both CIPT and DCT were then also incorporated into the foundation layer of the MARE based framework used for the HMD-AR warfarin counselling guide. Not only are the use of learning theories and developmental frameworks largely missing from most current AR development; but there had been no studies found which attempted to also gauge acceptance of AR tools which utilised these methods in their development.

The need for gauging of acceptance of technology prior to introduction of technology to users is paramount as poor acceptance can lead to reduced levels of actual use of these technologies (Hamid et al. 2016). If acceptance of technology by users is low, amendments to the user interface can be conducted in order to improve the level of acceptance and then hopefully the appeal of actual use (Hamid et al. 2016). This is especially true for emergent and disruptive technology which; can change existing practice and users are also less likely to have had significant interaction with these forms of technology previously (Rotolo et al. 2015; Psotka 2013). There can be a disparity between the expectations people hold for emergent and disruptive technology, which can ultimately lead to disillusionment upon actual use (Gartner 2015, 2017). One means to testing acceptance is the validated technology acceptance model (TAM) (Hamid et al. 2016; Bugembe 2010). There are several domains and factors within TAM which contain constructs aimed at determining the many levels which exist in acceptance, as illustrated in Fig. 5.5 (Park 2009). The factors include system accessibility, self-efficacy and subjective norm, while domains include perceived ease of use, perceived usefulness, attitude and behavioural intention (Park 2009). Factors influence the domains of TAM which in turn influence each other in the order mentioned, however the inverse relationship does not exist and any influence of the domains of TAM would not influence individual factors (Park 2009). Existing preconceptions of social norms can ultimately affect acceptance through influence on the individual factor of subjective norm in TAM, eventually influencing behavioural intention and the actual use of technology (Saleh 2014). The HMD-AR warfarin counselling guide presents a challenge, as it does not conform to pre-existing notions of patient counselling. Current patient counselling dictates close and precise

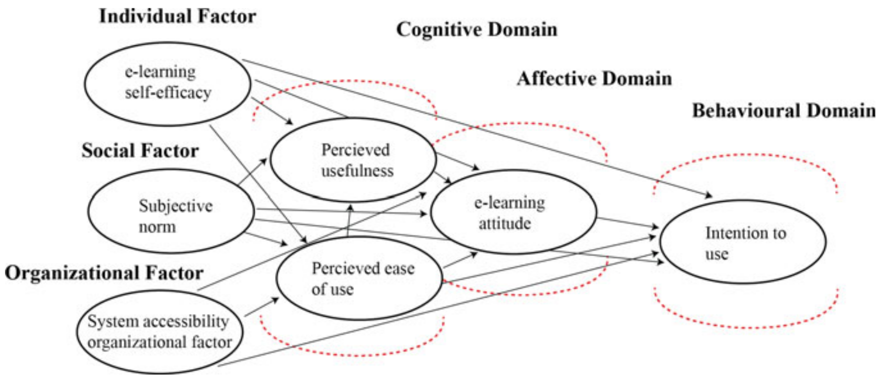

Fig. 5.5 The interrelatedness of the TAM constructs used, each arrow represents hypothesised causal relationship between constructs (Park 2009)

communication between patient and pharmacist (Hargie et al. 2000). Perceived distractions for either party involved may result in reduced quality of drug information exchange and learning on the part of the patient (Syrastad et al. 2004). HMD and AR technology may present the necessary information and indeed be helpful during clinical services such as warfarin counselling. However, these forms of emergent and disruptive technologies need to also appeal to social conventions which exist between health professional and patient to ensure acceptance by satisfying parameters such as subjective norm (Teo 2009; Chang et al. 2010).

There are obviously formal needs in the school of pharmacy to deliver information accurately and train students rigorously, however it has proven possible to use disruptive technology effectively to engage students. It is the gamification of tasks that delivers self-paced experience authentic to the student. Augmented Reality is crucial to the success of this delivery and although the students are not playing games, they are navigating their learning with the strategies of game theory and the tools of gameplay. It is possible and desirable that gameplay is encouraged as a principle of teaching and learning. The virtual environments constructed within the School of Pharmacy Griffith University, demonstrate that the learner can thrive in a safe and carefully monitored space using augmented frameworks to develop skills that are contextual to their discipline. It is through the gamification of the virtual and augmented environments that educators can maximise the opportunities afforded by these disruptive technologies and the students in turn are provided with a rich and multifaceted learning experience.

5.4 Augmented Reality—Transforming Situated Learning Through Realistic or Abstract Play

In the School of Design at Griffith University, digital worlds, virtual environments and game play, offer an interesting mechanism to transport any one of us, but in this case particularly the student, out of their normal world into a rich experience based, digital learning environment. Play within such a space is a critical element of the success of the virtual environment. The nature of play itself, activity without a specific required purpose, allows free exploration of these virtual game worlds that can potentially reveal new, student directed, ways of learning. In essence the play-based character of these worlds may be as important as the augmented content.

An AR based game for learning, is a new environment that is unreal, yet it remains strongly grounded in the students' personal "real-world" surroundings, bringing new virtual elements to life without completely leaving the frame of reference of the "real" world behind. The power of play, in this case digital AR game-play to enable the student to experiment in "real world" experiences, enhances the power of the experience.

This situated learning, playing a virtual AR game inside our "real-world", offers an extension to the fundamental concept of, (learning in, and through, being part of the practical real-world situation). It allows the student to place a new AR experience within the real world that they exist. Giving the student the experience of the virtual environment, its cues, interactions and experiences, not in a remote place, but right here and now, where they are. This capacity, provided through AR and game technologies plays a key role in bringing a desired situated learning scenario to the student. One where the student is not learning at a distance, or in theory without practice, but is instead situated amongst the practical working space, one where they can "play" with the environment and its scenarios (through game-based interaction), yet also be in the comparative comfort of their own spatial environment. As John Seely Brown suggests:

> Learning environments should be spaces in which all work is public, is subject to iterative critique by instructors and peers, and in which social interaction is primary. In such spaces, students and teachers engage in a situated cognition approach to teaching and learning where cognitive accomplishments rely in part on structures and processes outside the individual (Brown et al. 1989).

Although many AR based game experiences are potentially very powerful, they often miss one of the key components of a real-world situated learning environment, that of human social and interpersonal engagement. The nature of most AR systems involves a single user experiencing an augmented view of the world, allowing them to engage with the virtual space and its items and scenarios, but as identified by studies beginning with Brown et al. (1989), and more recent studies of digital learning spaces, with a situated approach, such as (Gomez and Lee 2015; Dunleavey and Dede 2014 and Carlson and Gagnon 2016), the significance of human interaction is critical to a learning environment of this type.

5.5 Game Play, Authenticity and Abstraction

Game worlds, in both AR and other forms, come in a large range of forms, styles and formats. From the highly realistic and immersive 3D computer graphics (but completely imaginary concepts/worlds and stories) seen in many commercial first-person games, to the stylized 2D scrolling games on mobile platforms. At the heart of any effective game experience is user/player engagement. Yet this variability in the nature and style of game-play raises the question of the importance of authenticity to a game whose primary purpose is learning. Can we learn as well from a stylized 2D animation as we can from a highly realistic immersive 3D experience, and does the game style really matter?

It is very clear that the game worlds must have a base of reality, but that reality can be both physical (for example a physical space that perfectly matches a real world space) or conceptual (for example visualizing information in a way that presents the knowledge but where the physical “visualization” could never exist in the real world).

The results from the studies discussed here highlight the fact that despite significant differences in the style of the AR games being delivered that one of the keys to educational value is user engagement around an underlying truth, represented as an authentic set of learning resources. The realism of the game world itself can be abstracted from “reality” and still achieve strong learning outcomes. Equally the highly realistic game worlds, which almost place the user in a work integrated learning game space can also be highly effective. These findings support the idea that the key to learning is engagement. For AR based game worlds their ability to bring something new to the students personal space, in itself is engaging, but to be truly successful the game world, its content, and interactions must connect with the user and begin their own process in exploration.

5.6 Learning Through In-Game AR Creation

The capacity for creative play based learning, where a student not only engages with a virtual AR game, but is also an active designer, builder and presenter (to other human users) of their creative practice in that game offers a potential mechanism to bring together the benefits of both ARs situated learning potential (as a personal tool to engage with environments) and its capacity to be a rich learning environment, where human social interactions can play a key role, much like that described by Brown et al. (1989).

The capacity for AR to bring our own virtual creations into the real world (and into our personal real world) is one that often brings responses of joy and pleasure. This pleasure in seeing our creations come to a form of existence in the real world or “virtual life” are reflected in studies looking at the applied use of AR games/tools in creative design courses. As Di Serio, Ibáñez and Kloos identified in their study of visual art courses with and without AR, the AR based courses raised student engagement and motivation, and despite the challenges of the technology, students continued and engaged with more enthusiasm in the AR courses (De serio et al. 2013).

Despite this obvious potential, currently much of what AR games offer is an involvement in play, the consumption of the creations of others, rather than empowering the user to be creative and build elements of the game world and its experiences themselves. This investigative research project looked at AR learning with games, not primarily as a rich source of materials and learning resources (although these were within the virtual game world), but as a playground for creatively altering the AR space and interactively engaging with other users of the shared AR game space to interact, learn and communicate. The primary concept of this work was to empower the student to be creatively, and even playfully, designing and building the virtual content of the AR game world and through that construction process (and the communication it generated with others) to better understand the underlying themes and concepts of the topic (by requiring them to not only understand the topic but to be able to produce a world that also described that same knowledge to others in the space). At its heart, it captured the concept of the student gaining understanding through their own exploration, but then enhancing that knowledge through communicating that understanding to others.

The aim of this project was to provide the student with a transformative experience, not only through experiencing the AR content, but through a sense of capacity to exist, create and remodel the very elements that make the AR environment itself. This provided a sense of control of the space, yet also an understanding of the impact those changes made on others who shared that space. The approach taken was to require students to engage in a creative task (constructing a virtual 3D game space to a particular theme) that was visualized in a shared AR system (tablet based through the window style AR using iPad tablets), with multiple users in the same space interacting and communicating about the AR game world that was being created by the group (of which each students' world was a sub-part). In many ways this was like a physical "real-world" classroom where the student was engaged in creation of the game world and where that student was also engaged in communicating the concept, goals and reasoning to other members of the group.

Each student engaged in the creation of their own *sub-world,* they then presented their world through the shared AR game to the group (made up of teaching staff and fellow students), interactively demonstrating its features, whilst also allowing others to interact with it and ask questions, all within the AR game itself. This creation-based game world system was tested using a randomized control trial (136 participants) where students were compared using both *creative* games (where they altered the world) and *control* games (where they only consumed the world). The results in terms of learning outcomes showed that the addition of the AR *Creative* elements did not lead to a significant change in learning outcomes for the student (note that the outcomes were better but not significantly). The results in terms of student engagement were notably different (see Fig. 5.6), with students self-reported "level of engagement" (on the 7-point Likert scale from Very low to Very High) being

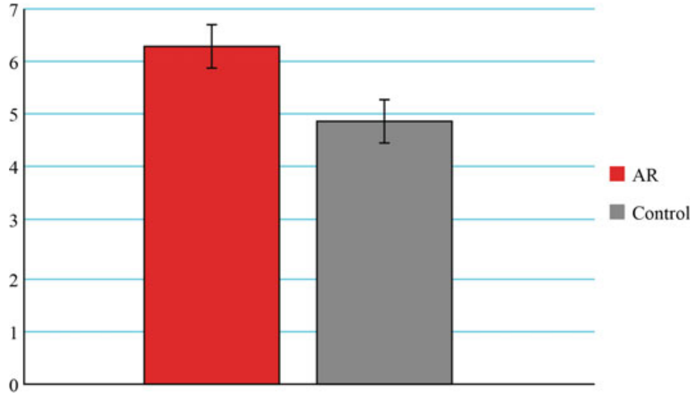

Fig. 5.6 Self-reported level of engagement

Table 5.1 Observational results, student in-class activity

	Control (%)	AR (%)
On task	36	30
Experimenting	25	11
Sharing	7	43
Off task	32	16

statistically significantly higher in the AR "creative" group (average 6.2 (±=0.71 95% confidence interval) on 7-point scale) than the Control (average 4.9 (±=0.44 95% confidence interval) on 7-point scale).

The in-class observational study provided some interesting results. One of the simplest observational tools involved the categorization of student activity (see Table 5.1). Fundamentally looking at whether the student was *on task*, *experimenting*, *sharing* or *off task*. This simple analysis showed that the AR group were more engaged in sharing than those from the Control group and that they spent less time *off-task*.

This indicates that the applied use of *creative activity* within an AR game can be a powerful tool in improving student engagement. These findings clearly highlight that a shared creative space is very effective as a means of generating student engagement through sharing concepts and ideas, but the study also revealed that for some tasks, (such as initial ideation and trial) students preferred a more personal space. As designers of educational frameworks, it is important that our AR game worlds provide for both of these types of interactive experience, shared and personal and space is allocated in curriculum design for that to occur.

5.7 Altered Perspectives Through Augmentation

Previous discussions within this chapter explore the necessity of student-centred, play-based learning and engagement by shifting a student's perspective *into* an altered environment. By taking a step back from this process, the use of immersive technology is seen to impact the transfer of presence between realities. Instead of continually engaging students in inward immersive experiences, can similar technologies assist in shifting a student's perspective *out* of one virtual environment into a higher level of augmented environment to gain a new perspective of their digital creations?

For years, consumers and content designers of digital media have interacted with interactive media through rectangular frames, disregarding all elements visible beyond its boundaries. With the recent uptake of mixed-reality (MR) technology, this frame can be redefined, allowing for virtual simulations to exist within the physical frame, effectively delivering an inception of physical and simulated interfaces. As experienced in the everyday, physical movement displaces our point of view as we experience a direct translation of our bodies. When looking through a window, we can significantly alter the content visible within the window frame by moving ourselves in relation to the window frame. If we could effortlessly move the window frame itself, more visual opportunities would become available. Efforts of this shift in perspective are also observed in cases of viewers watching a video or playing a video game, as they shift themselves in an attempt to achieve tasks like looking around corners. When dealing with frames of traditional mediums including mobile devices, televisions and cinema screens, these attempts are in vain, however, mixed reality, and more specifically augmented reality, has allowed more freedom of movement within these frames.

Munnerley et al. (2012) discuss the connection between existing learning and teaching theories and the idea of augmenting realities with varied perspectives. Although they direct their focus towards cognitive dissonance and variation, they note the importance of constructivism, activity theory and the concept of visual learning as frameworks for learning with AR. From a learning and teaching perspective within Design, students are required to visualise virtual spaces as they relate to digital interfaces, constantly adhering to the frames defined by each device. Strategies for learning content with such strong ties with visual discourse would benefit greatly from visual learning and variation theory. Continuing into the realm of AR, Munnerley et al. (2012) describe five special pedagogical opportunities offered by AR. Two of these, Visualisation and Alternative Perspectives, clearly align with the purpose of this section.

Furthermore, the SOLO taxonomy (Biggs and Collis 1982), a longstanding guide for pedagogical practice, describes the ability for AR to provide 'access to physically inaccessible views of an object, whether closer or more distant, from above or below, or from any other perspective that has the potential to render the object unrecognisable or strange. Radical perspective changes could be used to challenge students' senses of familiar objects, and to encourage them to reflect on how their *usual* view may not be that shared by others' (Munnerley et al. 2012). By shifting a students' perspective in an outward manner, we are, in fact, allowing them to reflect on what they know about constructed digital interfaces.

Understanding the affordances of a given device, specifically the bounding frame of the interface, allows for clarity in the learning process. The frame is the portal between the physical and the virtual, defining the visible and invisible content displayed from the virtual space. In a real-world demonstration, instructors are often pointing to blank space around interfaces to explain layouts of certain interactive interface 'states'. These states refer directly to the concept of a Finite State Machine, shifting between specified states determined by user interaction. Once an interaction is registered, the interface will shift to a different 'state', altering the digital content within the physical frame.

The ability to effectively explain to a student cohort the design elements contained within visible and invisible areas of virtual spaces is critical. The accuracy of a student's interpretation of these spaces can be defined by their understanding of spatial cognition. Devices can display both two-dimensional and three-dimensional content which is ultimately portrayed through a flat, or sometimes slightly curved screen. For the purpose of this section, only two-dimensional content is considered as it relates directly to the learning and teaching task of developing an interactive 2D game as an app for iOS devices. This task was generated for a student cohort that demonstrated strong visual perception allowing for more visually oriented teaching methods.

To begin exploring the virtual spaces available within the interface, a cartesian plane Fig. 5.7 was designed outlining the x and y axes as they relate to the visible frame of the screen. The purpose of the Cartesian plane was two-fold; to introduce the students to positive and negative pixel dimensions along both x and y axes to allow for accurate placement of objects on the screen, and to portray the considerable amount of virtual space not visible when using the device frame. When simulating the app through the included Simulator, the visible and invisible areas of the virtual space became apparent to the students. They were asked to place the Dolphin character at different x and y locations and discuss the location of the Dolphin when simulating the app. After completing this task, a number of students were still unable to accurately determine whether the character was going to be visible or not and pinpoint the approximate location of the character before it appeared.

To address this, an augmented reality (AR) application was developed to simulate the 2D iOS app and allow for all design elements positioned within the invisible area of the virtual space to become visible. The application was created using Unity 5 and the ARKit plugin and deployed to an iPad Pro. A simple animation of the 2D iOS app was generated within 3DS Max and placed within Unity. The iOS app animation was hidden when the AR app was launched, being initialised and becoming visible once the user tapped on the screen. Students held the iPad Pro looking towards a surface. Once the AR app determined a surface, the students were able to tap the screen and place the simulation animation. Once the virtual device is placed within the real environment, the physical device can be moved to adjust the external perspective of the virtual device, as seen in Fig. 5.8. This allows for a virtualised simulation of the

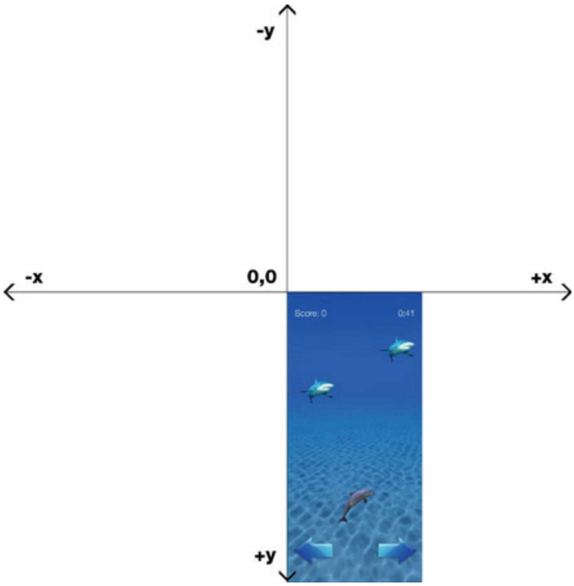

Fig. 5.7 Cartesian plane demonstrating pixel dimensions as they relate to virtual space (Image courtesy of the Author)

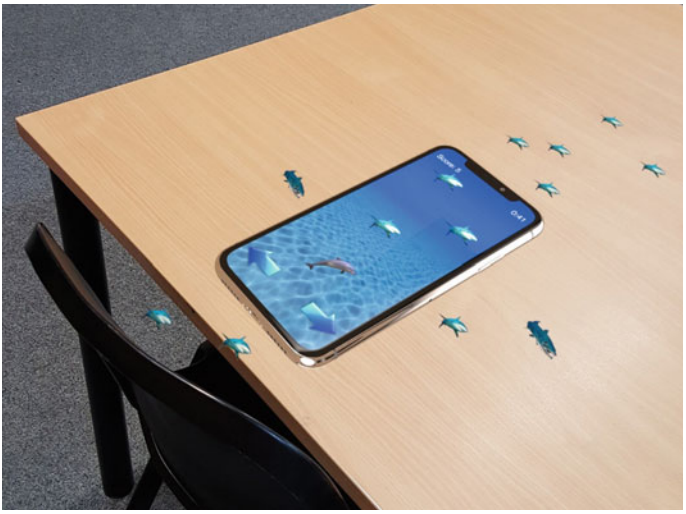

Fig. 5.8 Simulated iPhone X app as it appears inside physical iPad Pro (Image courtesy of the Author)

physical device to visibly demonstrate the capabilities of the space surrounding the device itself.

Clearly visible are the additional characters within the game, being spawned and animated through the simulated interface. As the demonstration environment existed within an AR app, the students could focus their attention on specific areas of the virtual space, moving closer or further away to gain a clearer understanding of spatial reasoning. Of the students that experienced the AR app there was an overwhelmingly positive response. All students expressed an understanding of approximate spatial location and spacing of the objects within a short timeframe. Extending beyond this simple demonstration, the simulation would best suit constructive and variation learning through the ability to update and simulate the virtual application in real-time. It is proposed that the implementation of an augmented reality environment with a rapid feedback loop such as this could greatly enhance the student experience as it allows the student to connect, integrate, construct and deconstruct their own meanings from their own simulations.

The applications of this demonstration method are wide reaching, as there are innumerable devices and interfaces able to display digital content. The potential now exists to extend both the capabilities of the AR simulation and the implementable areas of learning and teaching. For visually adept students, having the ability to display virtual elements that would otherwise be invisible can be a powerful tool as they are able to clearly visualise the virtual space in its entirety.

5.8 Conclusion

The utopian learning experiences portrayed through Ready Player One and Star Trek, offer a desirable vision for those looking to solidify the implementation of new technologies in learning and teaching. The evidence in this chapter demonstrates these technologies as adept tools for delivering learning experiences founded by existing teaching frameworks. Academics strive to achieve the level of engagement envisioned within Vulcan Academy and Ludus, with desired levels of engagement driven by deeper, student-centred learning experiences. As stated by Munnerley et al. 'there is a danger of educational applications being driven by what is technically possible, and by the interests and agendas of the early adopters, rather than what is pedagogically desirable, or empirically defensible' (Munnerley et al. 2012). When exploring variations of implemented learning activities across disciplines, namely Design and Pharmacy, the benefit and purpose of utilizing mixed-reality technologies to present gamified augmented learning experiences becomes apparent. The explorations within this chapter demonstrate potential for technology uptake by current students, providing a catalyst for the evolution of classrooms, now and into the future.

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Part II
Augmented Reality Games in Medicine and Healthcare

Chapter 6
Playful Ambient Augmented Reality Systems to Improve People's Well-Being

Julie Ducasse, Matjaž Kljun and Klen Čopič Pucihar

Abstract Intense stress, discomfort or sedentary behaviour are factors that have a negative impact on people's well-being and efficiency. A number of prototypes have been developed to help people address these issues. In parallel, gamification techniques have been successfully used in applications that aim to improve people's health by encouraging them to change their behaviour. In this chapter, we focus on the use of Ambient systems and/or Augmented Reality systems and discuss the potential of playful and gamified systems to improve people's well-being. We first describe several prototypes that aim to improve people's well-being. Then, we discuss the potential of gamification and projection-based AR systems in the context of well-being, and introduce the notion of playful projection-based ambient systems. We conclude by describing a scenario and discussing technical considerations for its implementation.

6.1 Introduction

Intense stress, discomfort or sedentary behaviour are factors that have a negative impact on people's well-being and efficiency. Therefore, it is not surprising that researchers from various fields (e.g. medicine, psychology, sociology, ICT, etc.) have been looking for innovative solutions to help people address these issues and increase their well-being.

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In relation to ICT and well-being, several research topics have emerged in the past 30 years, including affective computing (Tao and Tan 2005), physiological computing (Fairclough 2009) and even Human-Building Interaction (Alavi et al. 2016). Within the Human-Computer Interaction community, a number of interactive applications and physical artefacts have been proposed and developed. These tools leverage on the benefits of new technologies to provide people with the possibility to positively impact, adapt to and cope with their environments. In particular, working environments have been largely adopted as an interesting "playground" for the deployment of such prototypes. In parallel, gamification techniques have been successfully used in applications that aim to improve people's health by changing their behaviour patterns or mitigating stressful situations through playful experiences.

Although the spectrum of tools designed is very large, the underlying approach is often similar and can be presented in a simplified way as follows: (1) collect data related to the user's mental and physical states (e.g. physiological measures such as heart rate, respiration or skin conductance response) and/or to the user's environment (e.g. temperature or air quality); (2) process data in order to inform or alert the users and/or promote behavioural changes—be it by supporting the acquisition of self-regulating techniques (e.g. meditation), suggesting actions (e.g. opening the window if the air quality is poor), or even to directly alter the environment to impact users' comfort.

In this chapter, we will focus on the use of Ambient systems and/or Augmented Reality systems that have been designed to provide users with data related to their mental and physical state as well as to their environment, and we will discuss and illustrate the potential of gamification for such applications. Given the prevalence of systems intended to be deployed in the workplace, and in particular for white-collar workers, we mainly focus on built and working environments. We utilise the first section to delineate a number of factors that impact people's well-being, and briefly present different ways of assessing it. In the second section, we describe Ambient systems as well as projection-based Augmented-Reality systems. In the third section, we discuss the potential of gamification in the context of well-being. In the fourth and last section, we propose the design of Ambient Augmented Reality systems to improve people's well-being, focusing on the idea of peripheral interaction, calm technologies and gaming.

6.2 Well-Being

6.2.1 What Is Well-Being?

Definitions of well-being in the literature are not consistent, and the term is often used interchangeably with terms such as comfort and health (Pinto et al. 2017). Danna and Griffin (1999) view well-being as a broader concept that includes non-work satisfactions, job-related satisfactions and general health. Health is thus considered as a sub-component of well-being and is associated with physiological and psychological factors. Nevertheless, both are affected by three types of interrelated antecedents (the work setting, the personality traits and the occupational stress) and both can affect individuals and/or organizations (Cooper and Dewe 2008).

In this chapter, we will use the term "well-being" in a broad sense and we will consider that well-being can be affected by, among others, stress, health and comfort. We will first address occupational stress, followed by other health-related issues conditioned by the work setting, and finish with the concept of comfort. The notion of comfort constitutes a well-documented and delineated topic of research that is being studied within a variety of fields, including Architecture, Human-Building Interaction and Built Environment research.

6.2.1.1 Stress

Stress is a physiological and psychological response that happens when the environmental demand exceeds one person's adaptive capabilities. Stress is triggered by a "stressor" (an environmental stimulus or situation) and results in behavioural consequences that will eventually help to recover homeostasis. The stress responses involve the Autonomous Nervous Systems or ANS (e.g. through increased blood pressure, heart rate and breathing, sweating and muscle stiffening) as well as the Hypothalamus-pituitary-adrenocortical axis or HPAa, that is responsible for releasing hormones (and notably cortisol, that will redistribute energy). The different types of stress result in different patterns of activation of the ANS and the HPAa system (Jeunet et al. 2014). These types of stress include: physical stress, psychological stress (e.g. when a task is cognitively demanding) and psychosocial stress (triggered by a social-evaluative threat that "occurs when an important aspect of the self-identity is or could be negatively judged by others" Dickerson and Kemeny 2004). The detrimental effects of repeated stress on health are well-documented, and include depression, hypertension and various forms of cardiovascular diseases (McEwen and Seeman 2003).

6.2.1.2 Other Health-Related Factors

Nowadays, with the prevalence of computer stations at work, people spend most of their time sitting, and more than two thirds of office workers spend six hours or more sitting at their desk.[1] This has led researchers to investigate the effects of sedentary behaviour on people's health and, consequently, to propose solutions to encourage office workers to be more active. Sedentary behaviour is defined as any waking behaviour characterized by sitting or reclining while expending little energy (Mansoubi et al. 2015). Sedentary behaviour is known to be associated with obesity,

[1] https://www.office-angels.com/research-and-insights/news/office-workers-sit-at-desk-over-six-hours.

type 2 diabetes, cardiovascular disease and premature mortality. Another aspect of modern workplaces that has been addressed in the literature is the effect of incorrect sitting postures and extensive computer usage on people's health, which can lead to the development of musculoskeletal symptoms, e.g. for the shoulders, necks, lower back and upper limb regions (Lapointe et al. 2009). Other factors that have been addressed include chronic water deficiency (e.g. Chiu et al. 2009) as well as the computer vision syndrome (Blehm et al. 2005). This term refers to various problems such as eyestrain, tired eyes, irritation, burning sensation, redness, blurred vision, and double vision. It affects 70% of computer users and can result in headache and fatigue (e.g. Dementyev and Holz 2017).

6.2.1.3 Comfort

Although comfort includes several aspects, such as physical comfort or contact comfort, we will here focus on the notion of comfort as defined in research related to built environments. In that context, comfort is an essential aspect of indoor environment quality that includes four components: thermal comfort, visual comfort, acoustic comfort and respiratory comfort.

Thermal comfort is related to four physical variables (air temperature, radiant temperature, humidity and air velocity) as well as two personal parameters: the clothes worn by the people and their activity level (Fanger 1984).

Visual comfort includes the illuminance, luminance, colour of light and glare, amount of daylight, etc. Visual discomfort can be provoked by non-uniform illuminance, and by discomfort glare, which is "a sensation of annoyance caused by high or non-uniform distributions of brightness in the field of view" (Kaufman et al. 1981).

Acoustic comfort refers to the intensity and frequency of noise. Three issues can lead to acoustic discomfort: (i) too much noise entering the person's space outside the building; (ii) too much noise from adjacent spaces; (iii) lack of sound control in the space itself (Paradis 2016).

Respiratory comfort relates to the air quality of the environment. More precisely, the indoor air quality can be defined as "the physical, chemical and biological properties that indoor air must have in order: not to cause or aggravate illnesses in the building occupants; to secure high level of comfort to the building occupants in the performance of the designated activities for which the building has been intended and designed" (Bluyssen et al. 2003). Respiratory comfort also relates to "the absence of discomfort due to odour and sensory irritation" (Frontczak and Wargocki 2011).

6.2.2 *Measuring Well-Being*

People's mental and physical states can be assessed using a variety of methods, including:

- biochemical sensors that "require collection, analysis and disposal of body fluids" (Patel et al. 2012) (e.g. to measure salivary free cortisol quantity);
- physiological sensors (e.g. to obtain electrocardiograms or respiratory signals, see (YU et al. 2018a, b) for a review);
- neurophysiological sensors (e.g. electroencephalogram);
- indirect sensing (e.g. see Tao and Tan 2005 for a review of techniques to identify and convey emotions, and Hernandez et al. 2014 for a review of the use of computer mouse and keyboard to assess one's stress);
- questionnaires such as the State-Trait Anxiety Inventory (Spielberger et al. 2017), the Self-Assessment Manikin (Bradley and Lang 1994), the Daily Stress Inventory (Brantley et al. 1987) or the NASA-TLX (Hart and Staveland 1988).

Sedentary time and sitting posture can both be detected by sensors embedded into the worker's chair (e.g. Tan et al. 2001), wearables (e.g. Dunne et al. 2007), cameras (e.g. Pinto et al. 2017) or commercial products (e.g. PostureMinder[2] or VISOMATE-USB[3]).

Occupants' comfort within the built environments is usually determined using ambient sensors (e.g. to measure temperature, humidity, light intensity, concentration of CO2), cameras or microphones. In addition, physiological measures can be used (e.g. De Dear et al. 2013; Zhang et al. 2010; Liu et al. 2008), as well as questionnaires, such as the ASHRAE Standard 55 (of Heating and Engineers 2010) and the Post-Occupancy Evaluation questionnaire (Riley et al. 2010). Dedicated tools can also be used (e.g. Comfort Box by Alavi et al. 2017).

6.3 Ambient and Augmented-Reality Systems to Improve Well-Being

6.3.1 Ambient Systems

Ambient systems rely on lights, projections, sounds or objects moving at the periphery of the user. Pousman et al. (2006) discussed the various definitions of "ambient displays" that have been used in the literature, and proposed the term "ambient information system" to refer to systems that present the five following characteristics: (1) they display information that is important but not critical; (2) they can move from the periphery to the focus of attention and back again; (3) they focus on the tangible representations in the environment; (4) they provide subtle changes to reflect updates in information (they should not be distracting); (5) they are aesthetically pleasing and environmentally appropriate. The first two characteristics are closely related to

[2]https://www.posture-minder.com/. Last accessed December 9th 2018.

[3]https://usb.brando.com/visomate-usb-vision-and-posture-reminder_p00234c035d015.html. Last accessed December 09th 2018.

the notion of "glanceability" discussed by Rogers et al. (2010): "just as we momentarily look at a clock on the wall, [ambient displays] too are intended to be looked at occasionally and peripherally without distracting us from our ongoing activities, or compromising the objects or spaces in which they are embedded". The second characteristic is also related to the concept of attentive interfaces (Vertegaal 2002). In that sense, ambient displays can support the unobtrusive display of information, while subtly promoting behavioural changes. In this section, we describe several ambient displays that aimed at improving people's well-being. Instead of providing an exhaustive list of ambient prototypes, we chose to focus on illustrative examples.

6.3.1.1 Stress and Arousal

Several ambient lighting systems have been designed to display biosensor data such as the levels of arousal or stress (Roseway et al. 2015; Snyder et al. 2015; Yu et al. 2018a, b). For example, MoodLight (Snyder et al. 2015) consists of a lamp that can produce up to ten different hues: the higher the level of arousal, the warmer the colour of the light. This system was designed to enable "students to develop awareness of communication practices related to self-revelation", but also to help therapists introducing stress management techniques to students. Another example is BioCrystal (Roseway et al. 2015), a small lamp that can diffuse five colours in order to reflect the user's affective state along two axes: valence (positive or negative) and arousal (calm or energetic). A two-week user study revealed that "the Crystal helps to control stress, and can be successfully used to increase users' awareness of their affective state, which could lead to behavioural change".

The DeLight system (Yu et al. 2018a, b) is similar, but in addition to providing users with feedback about their level of stress, it also offers tools for relaxation assistance. Unlike previous prototypes, DeLight was composed of one central light and several ambient lights installed on the ceiling or projected on the wall (see Fig. 6.1). The authors investigated the design of warm-toned versus cold-toned colour mappings. Results showed that both conditions enable users to control their response to stress, although participants "were more likely to associate a warm-toned light with their increased stress when it turned to orange".

Dišimo (Mladenović et al. 2018b) is a physical artefact that relies on multimodal feedback to encourage users to breathe more regularly and deeply. When the system detects a decrease in heart rate variability, it emits a sound to subtlety alert the user, who can decide to take the device in his/her hands (see Fig. 6.2). Audio sounds are played as a breathing guide and physical particles flutter inside the device when heart rate variability increases. Several Dišimo can be used simultaneously, for collaborative relaxation sessions. In that case, light colour and brightness provide information about the other participants' activity.

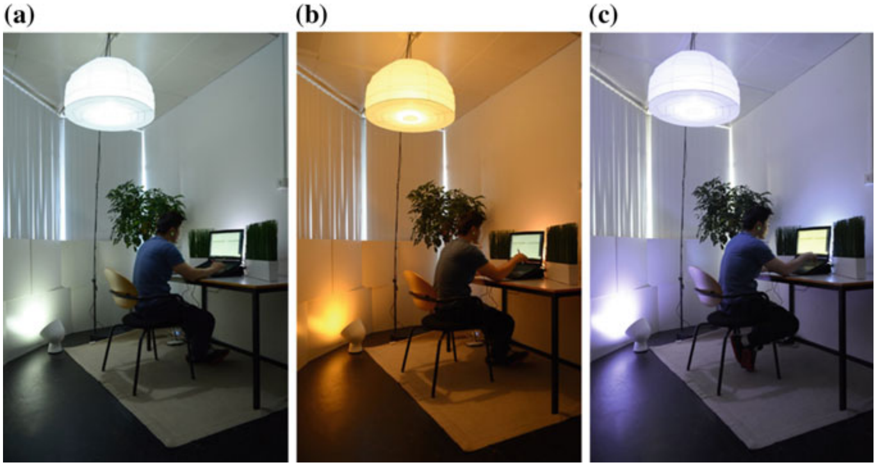

Fig. 6.1 The DeLight system provides biofeedback through ambient light for stress intervention. Light colors change according to the user's level of stress. **a** Low-stress; **b** high-stress (warm-toned mapping); **c** high-stress (cool-tone mapping). Illustration courtesy of the authors (Yu et al. 2018a, b)

Fig. 6.2 Dišimo provides multimodal biofeedback about heart rate variability in order to encourage and help users focusing on their breath. Illustration courtesy of Jérémy Frey (Mladenović et al. 2018b)

6.3.1.2 Sedentary Time

Other prototypes aimed at encouraging people to be more active, such as HealthBar (Mateevitsi et al. 2014), an ambient display with the shape of a light-tube that changes its colour depending on the user's physical activity (see Fig. 6.3). Similarly, in Fortmann et al. (2013), the authors investigated the use of a peripheral lamp to inform users about their physical activity, through variations in light. Similar to the HealthBar system, their design was based on the metaphor of a battery: the light colour progressively changes from green (fully charged) to red (discharged); when the user is active, the battery charges again and progressively switch from red to green. Results showed that participants increase their number of steps when using MoveLamp.

BreakAway (Jafarinaimi et al. 2005) is an actuated sculpture that relies on "body-language" notions to convey information about the time people have spent sitting. The sculpture reflects a body's shape and can look as if it were standing upright or slouching (see Fig. 6.4). Therefore, it is meant to encourage users to move before the sculpture reaches the slouching position. An initial evaluation with one office worker revealed that the time at which the worker took breaks was correlated with the sculpture's positions.

Fig. 6.3 The Health Bar prototype encourages users to take a break to reduce sedentary behavior (Mateevitsi et al. 2014). Illustration courtesy of Lance Long, Electronic Visualization Laboratory

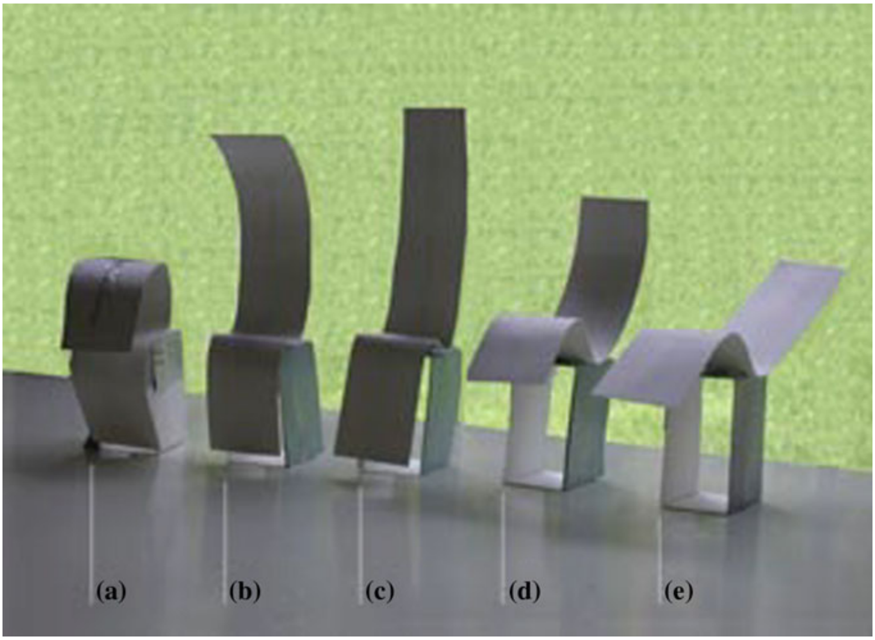

Fig. 6.4 The different postures of the BreakAway system, an ambient display that encourages people to take breaks more frequently. Illustration courtesy of the authors (Jafarinaimi et al. 2005)

6.3.1.3 Sitting Postures

In Haller et al. (2011), the authors investigated different ways to interrupt people when their sitting posture is inadequate in order to provide them with training sessions. One of the interfaces consisted of a physical and ambient plastic plant with leaves and petals that could be automatically changed to reflect the user's posture. A user study showed that participants found this ambient display less disruptive than vibrations. A similar prototype was designed by Hong et al. (2015) to improve people's posture at work.

6.3.1.4 Active Behaviour

Rogers et al. (2010) investigated whether an ambient display could influence people's behaviour by encouraging them to use the stairs instead of the elevator in their place of work. They designed three different ambient installations. *Follow-the-Lights* consist of a set of LEDs embedded into the carpet and that subtly guide people towards the stairwell instead of the elevator. The *Cloud* is a large display composed of two sets of coloured spheres hanging from the ceiling: the higher the number of people taking the stairs, the higher the cloud formed by the grey spheres. The *History* is a large screen showing pie charts that represent the ratio of people stair/elevator usage for each day. A 8-week study showed that despite the fact that people were not aware of changing their behaviour, there was a significant change in the use of the stairs. The authors suggest that this could be due to the fact that the installations raised people's awareness of their decisions.

6.3.1.5 Hydration

Ambient displays have also been designed in order to encourage workers to drink more frequently. Playful Bottle (Chiu et al. 2009) consists in an ambient smartphone application that detects the amount and regularity of water consumed by the users and that use these pieces of information as part of two games. The first game simply displays a tree that changes its aspect depending on the amount and regularity of the water consumed: if the user does not drink enough water, the tree's leaves change their colour from green to yellow and fall down. The second game is a multi-player game that connects together several Playful Bottle: all players' trees are visible and players can compete as well as send "hydration reminders" to others. However, in order to be able to send these reminders, they must first earn some credits by drinking. A 7-week user study showed that both games led to a higher amount of water consumed and that the multi-player game lead to better results in terms of amount and regularity. A similar metaphor was adopted for the design of the Mug-Tree prototype (Ko et al. 2007). More recently, Kaner et al. (2018) also used a tree metaphor: their GROW prototype consists in a bottle of water that embeds a thermo-chronic tree printing on its surface (see Fig. 6.5). Its aspect changes depending on the level of water in the bottle: the image is fully displayed only when the user drinks a sufficient amount of water.

6.3.1.6 Comfort

Although all the above-mentioned prototypes play a role in improving people's overall comfort, there is little work concerning the design of ambient displays to improve people's comfort at work, as defined in the context of the built environment research (i.e. thermal, visual, acoustic and respiratory comfort). One interesting example is a commercialized display developed by Jabra and called NoiseGuide.[4] It consists of a peripheral display that can be placed on office workers' desks and that indicates whenever the noise level is above a specified limit, through different colours (green, orange, red). Another commercial product is CubeSensors,[5] which consists in a set of small smart cubes that can be placed inside people's home or office. When they are shaken by the users, their colours change to indicate the air quality.

[4] https://www.jabra.fr/supportpages/jabra-noise-guide. Last accessed on October 26th 2018.
[5] https://cubesensors.com/. Last accessed December 9th 2018.

Fig. 6.5 GROW is a smart bottle that uses its surface as an ambient display to indicate the amount of water intake. The entire tree is shown when the user has drunk enough water. Illustration courtesy of the authors (Kaner et al. 2018)

Moreover, it is worth mentioning that a number of ambient displays have been developed to encourage people reducing their energy consumption; in particular, some of these displays aimed at improving existing Heating, Ventilating and Air Conditioning systems, which could in turn directly affect people's thermal and respiratory comfort.

6.3.2 Projection-Based AR Systems

Although ambient systems often rely on dedicated artefacts or additional displays, it is also possible to design ambient systems using Augmented Reality. Augmented Reality systems combine both physical elements and digital elements, by enhancing the former with the latter simultaneously (Van Krevelen and Poelman 2010). Systems are defined as "AR systems" if they fulfil the three following criteria (Azuma 1997): (1) they must combine real and virtual objects; (2) they must be interactive in real time and (3) they must be registered in 3D. Although current AR systems mainly rely on the visual modality, auditory, olfactory and tactile stimuli can also be used as a way to augment the real world.

Nowadays most often used AR systems are handheld systems such as mobile phone cameras that show the real world together with digital objects on the screen of the mobile phone. Another alternative is head mounted displays, which are commonly divided into video see-through and optical see-through displays. This division is based on the method used to achieve display transparency. Video see-through displays use a video camera and an opaque screen, whereas optical see-through displays are transparent. Examples of such displays are HoloLens[6] and MagicLeap.[7] Irrespective of recent advances in display technology, current see-through displays are not appropriate for the design of ambient systems, either because they require the users' full attention to hold the device in hand or because they require the users to wear a bulky headset or glasses. In addition, such systems can only augment a small field of view of the human eye viewing frustum, which makes it impossible to create ambient displays that sit in the periphery of the user.

Visual projections are another display technology used in AR systems and are commonly referred to as Spatial Augmented Reality or Projection-based AR systems. These systems present several advantages: "an improved ergonomics, a theoretically unlimited field of view, a scalable resolution, and an easier eye accommodation (because the virtual objects are typically rendered near their real world location)" (Bimber and Raskar 2005). Unlike see-through displays, projection-based systems can be used to enhance the user's environment in a very unobtrusive way and are therefore particularly adapted for the design of ambient systems. For example, the Dynamic Projection Institute company sells the Mirror Head,[8] a digitally-controlled mirror that can be attached to a projector in order to project images and textures into various elements of a room, such as curtains, floor, wall and ceiling.

In the context of well-being, two illustrative examples of projection-based systems are TOBE and Inner Garden. **TOBE** (Tangible Out-Of-Body Experience) (Gervais et al. 2016) is a tangible avatar onto which visual animations that reflect the user' inner state can be projected, using Spatial Augmented Reality (see Fig. 6.6). The physiological data being captured include: breathing, heart rate, perspiration, eye blinks and brain activity. Interestingly, the users are free to decide in which way they want their physiological data to be visualized on TOBE. An application enables them to associate one metric (e.g. arousal level, workload, vigilance) with one support (e.g. tangible avatar or sound) and one shape (e.g. a heart that changes its colour depending on the arousal level), in order to design tailored feedback. TOBE can be used as a biofeedback device and was also successfully used as a relaxation device for multiple users who had to synchronize their heart and reach cardiac coherence.

A similar approach was explored by the same group of researchers and resulted in the design of **Inner Garden** (Roo et al. 2016), a tool to support mindfulness

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[6] https://www.microsoft.com/fr-fr/hololens. Last accessed on October 26th 2018.

[7] https://www.magicleap.com/. Last accessed on October 26th 2018.

[8] https://www.dynamicprojection.com/mirror-head-en/. Last accessed on October 26th 2018.

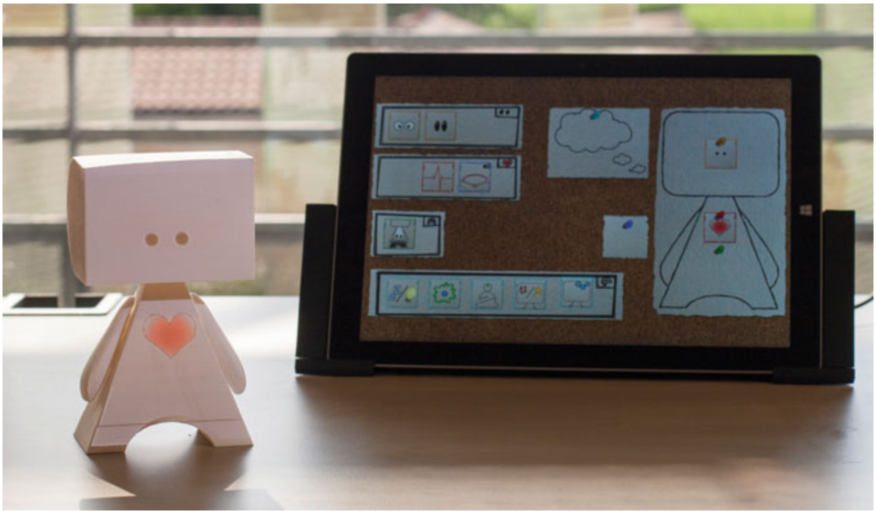

Fig. 6.6 TOBE (Gervais et al. 2016) is a tangible avatar onto which visual animations that reflect the user's inner state can be projected, using Spatial Augmented Reality. An interface enables users to customize the visualizations. Illustration courtesy of Potioc project-team (Inria, Universite Bordeaux, CNRS)

practises. This prototype is an augmented sand-box: users can first create a landscape by shaping the sand; then, various elements such as water, trees, clouds, etc. are projected onto this environment according to different measures of the user's mental state (see Fig. 6.7). For example, the breathing patterns are directly mapped to the water level of the mini-world. This mini-world continuously evolves based on the measured data. The users can also decide to immerse in this world using a VR helmet. (Although they are out of the scope of this chapter, it is also worth mentioning that a few VR systems have been developed to improve people's awareness of their mental states using biofeedback techniques and gaming approaches, such as Gaggioli et al. 2014.).

In addition to these prototypes related to stress management, a few prototypes have been developed that enable users to interact with their built environment using see-through displays in order to, for example, collect information about the temperature of the room (see Rauhala et al. 2006) for example and Wang et al. (2012) for a review of potential applications of AR within built environment).

Fig. 6.7 The Inner Garden system is an augmented sandbox, the appearance of which changes according to the user's physiological signals. Inner Garden supports mindfulness practices (Roo et al. 2016). Illustration courtesy of Potioc project-team (Inria, Universite Bordeaux, CNRS)

6.4 Gamification and Playfulness for Ambient and AR Systems

6.4.1 Ambient and AR Displays as Persuasive Technologies

In the previous section, we described several prototypes that have been designed to improve people's well-being, especially by trying to change their behaviour in the long term. As such, these systems can be defined as "persuasive technologies". A persuasive computing technology is "a computing system, device, or application intentionally designed to change a person's attitudes or behavior in a predetermined way" (Fogg 1999). Halko and Kientz (2010) identified different strategies that have been used in the field of persuasive technology: giving instructions through an agent (authoritative or non-authoritative); using social feedback (cooperative or competitive); enhancing motivation (intrinsic or extrinsic); using reinforcement techniques (positive or negative). Some of these strategies were used by the prototypes that we described, and are also core concepts of gamification. Gamification relies on the use of gamified elements (such as competition between participants) to reinforce behaviour, especially by enhancing the users' motivation, and it has been widely employed to promote behavioural change. In this section, we first define what is gamification, before discussing its potential to improve people's well-being and identified the "playful" and "gamified" elements of the persuasive systems that we described.

6.4.2 What Is Gamification?

According to Deterding et al. (2011), gamification is « the use of game design elements in non-game contexts". Gamification can improve user experience and user engagement but also positively influence users' behaviors and motivation. Gamification is different from playfulness, as it involves explicit rules and competition. It has been used in a number of contexts, such as commerce, education, health and work (Seaborn and Fels 2015).

Gamification builds on two main mechanisms: reinforcement and emotions (Robson et al. 2015). When the users perform the desired outcome, they are rewarded and experience positive feelings, which encourage them to perform the desired outcome another time, until the desired behavior becomes more habitual or even automatic. Motivation is also a crucial aspect to ensure that the desired behavior will continue over time. In fact, Ryan and Deci (2000) identified two types of motivation. Intrinsic motivation refers to activities that are being performed for their inherent qualities, e.g. because they are pleasant or necessary (Ryan and Deci 2000). On the other hand, activities that are performed with extrinsic motivation are performed not for themselves, but for another outcome, such as earning points in a game (Ryan and Deci 2000). One interesting characteristic of gamification is that it can positively affect intrinsic motivation if the participants perceived the game elements (e.g. points, levels, leaderboards) as informational. However, when perceived as controlling, these incentives may also impair intrinsic motivation (Mekler et al. 2013).

In order to trigger positive emotions and reinforcement, gamified applications and tools use a variety of building blocks, that can be described as Mechanics, Dynamics and Aesthetics, according to the MDA framework (Hunicke et al. 2004). Mechanics are "the various actions, behaviors and control mechanisms afforded to the player within a game context" (Hunicke et al. 2004). Dynamics are the player's interaction with the core elements of the game over time (i.e. with the mechanics). For example, a mechanic of badges can trigger competitive dynamics. Dynamics lead to particular emotional responses that are called aesthetics.

In Robson et al. (2015), the authors identified three types of mechanics: setup mechanics (e.g. the setting, the objects used, the mode of playing, such as competition or cooperation), rule mechanics (e.g. the set of actions that the player can choose and the constraints of the game), and progression mechanics, which affect the experience over time (e.g. achievement rewards). More generally, game mechanics can be very diverse and include the use of avatar, rewards, points, badges, level, challenges and time constraints (Zichermann and Cunningham 2011). The use of feedback and reinforcing game elements is also crucial for the overall user experience. In addition, social game mechanics such as leaderboards or the use of "bragging" notifications on social media can also be used as game mechanics to further engage the players and trigger reinforcement.

6.4.3 Gamification and Well-Being

Gamification has been particularly investigated in the context of health and well-being (Klasnja and Pratt 2012; Lister et al. 2014; Sardi et al. 2017). Johnson and al. identified several advantages of gamified applications and tools in such a context: they can positively influence intrinsic motivation, they can be broadly accessible and appealing to a large audience, they can be efficient in terms of cost, they fit into people's everyday lives (instead of games that require people to dedicate some time and space to play them) and they can inherently support well-being by triggering positive emotions (Johnson et al. 2016).

One well-known example is the prototype developed by Hall et al. (2013) to encourage participants to report on their well-being more frequently. The tool was implemented as a gamified Facebook app that includes various incentives (scores, points, stars, badges and social incentives), which enable participants to send points, brag or invite friends. The use of gamification elements proved successful to encourage people to answer the required questions and compute their Human Flourishing Scores. UbiFit (Consolvo et al. 2008) is another illustrative example of a mobile application to increase physical activity. It uses the wallpaper of the user's phone as a glanceable display, the appearance of which changes depending on whether the participants reached their goal or not.

Johnson et al. (2016) reviewed 19 studies related to well-being and gamification (most of which involved mobile applications and websites) and found out that positive effects of gamified interventions were reported in 59% of the studies, as well as neutral or mixed effects for 41% of the studies. Example of issues addressed included health monitoring, stress management and increasing physical activity. Rewards (including points and badges) were the most commonly used game element and were often used in combination with other game elements such as avatars, challenges, feedback, leaderboards, levels, progress, social interventions and stories/themes. The use of rewards was found to be efficient "to drive health behavior" such as an increase in physical activity; tools that use avatars were associated with positive outcomes; social interventions led to a better user experience.

Klasnja and Pratt reported similar positive results in their review of mobile apps for healthcare (Klasnja and Pratt 2012). They discussed the fact that several studies found that the use of entertaining mobile apps helped people to "engage […] with their health goals" and keep them "interested in the intervention", notably through the introduction of fun content into reminders and informational messages. Overall, the authors highlighted the need to further explore "strategies for motivating health behaviour and education through games and other forms of entertainment" (Klasnja and Pratt 2012).

6.4.4 Playful and Gamified Ambient and AR Systems

The Playful Bottle prototype (Chiu et al. 2009) described in a previous section is one of the rare ambient and AR systems that propose to improve people's well-being using gamification. In fact, the authors proposed in a previous publication a "play-based behavior modification model" that encompasses theories of play and playfulness as well as acquisition theories that relate to the reinforcement of behavior (Lo et al. 2007). This model illustrates how people can adopt a new behavior in the long term by being actively engaged into playful activities that rely on the idea of "partial reinforcement", i.e. positive reinforcement that does not occur systematically. The Playful Bottle prototype includes several game mechanics: progressive levels (the tree has five distinct appearances); use of avatars; social persuasion through competition within players; use of credits and rewards (a loving heart and animations).

Other prototypes described in a previous section did not integrate game elements into their design; however, most of them were designed with the aim of providing a playful experience to the users. For example, the design of Inner Garden (Roo et al. 2016) was inspired by "the playfulness and experimental nature of sandboxes". The three ambient displays designed to encourage people to use the stairs instead of the elevator were "designed to inform in subtle and playful ways" and the observations showed that the installations elicited curiosity and playfulness (Rogers et al. 2010). The HealthBar system (Mateevitsi et al. 2014) was inspired by the "life bar" that is used in video games to indicate the player's status. Although it did not incorporate a specific game, MoodLight (Snyder et al. 2015) was first presented to users using a game-like approach, during which participants were asked to "playfully engage the system with their partner". Dišimo (Mladenovic et al. 2018a) encourages cooperation between participants through different light colors (a mix of each user's color) and light brightness (the higher the number of participants who increase Heart Rate Variability, the brighter the light).

Interestingly, several prototypes included an anthropomorphic component in their design, such as flowers with leaves and stem that respectively represent the arms and the body of the user (Haller et al. 2011), tangible avatars (e.g. Gervais et al. 2016) or sculptures that can adopt a standing position or a slouching position (Jafarinaimi et al. 2005). Such an approach might positively affect the overall playfulness of the prototype and the users' willingness to engage with the systems.

6.5 Towards the Design of Playful Ambient AR Systems to Improve Well-Being

In the previous section, we described several ambient displays that aimed at improving people's well-being, especially in their working environment. Although very little research has been conducted on the design of AR systems to improve people's well-being, the two projects that we described (TOBE and Inner Garden) open interesting avenues. Among these two, Inner Garden is particularly appealing as it also acts as an ambient display. Building upon this work, we believe that using AR to design ambient displays is a promising approach to improve people's well-being in a non-obtrusive but yet efficient way. In addition, given the potential of gamification for well-being that we described in the previous section, we also believe that the integration of gamification into Ambient AR systems would be worth investigating further.

In this section, we first discuss why AR is an interesting medium to design ambient displays. Then, we discuss several design opportunities for Ambient AR systems, including the use of playful and gamified elements. Finally, we illustrate how these design considerations could be instantiated in a concrete way through the depiction of a playful Ambient AR office.

6.5.1 Ambient AR Systems

AR technology offers two key properties that could be particularly relevant for the design of ambient displays. The first one relates to the fact that AR systems support spatially-distributed information and interaction, while the second relates to the multimodality of AR systems.

6.5.1.1 Projection-Based AR Support for Spatially-Distributed Information and Interaction

A common approach for projection-based AR systems is to project images, textures or videos directly onto the users' environment. This offers several advantages. Firstly, as pointed out by Bimber and Raskar (2005), this makes it possible to display large field-of-view images instead of small-size pictures displayed on monitors, tablets or smartphones for example. At a larger scale, these images can be projected onto room's walls, doors or desktop, further enlarging the size and type of surfaces that can be used and, in turn, the amount of information that can be conveyed. Secondly, this technology makes it possible to display images at various positions, instead of using a single-location display such as a screen or a physical artefact.[9] Information can therefore be displayed far away or close to the users, depending on the context. This can support the design of interaction at the periphery or focus of attention of the user–a key characteristic of ambient displays. Thirdly, visualizations can be projected on real-world objects, which can enhance the sense of immersion of the user and make information more meaningful or easier to interpret, if it is closely related

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[9] See "Cupid flies in Brussels Airport. Skullmapping strikes again." https://vimeo.com/294352021?from=outro-embed for a real-life example of animated AR projections at Brussels airport. Made by http://skullmapping.com/ and posted by Dynamic Projection Institute https://vimeo.com/dynamicprojection.

to the object it is displayed on. We can therefore tap into the spatially-distributed characteristic of AR systems to design peripheral interaction, calm technologies and embedded representations–the three of which we discuss in the next section.

6.5.1.2 AR Support for Multimodality

Another interesting aspect of AR systems is that they can provide multimodal interaction. In fact, AR encompasses a variety of sensory modalities, including visual, auditory, haptic, somatosensory, and olfactory. Although those last three modalities have not seen many implementations, the multimodality of AR systems opens new avenues for the design of ambient applications, especially by taking into account users' perceptual abilities. For example, tactile and visual acuities are different, and using one modality over the other for conveying a particular piece of information could minimise the user's workflow disruption by requiring less or more attention. Multimodality is also important to make the virtual elements more integrated into the real world and to increase the sense of immersion of the user, using a combination of lights, spatial sound and projections. Finally, multimodality can be an efficient way to increase the sense of "playfulness" of a system, for example by combining sounds and animations to design an ambient game. Nevertheless, it is important to note that current technology is limited in how well the sense of touch, somatosensory, and olfactory can be augmented, particularly if no modification to the environment is made.

6.5.1.3 Ambient Projection-Based AR Systems: Proposed Definition

The term 'ambient AR applications' was first used in Billinghurst et al. (2009), in order to define applications that "use AR technology to represent context information from an Ambient Interface".

According to the definitions of ambient displays and of AR systems that we discussed previously, and also building on the two properties of AR systems discussed, we propose to define Ambient projection-based AR systems as a subset of ambient information systems (in the sense of Pousman and Stasko 2006) that present the following additional characteristics:

i. they augment *existing* environment with digital content, focusing on tangible elements;
ii. they use digital content that is registered in 3D and *can be moved around* from one object/surface to another;
iii. they can be interactive in real-time.

We use the term "digital content" to refer to multimodal media such as pictures, videos, sounds, lights or even olfactory elements. This definition also highlights the fact that unlike most ambient displays, AR ambient displays do not require dedicated artefacts and are not limited to a dedicated space within the user's environment.

6.5.2 Design Opportunities for Ambient Projection-Based Augmented Reality Systems

6.5.2.1 "Mobile" Interaction: From Periphery to Centre and Away

Both the spatial flexibility and multimodality of projection-based AR systems provide interesting means to design "mobile" perceptions and interactions. This term can first be understood from a spatial and cognitive perspective. In the first case, the information or means of interaction can be "physically" located at different positions and distances to the user, depending on the context or the relevance of the information. In the second case, the information or interaction can happen at the periphery or centre of attention, using different locations (close vs. far away) or different modalities (e.g. audio vs visual, light vs. dark colours, feeble vs. loud sounds, etc.). This is the core idea of peripheral displays and of peripheral interaction, which both build upon theories of divided attention that concern the use of multiple stimuli and performing of various tasks at the same time.

From a more abstract perspective, ambient AR systems could also support (sub)conscious "moves" between involuntary state and voluntary state, as described in the user's model of comfort proposed in Alavi et al. (2017). According to this model, comfort is continuously evaluated in an *involuntary* way by the occupant's sensory system (e.g. photoreceptors, haptic memory, etc.) and autonomic actions take place to maintain homeostasis, such as shivering or sweating. When the outcome of these actions is not sufficient enough or when the occupants are asked to assess their comfort, the occupants become aware of their state of (dis)comfort and evaluate it *voluntary*. Then, they can adapt their behaviour in order to recover their sense of comfort, e.g. by opening the window (i.e. behavioural response instead of automatic response).

This echoes the idea of "scalable notifications" (Matthies et al. 2017), which "can on the one hand, provide very subtle feedback to the user while, on the other hand, can intervene and force the user to take action". For example, Matthies et al. (2017) designed a haptuator device to help people adopt a correct posture while sitting. The device notifies the user through mecano-pressure ranging from subtle feedback to forcing feedback (which triggers a natural reflex that straightens the back). Other modalities were also successfully investigated such as thermal feedback and electrical feedback. This research opens new avenues for the design of scalable and multimodal notifications to promote behavioural or autonomic responses.

Another interesting property of projection-based AR systems is that they can easily be embedded within the existing user's environment and that they do not require a lot of additional hardware or physical modification of the environment. Therefore, in situations where the user does not want or need to use the system, it can simply disappear, visually and cognitively. Unlike projection-based AR systems, ambient displays that use physical artefacts cannot take advantage of this kind of "spatio-temporal" mobility.

6.5.2.2 Calm Technologies

The concept of "calm technology", first described by Weiser and Brown (1996), integrates two important notions: they inform *and* encalm the user. "Calm technology engages both the centre and the periphery of our attention, and in fact moves back and forth between the two" (Weiser and Brown 1996). In that sense, they are closely related to the idea of peripheral interaction. However, by enabling the user to take control of the technology by recentering it, the "periphery is a fundamental enabler of calm through increased awareness and power". By supporting peripheral interaction, ambient AR systems could then also support calming interaction, and affect people's level of stress and overall well-being.

The idea of "calm technologies" can also be interpreted through the prism of restorative theories, and in particular attention restoration theory. The core idea behind these theories is that (views of) natural environment can help individual recover from stress or restore their attention. For example, Raanaas et al. (2011) showed that the presence of plants could positively impact the performance of participants in terms of attention. View of nature in the office environment can also decrease job stress. Brown et al. (2013) showed that viewing pictures of natural scenes could improve the recovery process following a stressor. Although the benefits of digital natures scenes as compared to real natural scenes cannot be systematically observed (see Kahn et al. 2008 for example), ambient AR systems could be used to project large natural scenes into the user's room and/or to alter the users' environment to make it look and sound more natural (e.g. by projecting wooden-like textures onto the user's desktop—wood is known for its restorative effects (Burnard and Kutnar 2015)—or by playing natural bird sounds in the background), once again building on the spatial and multimodal characteristics of AR.

6.5.2.3 Embedded and Situated Representations

AR enables the design of "embedded" data representations, as formalized by Willett et al. (2017). Embedded representations "display data so that it spatially coincides with data referents", i.e. with "the physical object of space to which the data refers". The Playful Bottle prototype (Chiu et al. 2009) is an illustrative example: the data representation (i.e. the tree showing the amount of water drunk) is embedded into the physical object from which the data is sensed (the bottle). This differs from traditional ways of visualizing data, such as screens which usually present non-situated data representations. In fact, screens are often used to display information in a spatially-remote way (because the screen is not close to the object to which the data refer) and/or in a temporally-remote way (because what is being displayed is not live data). The design of embedded representations could be beneficial in terms of (visual) attention and cognitive demand, as it can make relationships between data and physical objects more explicit and therefore easier to perceive, interpret and understand. This could also decrease the perceived obtrusiveness of the applications.

The seamless integration of representations into people's physical spaces (and for example into workers' desktops and offices) could also lead to a more integrated approach of tools for improving people's well-being. Instead of designing dedicated physical artefacts or installations for various aspects of people's well-being, we could rely on physical objects such as desktops, chairs, clothes, walls, etc., that already exist within people's environment and use similar metaphors or means of interaction for different aspects of well-being across the whole environment.

6.5.2.4 Playful Technologies

Finally, we see in the use of AR for ambient systems a good potential in terms of playfulness and gamification. Using different modalities can increase the user experience. It can also be a particularly interesting approach for the design of playful games. Another interesting aspect is that AR supports the design of animations that are not limited to one screen only and that can span the whole user's environment, for example to draw the user's attention from her laptop to a specific object in the room, such as the door (if the user needs to be more active) or the window (if the air quality is poor). Such multimodal and spatial animations could therefore be used to design playful ways of notifying or informing the users. In addition, when the whole room is augmented, it is possible to trigger cooperation or competition between people present in this room, using projections and/or spatialized sounds for example. This opens interesting avenues for the design of full-scale games or gamified applications.

6.5.3 Scenario

To better illustrate the potential of AR for ambient systems, we present a scenario of an envisioned system that builds on the design considerations previously discussed (see Fig. 6.8). Such a system could be implemented, for example, by using the above-mentioned Mirror Head system, thanks to which "projections can be moved around from one surface to another or remain statically projected onto one specific surface".[10]

Anna is an office worker who spends around 8 h a day in her office, alongside her two co-workers. Their office is equipped with different ambient lights as well as a set of projectors.

The system continuously projects an avatar onto each co-worker desktop that reflects their activity in a humorous way (*playfulness*). When Anna is working, she can also see the avatar working. However, the avatar sometimes moves around her desktop and her office to suggest her to do something (*mobile interaction*). For example, the avatar walks from its home place (a piece of paper or another element of the desktop) to Anna's bottle of water to indicate that she must drink. The bottle is

[10]https://www.dynamicprojection.com/mirror-head-en/.

Fig. 6.8 Illustration of a playful ambient AR system to improve people's well-being in the office. Projections can be used to highlights some elements (e.g. the window if the air quality is poor or a bottle of water if one person does not drink enough), to display footprints to suggest actions to users (e.g. taking a break), or to provide users with relaxing pictures (e.g. flowers on the desktop). Ambient lights can be used to help users focus on their work, or to indicate if someone is too noisy

then highlighted and augmented with a line that tells Anna the amount of water she should drink (*embedded data representations*). The avatar can also move towards the windows to tell Anna that she needs to open it in order to lower the temperature of the room. If Anna does not notice the avatar, the objects or the furniture can be highlighted using ambient lights, and the avatar can come closer to Anna's laptop to attract her attention. It can even "enter" the laptop for more obtrusive notifications when necessary (*mobile interaction*).[11] The avatar also mimics Anna's sitting posture. Whenever Anna's sitting posture is incorrect, the avatar shows her how she could correct her posture.

[11] See "Animator versus Animation" by Alan Backer https://www.youtube.com/watch?v=npTC6b5-yvM for example.

The avatar can also move towards the door (its footprints are projected onto the floor) to tell someone that he/she must take a break and be more active. This is in fact part of a game–each co-worker earns or loses points depending on their level of activity and the total number of points is continuously projected on the ceiling (*gamification*). At the end of the week, the less active co-worker must do something (e.g. bring a cake).

Tomas, one of Anna's co-worker, is often stressed. His avatar reacts accordingly, showing signs of excitation and irritation. Tomas tries to breathe more deeply to help his avatar recovering a calm state. To help him achieving it, the system uses projected animations to display blooming flowers and growing plants on and around Tomas' laptop. Tomas can also use his headphones to listen to natural sounds such as bird sounds (*calm technologies*).

As for Alice, the third co-worker, she is doing a demanding task and she needs a silent environment. The system detects Alice's activity as well as the noises around her. The system first uses ambient lights to make Alice's desktop more cosy (*calm technologies*) but also to indicate to Anna and Tomas that Alice needs to be very focused. It also highlights Anna and Tomas' desktops to reflect how noisy they are. As Tomas's desktop is very red, he understands that he is speaking too loudly and starts speaking more quietly.

All of them are also regularly encouraged to look away from the computer to prevent visual fatigue.[12] Twice an hour, animated images are projected onto an existing frame placed on the wall and are used to subtly attract the co-worker's gazes. The images disappear when the workers have been looking at them for a certain amount of time, or become more and more visible otherwise.

The above scenarios illustrated some possibilities of what could ambient projected interface provide. In Table 6.1 we categorised these and other possibilities based on the projection type and the type of intervention as described in this chapter.

6.5.4 *The System*

While designing a system as described in the above scenario, several issues have to be considered. As visible in Table 6.1, we have not used any example of constant animation in periphery. Animation grabs attention, it can disturb users' workflow and it should be used sparingly and only when needed. For example, in our scenario we have described that the avatar starts moving from the periphery into the field of view only when there is a need for it. It is important that every intervention starts in an inobtrusive way in the periphery and that the changes are not sudden but happen over a period of time and slowly move into the users' visual field to engage them in interaction. Moreover, the systems should not overwhelm the users with suggestions and they should learn what kind of intervention the users react to. Users

[12] As stated in Blehm et al. (2005), "looking away at a distant object at least twice an hour during computer usage is sufficient for prevention of visual fatigue".

Table 6.1 Examples of playful ambient augmented reality systems to improve people's well-being divided by projection type and intervention targeted

	Occasional animation	Occasional static highlight (e.g. spotlight effect)	Constant projection
Stress	Avatar starts moving (e.g. showing signs of excitation and irritation) on the working surface including monitor and desk surroundings Projecting blooming flowers and growing plants on and around one's laptop to help with breathing	Projecting ambient light to make one's desktop cosier	Projecting on the desk the status of various variables related to stress
Sedentary time	Avatar starts moving (e.g. inviting user to take a walk) on the working surface including monitor and desk surroundings		Projecting the score board of everyone in the office with earned points for taking breaks, doing exercises, etc.
Sitting posture	Avatar starts moving (e.g. mimicking the sitting posture) on the working surface including monitor and desk surroundings		Highlighting the chair with different colours based on the user's posture (e.g. red for an incorrect posture)
Active behaviour	Avatar starts moving (e.g. inviting user to take a walk) on the working surface including monitor and desk surroundings	Illuminating window that should be opened (taking a break, lowering the temperature, ventilating the room)	
Hydration	Avatar starts moving (e.g. walking around the bottle) on the working surface including monitor and desk surroundings	Illuminating a bottle by showing the amount of water that should be drank in a certain amount of time	Projecting the score board of everyone in the office with earned points for hydrating
Comfort		Projecting ambient light on one's desktop to make them aware of their effects on other people's comfort and stress (e.g. indicating the noise level)	

in a study of triggers have for example reacted more positively when triggers were adapting to their behaviour, as compared to non-adaptive triggers that have led to trigger overload and consequently to users ignoring them Kljun et al. (2018). Similar information overload has been shown also for other information types such as email, social networks (Maier et al. 2015), and other fields (Eppler and Mengis 2004).

The need for users to have a control over their environment has also been stressed as important in the literature (Ghani and Deshpande 1994). Being unable to control the system or interacting with a system that behaves in an unpredicted way (e.g. not notifying the user of what has been done and why) often leads to frustration and helplessness. Even worse, it can decrease users' comfort and lead to stress. It is thus necessary to give users the possibility to refuse suggestions made by the system, if they are temporarily not able to or do not want to interact. Users should also be able to turn off the system if necessary. In addition, there are some tasks that should not be interrupted such as meetings. The system should be aware of such occasions and start engaging the user only after such tasks are over. Overall, the system should be designed to help overcome frustration rather than create it Klein et al. (2002).

For the implementation of the above-mentioned projection types, we propose a mirror head projection system which moves the projection around the room by rotating a mirror (see Fig. 6.9). In such a system the mirror rotates around two different axes, on Fig. 6.9 marked as pan and tilt angle. For the above scenarios an ideal mirror head system would enable 180° of tilt and pan rotations, enabling one to direct the centre of projection to any point on half sphere (see Fig. 6.9). Existing commercially available systems, such as the Mirror Head[13] from Dynamic Projection Institute can pan the projection in the range of 180° and tilt the projection in the range of 162°. Even though this is not ideal, such a system provides sufficient capabilities for building a prototype system, particularly when the projector is mounted close to the top of the ceiling.

The second consideration one needs to make is the fact that the projection distance, defined as the distance between the surface of the projection and the projector, changes as the mirror head moves the projection around. This introduces two additional points to consider: the projection size and the projection focus. As the projection distance changes, so does the projection size, which in turn affects the pixel density of the projection.

Here we estimate the projection distance for the proposed scenario of the office space. If we consider mounting the projection in the centre of the room with a standard ceiling height of 2.4 m[14] and a room size of 4 × 4 m, the projection distance varies from 1.4 m (when projecting directly down onto the table surface) to 3.7 m (when projecting into the farthest corner of the room, cf. (6.1)).

$$\text{Max projection distance} = \sqrt{\left(\frac{width}{2}\right)^2 + \left(\frac{length}{2}\right)^2 + (height)^2} \tag{6.1}$$

[13] https://www.dynamicprojection.com/mirror-head-en/. Last accessed on October 26th 2018.

[14] https://designfor-me.com/advice-and-tips/ceiling-height-average-minimum-house/.

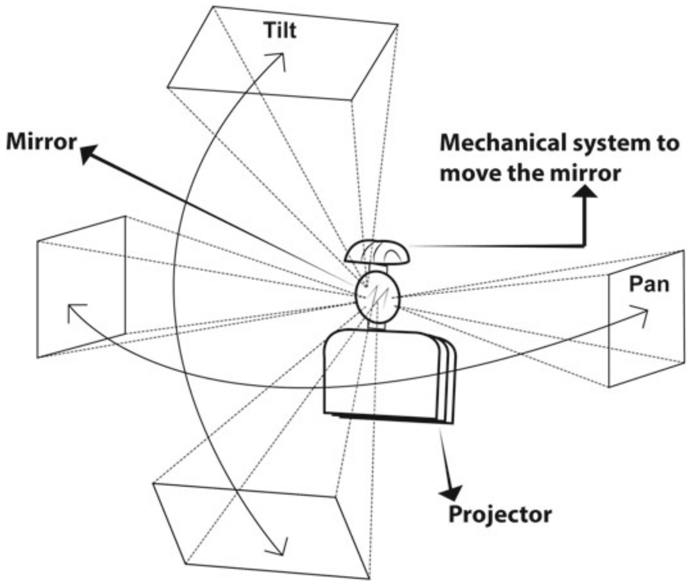

Fig. 6.9 Projector with a digitally-controlled mirror that can project images and textures into various elements of a room

If the throw ratio (defined as projection distance/width of projection) of the projector's optical system is not changed, the size of projection changes linearly to the projection distance. For the proposed room size, the size of the projection from *min projection distance* to *max projection distance* would increase by a factor of 2.6. To control this change of projection size and keep the projection in focus, we propose to use a projection system with a motorized zoom lens and focusing. These features are available on some commercially available projectors, such as Optoma zu1050.[15]

Another consideration is related to the required brightness of the projector. Ambient light, projection surface, size and desired contrast of projection are key factors to estimate the required brightness of a projector. For the scenario above, we limit the projection size to 1.2 m in diagonal and calculate the required projector luminance as follows.[16]

As stated by the guidelines in a guide published by Dnp danemark,[17] the projection luminance should be 2–3 times the luminance at the desk in order to provide the users with a comfortable viewing experience. In addition, according to US General Services Administration,[18] 500 lx of light is deemed appropriate for the workspace. Hence, we require a brightness of 1000 lx. To estimate projector brightness, we also need to

[15]https://www.optoma.fr/product-details/zu1050.

[16]https://www.dnp-screens.com/media/1763/free_guide.pdf. Last accessed January 3rd 2019.

[17]https://www.dnp-screens.com/media/1763/free_guide.pdf.

[18]https://www.gsa.gov/node/82715.

consider other factors such as: surface reflectance (we take reflectance factor of white wall which is 0.25), projector contrast (2.000.000/1),[19] desired contrast (20/1), image area (0.848 m^2)[20] and adjustment for calibration loss (10%). According to Eq. (6.2) and (6.3), the minimal required projection brightness for our scenario is therefore 7000 lm.

$$\begin{aligned} \text{image\_brightness} &= \text{light\_at\_projection} * \text{surface\_reflectance} * \text{projector\_contrast} \\ &\quad * (\text{image\_contrast} - 1)/(\text{projection\_contrast} - \text{image\_contrast}) \\ &= 500 * 0.25 * 2{,}000{,}000 * (20 - 1)/(2{,}000{,}000 - 20) = 2375\,\text{lx} \end{aligned} \tag{6.2}$$

$$\begin{aligned} \text{min\_projector\_brightness} &= \text{image\_brightness} * \text{image\_area} * \text{PI}/\text{screen\_gain} \\ &\quad * \text{adjustment\_for\_calibration\_loss} \\ &= 2375\,\text{lx} * 0.848 * 3.14/1 * 1.1 = 6956\,\text{lm} \end{aligned} \tag{6.3}$$

The above considerations illustrated key characteristics to build a system that is capable of creating the projections described in Table 6.1, allowing one to implement the foreseen scenario.

6.6 Conclusions

In this chapter, we discussed the potential of gamification of the design of AR ambient systems for the improvement of people's well-being. We first briefly described several aspects of well-being that have been addressed within the HCI community, such as stress, sedentary behaviour and hydration. We also included the concept of "comfort" in the scope of this chapter. We believe that the continuously growing number of pervasive (bio)-sensors provide excellent opportunities for the development of tools that could improve people's well-being, in particular within the context of work.

Although these tools are often implemented as mobile/wearable apps or websites, researchers have also investigated other ways of exploiting these data in innovative ways, using different types of interaction. In the framework of this chapter, we focused on Ambient displays, including augmented-reality based displays. In fact, we highlighted two properties of projection-based Augmented Reality that make it an efficient medium for Ambient displays: it supports spatially-distributed information and interaction, as well as multimodality. We thereafter proposed the notion of Ambient projection-based AR systems as a subset of Ambient displays that (1) augment existing environment with digital content; (2) use digital content that is registered in 3D and can be moved around the user's environment; (3) can be interactive in real-time.

In addition, we discussed how gamification has been successfully used for well-being and health purposes, in particular for mobile apps and websites. We also

[19] https://www.optoma.fr/product-details/zu1050#specifications.

[20] Based on diagonal of 1 m for a 16/10 screen.

reviewed the playful and gamified elements of existing Ambient AR tools. Given the promising results, we suggest the use of gamification with Ambient AR systems as an efficient way to improve people's well-being. To better illustrate our vision, we concluded this chapter with the description of scenarios related to the use of a playful AR ambient office that promotes healthy behaviour and attempts to improve workplace comfort level.

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Chapter 7
Augmented Reality Games for Health Promotion in Old Age

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Abstract Augmented reality game concepts can be used for health-related purposes in old age. Physical activity is a key aspect for healthy aging. Conceptual considerations and current research in the field of technology and aging are examined here to recommend designs for augmented reality games for older adults. We explore relevant trends in augmented reality and possibilities to integrate this technology into individual health promotion. Research on the use of mobile devices and applications by older people, and older adults' interest in using this technology for health-related purposes is presented. From this we deduce older adults' readiness to use augmented reality games on mobile devices in their everyday lives and for health promotion. Design recommendations include considerations of which technology is used by older people, how to create meaningful games, how to involve older adults' social

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networks, issues of data security, and the special requirements for designing health-related augmented reality games as a whole. The combination of empirical findings from gerontological and technical research groups allows us to discuss these issues in a broader perspective and define relevant factors for developing augmented reality games for older adults.

7.1 Introduction

The importance of augmented reality (AR) and its applications with mobile technology has steadily increased in recent years (McCallum and Boletsis 2013; Hamari et al. 2018). Drivers for this development include the technological evolution of smartphones and tablets and the success of AR-based games such as Pokémon GO. Millions of people have left their couches to play this game among others at Pokéstops or arenas (Paavilainen et al. 2017).

Encouraged by the high numbers of players and the worldwide success of Pokémon GO, location-based gaming concepts including AR have become a focus of scientific research. Also referred to as urban exergames, physical activity is part of this game concept (Knöll et al. 2014). Urban exergames like Pokémon GO are generally played in an urban environment, and are run on smartphones making use of the mobile device's built-in sensors (Knöll et al. 2014). The location-based concept and the AR function are two main reasons (beyond its great success) why Pokémon GO gained such popularity within scientific research (Rasche et al. 2017b). Because of the large user community, questions arise as to whether AR is generally accepted within the population and how this technology could change the types and methods of health promotion and disease prevention if embedded in *serious gaming*. Serious gaming is "defined as the application of (digital) games to improve users' skills, knowledge, or attitudes in real life" (Graafland and Schijven 2018). We explore the use of serious games to enable the targeting of the "tiresome" topic of disease prevention through game elements to reach groups of people previously unwilling to take part in regular disease prevention programs.

Health-related issues and disease management become more important as individuals get older (World Health Organization 2015). Two relevant questions, therefore, are: (1) whether older adults are interested in playing AR-based serious games; and (2) whether this group could benefit from AR-based serious games addressing health-related behavior and disease prevention. A recent overview by Graafland and Schijven (2018) analyzes seven systematic reviews assessing the effectiveness of games for health, and shows that games have a positive impact on health behavior in adolescents. Within the group of older adults, Graafland and Schijven (2018) revealed no striking positive answer for the question of whether games support older adults' healthcare. Nevertheless, serious games are considered a potential solution for healthy aging (Wilkowska et al. 2018).

Sufficient levels of physical activity are one key success factor for healthy aging. The term *physical activity* covers any bodily movement that is produced by skeletal muscles and that results in energy consumption (Caspersen et al. 1985). Research has shown a broad range of positive effects of physical activity including the improvement or maintenance of objective health (Peel et al. 2005), preventing falls (Rasche et al. 2017a), and cognitive functioning (Newson and Kemps 2005). Many health-related constructs such as mortality, frailty, cognitive state, and well-being are also associated with physical activity levels (Schlicht et al. 2013).

Despite the proven benefits, physical inactivity is still a major risk factor for many non-communicable diseases (e.g., cardiovascular diseases and diabetes type 2 mellitus) worldwide (Haskell et al. 2009; Lee et al. 2012). One-third of adults worldwide do not meet physical activity guidelines (Hallal et al. 2012). In Germany, over half of the entire population do not reach sufficient physical activity levels (Froböse and Wallmann-Sperlich 2012). Furthermore, the levels of physical activity decrease with age (Hallal et al. 2012). Serious games with an AR approach can include physical-related interventions, so that older adults who play the games are motivated to do physical activities. Therefore, there are potential benefits in developing physical activity-related serious games for older adults.

The importance of physical activity for healthy aging and disease prevention, the high levels of inactivity in the population, and the increasing interest of the research community in the topic of AR-based serious games serve as the background for this chapter. We will discuss AR games for health from a gerontological perspective, combining the work of three research groups from Germany and Switzerland. We focus on the level of digitization in older adults with a special focus on mobile devices and health technology. Based on our research, we identify relevant aspects important for the development of AR games for health promotion in old age. First, relevant conceptual considerations regarding older adults and technology are presented. Next, we synopsize research on older adults' technology use in general and for health-related purposes. Finally, we present recommendations for the design of AR games for older adults.

7.2 Conceptual Considerations on Older Adults and Technology

From an environmental gerontology perspective, new technologies may contribute to a stimulating environment for successful aging (Schulz et al. 2015). However, older adults' use of new technologies and the development of technological products for older adults is associated with certain challenges. Before we address these specific challenges, it is necessary to establish a conceptual basis. When discussing age-related differences and particularities, it is important to distinguish *age effects* (changes within an individual over the lifespan) from *cohort effects* (changes in aggregate opinions or attitudes of people belonging to the same generation) (Marshall and Bengston 2012). In the context of technology use, Docampo Rama et al. (2001) showed that both age effects and cohort effects could explain older adults' difficulties with technology use.

7.2.1 Age effects in Older Adults' Technology Use

People generally become more vulnerable as they grow older. They may require more effort to learn new technologies because they often possess fewer cognitive, physical, financial, and social resources (Czaja et al. 2006; Schulz et al. 2015). Age-related technology usability limitations include physical impairments that inhibit dexterity in the hands and fine motor skills, making, for example, smartphone use difficult. Furthermore, visual and hearing impairments can limit the effectiveness of multimedia content or visual effects. Cognitive impairments can prevent engagement in games because older adults may have difficulties performing multiple sequential tasks, take in new information slowly, and have concentration problems or memory gaps. Furthermore, older adults often fear technical problems, and have difficulties learning new technologies. Thus, physical, social, and biological issues and requirements need to be considered in studies on technology use and in developing technologies for older adults (Darvishy et al. 2017; Seifert and Schelling 2015).

7.2.2 Cohort Effects in Older Adults' Technology Use

The consideration of cohort effects in technology use has been described in the concept of *technology generations* (Sackmann et al. 1994; Sackmann and Winkler 2013; see Table 7.1). A technology generation is defined as "a group of birth cohorts whose behavior and attitudes towards technology show the effect of one or more major technological changes that occurred in their formative period" (van de Goor and Becker 2001). According to the concept of technology generations, knowledge gained during the formative period (between the age of ten and 25) is more easily remembered in later life. New technology available during this time is more easily learned and effectively used. Today's older generations have not grown up with digital technologies and might therefore be more reluctant to use such technology in general and for health purposes. They were not socialized with technologies such as smartphones or tablet computers in their youth or working life. On the other hand, *digital natives* are individuals of a generation born after 1980 who are more accustomed to Internet-based technologies, having grown up with them (Palfrey and Gasser 2008). Also, older adults often use modern technology in a more functional and less explorative manner than younger people (Misoch et al. 2014). These generational differences should inform the development process of health-related technology in general and in designing technology using AR features for older adults.

Table 7.1 Overview of technology generations (Sackmann et al. 1994; Sackmann and Winkler 2013)

Technology generations	Years of birth according to theory	Technological advance in formative period	Important technical devices in youth
Mechanical generation	<1938	Very few technologies available, electricity	Bike, radio
Generation of household revolution	1939–1948	First electrical household appliances available	Washing machine, car, television, motorbike
Generation of technology spread	1949–1963	Growing spread of electrical household appliances	Record player, tape, tape recorder
Computer generation	1964–1980	Personal computers as part of everyday life	Personal computer, CD player
Internet generation	>1980	Spread of the Internet	Internet

7.3 Use of Digital Technology by Older Adults

In the context of these conceptual considerations, the question arises: how prominent is the actual use of digital technologies among older generations? Serious games and especially AR-based games need specific hardware (e.g., smartphone, tablet, or smartwatch technology with sensors to capture the real-life environment; fast processors, and interfaces for user input). Thus, we address the question of whether older adults are using the technology necessary to play these games. Furthermore, we will discuss to what extent digital technology is already used by older adults in general and in health-related settings like disease prevention and the promotion of physical activity. Germany and Switzerland will serve as two examples since both countries are experiencing demographic changes and, on average, have a relatively high per capita wealth, both of which generally promote the use of modern information and communication technology (ICT) products.

7.3.1 The Use of Mobile Digital Technology by Older Adults

The popularity of the Internet and Internet-based technologies have substantially increased the importance of digital technology for daily lives in diverse and all-encompassing ways. When focusing on the distribution of user rates within the general population, empirical studies show a significant digital gap between generations (Hunsaker and Hargittai 2018; Seifert and Schelling 2015; Seifert et al. 2017a, b), which has been referred to as a *digital divide* (van Deursen and van Dijk 2011).

Table 7.2 Internet use among older adults in Europe (König et al. 2018)

	Percentages of Internet users among people 50+ (%)
Denmark	83
Sweden	79
Switzerland	72
Belgium	66
Luxembourg	61
France	61
Germany	58
Austria	53
Czechia	52
Estonia	50
Slovenia	42
Spain	39
Italy	35
Portugal	33
Poland	33
Greece	28
Croatia	27

Sorted by percentages of internet users

Results from a 2015 representative survey of respondents from 17 European Union countries, including Switzerland and Germany, show that only 49% of respondents aged 50 years and older used the Internet (König et al. 2018; see Table 7.2).

The study further indicates that Internet use among older adults was driven by personal factors such as age, gender, education, and income. Additionally, prior experiences with technology, social salience (Internet use among members of one's social network), and contextual factors, such as country-specific wealth and communication technology infrastructure, predict older adults' Internet use. Even though only a few years have passed since that survey, older adults today may be using digital media at higher rates, and we can expect following generations to have even higher usage rates (König et al. 2018).

Another study from 2017 involved a more detailed telephone survey focused on the use of mobile technologies (smartwatches, smartphones, and tablets) in a representative sample within Switzerland of individuals older than 50 years (Seifert et al. 2017a). User and non-user characteristics and interrelations with other variables, e.g., gender, education, interest in new technology, and satisfaction with individual health, were analyzed. In total, 1,013 older adults participated in the computer-assisted telephone survey. Results showed that 62.3% of respondents used a smartphone, 45.0% used a tablet, and 6.6% used a smartwatch. Bivariate analyses revealed that younger individuals (aged 50-64) and those with a strong interest in new technology used

Table 7.3 Use of mobile devices and applications by older adults (Seifert et al. 2017a)

		Age				Interest in new technology		
	Total number of users (n = 1,013) (%)	50–64 (n = 522) (%)	65–79 (n = 358) (%)	≥80 (n = 133 (%))	Significance	Strong (n = 423)	Low (n = 586)	Significance
Smartphone (device)	62.3 (thereof daily: 89.6%)	78.4	52.5	24.6	V = 0.39, $P < 0.001$	74.4	53.7	V = 0.21, $P < 0.001$
Tablet (device)	45.0 (thereof daily: 65.6%)	54.6	39.5	21.5	V = 0.23, $P < 0.001$	57.4	36.3	V = 0.21, $P < 0.001$
Smartwatch (device)	6.6 (thereof daily: 71.2%)	7.5	6.8	2.3	V = 0.07, $P = 0.106$	10.3	4.0	V = 0.13, $P < 0.001$

V = Cramér's V. Interest in new technology measured on a 5-point Likert scale: 4–5 = strong interest, 1–3 = low interest

mobile devices more often than older respondents and those in with a low interest in new technology (Seifert et al. 2017a, see also Table 7.3).

A multivariate regression analysis showed that males and younger people were more likely users of mobile technologies than females and older people. Stronger interest in new technology contributed to a higher chance of using, too. No significant effect of educational level, satisfaction with health, or subjective level of physical activity was found in this analysis (Seifert et al. 2017a).

A survey in Germany regarding the use of mobile technologies was conducted in 2016 (Mertens et al. 2017). In total, 551 older adults answered a paper-based questionnaire. Among these, 49.2% used a smartphone, 28.3% used a tablet and only 1.1 % used a smartwatch. Again, younger age and strong interest in new technologies were associated with a higher use rate.

There is evidence for age differences in several levels of digitization including access, use, competencies, and openness (Initiative D21 2018). Older, less educated, and poorer people appear to be excluded from the potentials of digital technology (Hunsaker and Hargittai 2018). This body of research shows that interest in technology is an important driver for the use of new technologies and could be independent of individual age. However, given the rapid developments in mobile technology we expect a growing proportion of users to be older in Germany and Switzerland. As such, an increasing number of older people will own devices necessary to access AR games.

7.3.2 The Use of Mobile Digital Technology for Health Promotion

Beyond the general use of mobile technologies in older adults, we examine how health-related digital products are already used within this group to gain insights into older adults' openness to integrate digital technologies into their life.

A scoping review of older adults' readiness to use digital devices for self-management showed that older adults are interested to include smartphones and other wearable technology into their healthcare (Kim and Lee 2017). Important facilitators to use technologies for self-management included the recognition of benefits; the gained understanding of relationships between behaviors and their impact on health; and the increased awareness, motivation, and engagement in disease management. Barriers to use included reduced motivations due to poor usability and insufficient training to use the devices (Kim and Lee 2017). Joyce and Loe (2011) recognize older users of technology as "individuals who create, use, and adapt technologies to negotiate health and illness in daily life." Joyce and Loe also stress the high relevance of health promotion in this group and an openness to use technology to this end. In our research focused in Germany and Switzerland, we examined the proportion of older users, characteristics of users and non-users, and the reasons for using mobile devices to track one's physical activity. Given the high relevance of physical activity in the context of health as described in the Introduction, we will use physical activity tracking as one example for the potentially successful use of new technologies for health promotion in older adults.

To investigate these trends in Switzerland, a 2017 study was conducted with the following results: 10.8% of all 1,013 respondents aged 50 years and older used an activity tracker, 1.7% used a smartwatch, and 15.1% used a smartphone or tablet to track physical activity (Seifert et al. 2017a). Males and younger individuals were more likely to track physical activity (see Table 7.4). Multivariate analyses showed that a higher frequency of exercising and a stronger interest in new technologies also increased the chance of using these technologies (Seifert et al. 2017a).

The most important reason, however, was a general interest in tracking one's physical activity. The second most important reason was the motivation to remain healthy. Exchanging the data with others did not appear to be important (see Table 7.5).

A German survey conducted by Mertens et al. (2017) showed that 16.5% of respondents used at least one health-related application on a smartphone or tablet, 7.1% used an activity tracker, and 1% used a smartwatch in their daily lives. The main reason for purchasing these products was to improve personal fitness, and the main reasons for not using health-related applications were a lack of trust in these applications, concerns regarding data privacy, and the fear of misdiagnosis by the applications. Barriers identified by non-users included poor usability of the devices and a lack of self-confidence (see Table 7.6). These barriers, therefore, may explain why non-users do not engage with health applications or related wearable technology (Rasche et al. 2018).

Table 7.4 Use of mobile devices and applications for physical activity tracking (Seifert et al. 2017a)

		Age				Gender		
	Total number of users (n = 1,013) (%)	50–64 (n = 522) (%)	65–79 (n = 358) (%)	≥ 80 (n = 133) (%)	Significance	Male (n = 475)	Female (n = 538) (%)	Significance
Activity tracker	10.8 (thereof daily: 45.4%)	13.5	8.5	6.2	V = 0.09, *P* = 0.013	11.9	9.8	V = 0.34, *P* = 0.276
Smartwatch to track physical activity	1.7 (thereof daily: 88.2%)	1.9	2.0	0	V = 0.13, *P* = 0.552	2.7	0.7	V = 0.29, *P* = 0.017
Smartphone or tablet applications	15.1 (thereof often: 51.0%)	19.5	13.4	2.3	V = 0.10, *P* = 0.041	19.2	11.5	V = 0.10, *P* = 0.006

V = Cramér's V

Table 7.5 Reasons for mobile physical activity tracking (Seifert et al. 2017a)

Reasons	Users of physical activity tracking (n = 208) (%)
To track my daily physical activity	65.8
To motivate myself to remain healthy	58.9
To exchange data on physical activity and health with friends	21.5
To document my data on physical activity and health for my physician	17.2
To track my sleep quality	13.7

In summary, the results of the two studies presented suggest that a small proportion of older populations within Germany and Switzerland are already using technology required to access AR-based serious games and are willing to use this technology in a health context. This subgroup can be an important target group for health technology using AR elements. Nevertheless, there are still important barriers to use (e.g., lack of trust, privacy concerns, and poor usability), and a significant proportion of older adults do not even own or use the relevant technology. Age-related differences still exist regarding ownership, use, and openness. As such, a significant proportion of older people is still excluded from the potential advantages of AR-based health technologies and such programs can currently only target a subgroup of older adults. Therefore, it is crucial to consider specific design approaches when developing AR games to broaden the accessibility for older adults.

Table 7.6 Reasons for decreasing subjective acceptance of health apps (multiple answers allowed) (Rasche et al. 2018)

	User groups		Significance
	Health app users (n = 95)	General app users (n = 216)	
Mean number of reasons mentioned (SD)	1.23 (SD = 0.98)	1.45 (SD = 0.95)	t(310) = 25.37, *P* < 0.001
Lack of trust	65%	89%	χ^2 (1) = 1.75, *P* = 0.19
Data privacy concerns	28%	39%	χ^2 (1) = 0.02, *P* = 0.89
Fear of misdiagnosis	21%	15%	χ^2 (1) = 1.56, *P* = 0.21
Poor usability	6%	15%	χ^2 (1) = 4.83, *P* = 0.02
Lack of self-confidence	1%	7%	χ^2 (1) = 4.69, *P* = 0.03
Lack of interest/demand[a]	1%	6%	χ^2 (3) = 3.79, *P* = 0.05
Pressure to perform[a]	0%	1%	
Technical reasons[a]	0%	1%	

[a] Answers to open-ended answer option; coded for analysis

7.4 Designing Augmented Reality Games for Older Adults

The conceptual foundations were presented and the question of whether older adults use digital technologies was discussed based on the data from the two selected European countries. In this section, we discuss design recommendations for AR games based on the presented research results and our expertise.

7.4.1 Consider Which Technology is Wished-for by Older Adults

As previously described, older adults may have age-related limitations in physical, cognitive, and social resources (Rasche et al. 2016). Therefore, it is important to consider feedback from older adults in the development process of a new product (Wille et al. 2016). Also, as described in the previous section, a growing number of older adults own and use mobile technologies. However, older adults often receive old phones from their children or grandchildren, which means they likely possess outdated technology (Mertens et al. 2017). Also, however, research shows older adults do not want mobile phones specifically designed for seniors; rather, they want the same phones that their children, grandchildren, and others around them have (Seifert and Schelling 2015).

Based on the body or research presented, the following considerations are essential when designing an application: the hardware should consider usability needs of older adults; and the content of the applications should be presented clearly, transparently, and consistently. Menu navigation and general navigation within the application should be logical, with steps being clear and kept to a minimum. The application should be intuitive and self-explanatory, and the system response should be transparent and predictable (Rasche et al. 2017a; Darvishy et al. 2017). Because smartphones and tablets are smaller than the conventional computers older adults may be more familiar with, it is even more important for application displays to be uncluttered and for operations to be uncomplicated. If support functions are inadequate or elements of the mobile application are inaccessible because of age-related impairments or the lack of a user-friendly interface, older people will likely avoid the application altogether. It is important, therefore, for application developers to actively respond to the expectations and needs of the older generation (Darvishy et al. 2017). Darvishy et al. (2017) presented a useful brochure for designing age-appropriated mobile applications.

7.4.2 Create Meaningful Games

The well-known *technology acceptance model* (Davis 1989) stresses the importance of usefulness and ease of use. Older, retired adults generally do not need new technologies for employment purposes, which might reduce their motivation to learn and use new technologies. In other words, older adults decide which technologies are useful in their daily lives. Understanding the user defines the usefulness is crucial in developing new technology and games. The older user also determines the technology's ease of use, which can differ between individuals. One strategy to ensure usefulness could be to adapt known motivational elements of games. To ensure ease of use, easy game rules and instructions should be applied for older target groups (Zahn and Senger 2012). It is important to integrate potential users in the development process as early as possible to ensure acceptance of technology and high usability (Wille et al. 2016). In this way, older adults' motivations to use new gaming concepts and technologies can be considered in designing an application.

7.4.3 Involve and Stimulate Older Adults' Social Networks

Game mode is an important consideration in game design. In a single-player game mode, there is no contact within the game with fellow (real people) players. In a multiplayer mode, several people play against or with each other in the same environment. One of the best known examples of a multiplayer mode is the game *World of Warcraft* (Williams et al. 2006; Corneliussen and Rettberg 2008; Ducheneaut et al. 2007). In this game, while players can develop their own character and abilities, people from anywhere in the world can play as a team or "guild."

A further example of the relevance of game mode is the AR game Pokémon GO, which in the first version, was a single-player game. While multiple people played in the same game environment and could compete against each other, a cooperation of

Table 7.7 Missing functions in Pokémon GO (Rasche et al. 2017b)

	Pokémon GO users		Significance
	Active (n = 81)	Former (n = 56)	
Missing functions: mean number of functions (SD)	2.8 (SD = 1.6)	2.8 (SD = 1.5)	t (135) = 0.08, $P = 0.93$
No missing functions	3.7%	3.6%	χ^2 (1) = 0.00, $P = 0.97$
More Pokémon in my neighbourhood	58.0%	62.5%	χ^2 (1) = 0.28, $P = 0.60$
Exchanging Pokémon	55.6%	75.0%	χ^2 (1) = 5.40, $P = 0.02$
Direct fights against others	54.3%	67.9%	χ^2 (1) = 2.52, $P = 0.11$
More Pokéstops	44.4%	21.4%	χ^2 (1) = 7.71, $P = 0.01$
More updates	38.3%	25.0%	χ^2 (1) = 2.64, $P = 0.10$
More arenas	25.9%	10.7%	χ^2 (1) = 4.84, $P = 0.03$
Better augmented reality	2.5%	14.3%	χ^2 (1) = 6.83, $P = 0.01$

players was not enabled in this first version. Our research into this version of Pokémon GO showed that players wanted social exchange not just as they met at physical spaces, but also within the game and the AR environment (Rasche et al. 2017b). The exchanging of Pokémon and direct fights against others were important missing functions especially for former Pokémon GO users (see Table 7.7). The creators of Pokémon GO subsequently identified this demand and reacted to it. Players are now able to join teams and play the game not just physically in the same place but also in cooperation with each other.

Pokémon GO illustrates the opportunity AR-based games present to play together with friends, family members, or even make new social contacts. Playing together may provide older adults the motivation to try these games. Digital devices used by older adults are often administered by friends and family who could also support an older adult's initial contact with the game (Mertens et al. 2017). This research suggests social isolation of older people might be partly alleviated by playing AR games (Chen and Schulz 2016), as new social contacts are encouraged as they meet other players in person or online. A sense of connectedness when using health-related technological interventions will facilitate use among older adults (Kim and Lee 2017).

Another advantage of a multiplayer design is that older people could share their data, including health-related data, with close friends, family members, and potentially even their doctors. In this context, it would be beneficial to not only exchange raw data (i.e., smartphone sensor data) but to provide grant access to analyzed data by, i.e., visualizing it through the game progress. Another benefit of tracking physical activity is to provide information and data to researchers in the health sector, and 57.2% of older participants who tracked their health indicated they were willing to do so (Seifert et al. 2018).

In the Swiss study by Seifert et al. (2017a), only 21.5% of mobile device users mentioned exchanging data on physical activity with family and friends as a reason to use activity trackers. Similarly, research on the long-term use of fitness trackers showed older people mainly used the devices passively in daily life and did not exchange their data with others (Schlomann 2017). Only a minority connected the device to a smartphone or personal computer to have access to the collected data and further visualization (Schlomann 2017). In the context of health behavior, 17.2% of the participants in the Seifert et al.'s study (2017a) reported they tracked physical activity to share the data with physicians.

In sum, AR games for older adults can be used for social connection including meeting in person. In addition, evidence suggests there is currently little exchange of the older adults' self-tracked data with friends, families or with their physicians. However, data exchange opportunities might further facilitate use and should be further studied.

7.4.4 Considerations for Designing Games for Health Promotion

When designing games for health promotion, an individual's motivations to start using health-related games on mobile devices is important. A study by Seifert and Meidert (2018) found that the motivation among older adults to use wearable technology was to stay healthy and fit, while to be *fun and try something new* was the dominant motivation among younger users. Rasche et al. (2017b) demonstrated that curiosity (i.e., trying something new) was an important motivation among active and former users of Pokémon GO to try this AR game. The reported motivation to start playing Pokémon GO was very similar between active and former Pokémon GO users (see Table 7.8). This suggests that users are not always concerned with immediate health monitoring and promotion, rather new technologies and games are also purchased because of the new possibilities they offer in general.

A second important consideration is the motivation created from the game itself, including its goals. In other words, which goals regarding sufficient physical activity should be defined within the game? Behavioral change theories like goal setting theory (Locke et al. 1990) or self-regulation theory (Baumeister et al. 2007) stress the importance of action planning, self-regulation, and self-efficacy to turn intentions into actual behavior. Mobile technologies (e.g., self-tracking devices and applications) can provide relevant information necessary for goal setting or action planning, and thus can help individuals make healthy choices or train healthy behavior, particularly if using a *gamification* approach (Deterding 2012; McCallum 2012). As a result, the *intention-behavior gap* (Sniehotta et al. 2005), or the gap between individual's intention to be healthy and his or her actual health-related behavior, could be overcome by these technologies, applications, and games. Through games, individuals can be motivated, ideally self-motivated, to engage in healthy behavior, such as

Table 7.8 Motivation to start playing Pokémon GO (Rasche et al. 2017b)

	Pokémon GO users		Significance
	Active (n = 81)	Former (n = 56)	
Motivation to start playing: mean number of reasons	1.9 (SD = 1.1)	2.0 (SD = 1.1)	t (135) = −0.53, $P = 0.60$
Curiosity	67.9%	64.3%	χ^2 (1) = 0.19, $P = 0.66$
Being a Pokémon fan	39.5%	37.5%	χ^2 (1) = 0.06, $P = 0.81$
Media reports	28.4%	26.8%	χ^2 (1) = 0.04, $P = 0.83$
Reports from friends	27.2%	39.3%	χ^2 (1) = 2.23, $P = 0.13$
Everybody around me plays it	13.6%	8.9%	χ^2 (1) = 0.70, $P = 0.41$
Being fascinated by the augmented reality function	6.2%	19.6%	χ^2 (1) = 5.82, $P = 0.02$
Combining fun and physical activity[a]	3.7%	0%	χ^2 (1) = 2.12, $P = 0.15$
Game for traveling[a]	2.5%	0%	χ^2 (1) = 1.40, $P = 0.24$
Nostalgia[a]	1.2%	3.6%	χ^2 (1) = 0.84, $P = 0.36$

[a] Answers to open-ended questions; coded for analysis

physical activities, in a playful way. This could result in positive behavioral changes since individuals are enabled to actively participate in self-care and decision making (Bhavnani et al. 2016).

A third important aspect is the intervention goal of a health-related game. For example, how much physical activity should the game encourage daily? The World Health Organization recommends taking 10,000 steps a day (World Health Organization 2010). Other guidelines suggest 150 min a week of moderate-intense or 75 minutes a week of vigorous-intense physical activity (U.S. Department of Health and Human Services 2008). These recommendations apply to all adults in good health who do not suffer from chronic conditions or disabilities. But among older adults, the possibility of compromised health or chronic conditions is quite high. Therefore, defining appropriate goals is difficult as Schlomann et al. (2016) revealed in their study regarding the long-term motivation derived from using activity trackers. They recommend using official institutional guideline values as a starting reference point, and then adapting them based on subjectively- and objectively-measured user performance, with the goal of avoiding feelings of being overstrained. The general guidelines for physical activity might exceed older adults' abilities and thus they risk certain injuries or health problems. Ultimately, this could cause discontinued use of the game. A solution to this problem might be the objective and subjective measurement of physical activity over longer periods of time. A mobile device and an AR game can measure objective movements (e.g. physical activities measured with smartphone-based sensors such as accelerometry or Global Positioning Systems) and combine this with subjective measurement of activity levels or well-being in general. A design goal of an AR game should be to collect a broad range of data to analyze players' lifestyle and behavior, to provide feedback to the user, and to enable better health decisions.

7.4.5 Facilitate Long-Term Use of Games for Health Promotion

One way to facilitate long-term use of devices and applications aimed at health promotion is to collect the individual performance and make this data available for later use. Accessing their own health-related data can help individuals to detect possible correlations between their behavior and health outcomes. Current applications do not appear to be very effective in their strategies to facilitate long-term use. A study by Ernsting et al. (2017) reports on the gap between the planned and the actual use of health-related applications on the smartphone. The study showed that the health applications people have installed on their smartphones are related to their intended behavior (i.e., behavior they would like to change), but not to their actual behavior (Ernsting et al. 2017). Another study showed that 80% of the users of smart devices abandoned their use after two months (Lazar et al. 2015). Rasche et al. (2017b) asked former Pokémon GO players for reasons why they quit playing the game. The top reason was boredom. Other reasons included being disappointed by the game, difficulties in reaching higher levels, and technical issues. Also, missing functions in the game and a lack of co-users were important (Rasche et al. 2017b).

One way to best facilitate long-term use might be to adapt the applications to the specific needs and interests of the users. In the context of older age, this means that games should be adapted to potential limitations, but also adapted to the individual goals of the older user. This can be done by either pre-determined criteria or ongoing adaptation during use. The automatic adaptation or *evolvement* is more complex, but more likely to encourage long-term use. The long-term study on the use of a fitness tracker showed that older adults might feel overstrained by predetermined goals that are not individualized (Schlomann et al. 2016). This tendency, however, was reported after only one month of use. After one year, use was mainly individualized and no feelings of being overstrained were reported; some participants used the device every day and others used it only for special occasions like hiking tours (Schlomann 2017). This is an indicator that older adults can use the technologies creatively and adaptively. Sometimes, the devices are used very selectively and not as designed. Therefore, AR games for older adults should provide flexibility for individualized adaptations.

7.4.6 Ensuring Data Security

Fears about data loss, misuse of data, and criminally motivated attacks on the application are an important issue. Seifert and Schelling (2015) found that safety concerns, such as data security, data transparency, and the threat of cybercrimes are the primary reasons behind older adults not using the Internet or applications on mobile devices. Therefore, application and game developers need to address these concerns by optimizing participant and content safety (Bleakley et al. 2013). Furthermore, Rasche et al. (2018) indicate that a lack of trust, privacy concerns, and the risk of misdiagnosis by the applications most commonly prevent older people from using health applications; in fact, applications where security is critical (e.g. online banking) are only used with strong reservations. These challenges are more prevalent in mobile devices, as opposed to stationary-use computers (Darvishy et al. 2017). One way to counter these concerns is ensure the transparency of information regarding what data is collected and for what purposes. Additionally, a personal support or contact person for an AR game could be available for assistance. For example, a game developer could provide local support or training videos (e.g., tutorials).

7.5 Conclusion

In this chapter, we have discussed the potential of AR games for health promotion in old age. The increasing use of modern digital products supports this potential. Today, many devices and applications already monitor health and encourage engagement in healthy behaviors among older adults. Also, several studies have shown that older adults already use digital products in their personal health care. Our research showed that older adults are a specific population with distinctive characteristics, interests, technology background, and specific preferences regarding usefulness and usability. Nonetheless, there exist good prerequisites for the success of AR games for health support in older people in the future. Based on our studies on three gerontological and technical research groups, we presented the challenges of developing these types of products for older people. Developers of AR games could consider this research in developing sustainable games with, and for, older adults.

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Chapter 8
Gamification in Cognitive Assessment and Cognitive Training for Mild Cognitive Impairment

Vida Groznik and Aleksander Sadikov

Abstract A most important aspect of gamification is its inherent ability to encourage engagement with a product or service. While this is often used as a marketing technique it proved very worthwhile applying it to a medical domain. Good games or just some game properties challenge and encourage users to, sometimes unknowingly, perform to the best of their abilities and that is often important in (automatic) cognitive assessment. Furthermore, games often have the ability to maintain users' motivation over a longer period of time, a very important aspect in sustained cognitive training. This chapter critically comments and looks at research and applications in the area of cognitive assessment and cognitive training for Mild Cognitive Impairment (MCI) from a gamification perspective.

8.1 Introduction

Mild Cognitive Impairment (MCI) is considered to be a transitional stage between normal cognitive aging and Alzheimer Disease (AD) (Petersen 1995; Petersen et al. 1999; Morris et al. 2001). The difference between healthy aging and people with MCI is in their memory performance while at the same time they have comparable cognitive functions. If we compare the patients with MCI to patients with mild AD, they have similar memory performance. Cognitive functions, on the other hand, are more impaired in patients with AD (Petersen et al. 1999). The prevalence of cognitive impairment without dementia is 10.7% for people between 65 and 84 years old and it is higher in women (Di Carlo et al. 2000). People with MCI have up to 25% higher risk of developing AD (Dawe et al. 1992). Therefore, it is very important to diagnose

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these individuals as early as possible so they can undertake targeted treatment and cognitive training to delay the progression of the disease.

There are several standardised neuropsychological tests which can be used to detect MCI. One of the most widely used assessment tests is the Mini-Mental State Examination (MMSE; Folstein et al. 1975) although there have been reports of difficulties in detecting dementia in its early stages with it (Tombaugh and McIntyre 1992; Wind et al. 1997). MMSE is a simple five to ten minute test which includes simple questions to test several cognitive areas: time and place of the test, words repetition, spelling and language, recall, repetition, and understanding of complex commands.

A study performed on 1,227 participants showed that MMSE is not sensitive enough to detect MCI and could not be used as a standalone diagnostic test (Tang-Wai et al. 2003). To overcome this downside and to provide physicians with a simple test to evaluate MCI, the Montreal Cognitive Assessment (MoCA)[1] test was developed (Nasreddine et al. 2005). The test takes approximately ten minutes and assesses various cognitive areas: short-term memory recall (learning and recalling of five nouns), visuospatial abilities (drawing a clock and copying a 3D cube), executive functions (trail-making task, phonemic fluency), language (animal naming, repetition of two sentences, fluency task), attention together with concentration and working memory (detecting the target with tapping, serial subtraction, repeating digits forward and backward), and time and place orientation. Due to the variety of the cognitive domains the test covers, the studies show it can be used to assess other neurological diseases such as Parkinson's disease (e.g. Dalrymple-Alford et al. 2010; Kasten et al. 2010), Huntington's disease (e.g. Videnovic et al. 2010), vascular cognitive impairment (e.g. Wong et al. 2009), diabetes-related dementia (e.g. Yamakawa et al. 2017), schizophrenia (e.g. Fisekovic et al. 2012) etc.

Another often used neuropsychological test is the California Verbal Learning Test (CVLT; Delis et al. 1987). The CVLT measures how much a person has learned, what kind of processes or strategies they have used for learning, and types of errors they have made (Delis et al. 1988). It measures a wide range of cognitive areas such as "free and cued recall, serial position effects (including primacy and recency), semantic clustering, intrusions, interference and recognition" (Elwood 1995). Due to several criticisms that CVLT has "poor standardisation and inflated norms" (Elwood 1995) and that it is biased towards people with higher education, an updated version, CVLT-II, was published in 2000 (Delis et al. 2000). In the new version some of the tasks were made easier and normatives included the education level as a variable. To be able to use the CVLT with children (aged 5–16 years), the California Verbal Learning Test for Children (CVLT-C) was developed (Delis et al. 1994).

Unlike the previous two tests we have described, the CVLT is much longer and takes more time to conduct. For testing free recall, an experimenter reads out loud 16 nouns five times in the same order and with the same pace. The nouns are from four different semantic categories. After each round, the subject is asked to repeat as many words as he or she can remember (in any order). In the next task, the subject

[1] MoCA test can be obtained from MoCA webpage: https://www.mocatest.org/.

Fig. 8.1 Example of a Stroop test

is shown a list that includes nouns from two categories from the previous task and nouns from two categories which have not been in the previous task. A person has to make free and cued (the subject is prompted with a category) recall of the nouns from the previous task immediately and again after twenty minutes. The last task is a recognition task where the subject is presented with a list consisting of 44 words. The subject's task is to specify whether each word is a target word or a distractor.

In 1935, John Ridley Stroop published a paper (Stroop 1935) which was taken as the basis for the psychological test known as the Stroop test. The test can be used to measure attention capacity, skills, and speed ability (Lamers et al. 2010). The Stroop test has several variations, mainly in the number of subtasks, types of stimuli, time to perform the task, and scoring (Howieson et al. 2004). The basic test is performed in three steps. In the first step the subject has to read out the color name. The colour of the ink with which the colour name is written and the named colour are different. In the next step, the subject has to name the actual ink colours with which the names are written. In the last step all the colour names are written in black—the subject has to read the names of the colours written. The actual sequence can differ among the tests. Some can also include dots or squares in different colours and the subject has to name the colours. The example of the Stroop test is shown in Fig. 8.1.

The last test we would like to mention, although there are plenty more, is Activities of Daily Living test proposed by Katz et al. (1963). The test is used to grade the "functional independence or dependence in bathing, dressing, toileting and continence, transferring, and feeding/eating" (Noelker et al. 2014). After several years of experience using the test, an improved version was published in 1970 (Katz et al. 1970). Lawton and Brody (1969) expanded the ADL with instrumental activities of daily living (iADL). "Their original scale covered eight domains for women: using the telephone, shopping, preparing food, housekeeping, doing laundry, using transportation, taking medications, and handling finances. (Housekeeping, laundry, and food preparation were excluded for men.)" (Noelker et al. 2014).

We have mentioned only a few of the existing neuropsychological and memory tests which can be used to assess whether the tested subject shows the signs of MCI or dementia. There are several more, but we have highlighted only those which are more commonly used and are necessary for understanding the rest of this chapter.

The neuropsychological tests have to be carried out and analysed by a trained specialist and are usually very time-consuming. In most of the cases, using only one of the tests is not enough to appropriately assess the cognitive decline so the specialist has to combine several tests during the examination. In addition to neuropsychological tests the evaluation also includes neurological examinations, laboratory tests, and the inspection of medical history. Due to the need for a trained specialist (or several of them), these tests cannot be self-administered and cannot be performed regularly to track the progression of cognitive decline. "Serious games for cognitive screening may be an alternative to traditional, pen-and-paper and computerised cognitive screening tests, potentially motivating and engaging the user to regularly perform cognitive screening tasks, thus providing more, timely cognitive-related data and facilitating the recognition of cognitive decline, triggering referral for a more comprehensive formal assessment and earlier detection of cognitive impairment." (Boletsis and McCallum 2016b).

In most cases, after being diagnosed with MCI or dementia, people are looking for ways to improve their cognitive abilities and to delay the progression of the disease. Currently there are no approved medications for treating MCI. However, doctors tend to give the patients drugs to treat the symptoms of AD although there is no evidence that these drugs actually delay or prevent the progression of the disease to AD. Basic instructions the patients get from the doctors are mainly focused on healthy lifestyle—regular physical and mental exercise/cognitive training, healthy food focusing on the mediterranean diet (fish, vegetables, fruit), staying hydrated, and engaging in social activities.

The results of the studies show that cognitive training improves cognitive abilities (e.g. Ball et al. 2002) and that cognitive interventions are efficacious (Jaeggi et al. 2011). They are even more effective before the occurrence of cognitive decline. It is therefore advised to start with cognitive training already in the middle years (Faucounau et al. 2010). "Consequently, the interest in cognitive training software, as well as interaction, for prevention of cognitive abilities in older adults has grown during latest years." (Mora et al. 2016). To increase the engagement of the users in using training software, the gamification techniques can be incorporated in the design of such solutions.

In June 2006, Nintendo has published one of the first popular brain training games—Dr. Kawashima's Brain Training: How Old is Your Brain? for its Nintendo DS system (Nintendo 2006) which includes several psychological (eg. Stroop test), mathematical (calculations) and memory tests. Shortly after Nintendo's successful game, the Lumos Labs has launched Lumosity programme for brain training (Hardy and Scanlon 2009) which has become one of the most widely known and used brain training programmes. Other popular training programmes include Mensa Brain Training (Mensa International Limited 2019), CogniFit: Memory Games and Memory Brain Training (Cognifit 2019), BrainyApp (Dementia Australia and Bupa Health Foundation 2019), BrainHQ (Posit Science 2019), Complete Brain Workout (Oak Systems 2019) etc.

An independent market research firm SharpBrains, which focuses on tracking digital brain health market, states in its 2013 market report that the market for brain health applications was worth $210 million in 2005. Since then it has been growing exponentially and the predictions are that it is going to be worth $6 billion in 2020 (SharpBrains 2013).

The importance of developing ICT solutions for people with MCI or dementia can be seen from the number of research projects that have been funded by the European Union. The DOREMI project (Decrease of cOgnitive decline, malnutRition and sedEntariness by elderly empowerment in lifestyle Management and social Inclusion) aimed to design cognitive training games for people with cognitive impairment (Musian and Ascolese 2016). They have designed four different games for Android tablet to train different cognitive functions (DOREMI project 2018). The goals of ICT4Life Project (ICT4Life 2018) and CAREGIVERSPRO-MMD (Zafeiridi et al. 2018) projects were to develop a health platform for people with dementia, their doctors, and their caregivers to improve the quality of life and to provide personalised services. Games for Olders Active Life is a H2020 project "that will deliver a platform to foster an ecosystem of games and applications that help people stay motivated to lead socially engaged, physically and cognitively active lifestyles" (GOAL 2019; Martini et al. 2019).

In addition to the research projects, there have been a number of final (e.g. Wohlfahrt-Laymann 2017), master (e.g. Berga Quintana 2015; De Abreu Ferreira 2015; Jönkkäri 2016; Oetting 2016; Eisapour 2018; Ni 2018) and doctoral (e.g. Boletsis 2016; Clark 2016; Nikolaidis 2016; Cutler 2017) theses focused on the topic of ICT technologies for cognitive assessment or cognitive training in the last five years.

In this chapter we focus on gamification in serious games and other systems developed for cognitive assessment and cognitive training for people with MCI. We were striving to cover the most interesting non-commercial work that has been published in recent years. The other surveys on similar topics including commercial applications are by McCallum and Boletsis (2013a, b), Dormann (2016), Lumsden et al. (2016), Ienca et al. (2017), and Costa et al. (2018).

8.2 Gamification Design for Elderly People

It is common knowledge that gamification can increase the user's engagement and entertainment while performing healthcare activities with positive outcomes (Lenihan 2012). When designing solutions which include gamification, we have to take into consideration the target user group. The game design principles vary a lot if the target group consists of youngsters, adults, or elderly people.

While young people like to compete and compare their achievements to others when playing games, this is not desired in solutions developed for elderly people (Itoko et al. 2014; Koivisto and Hamari 2014; Morschheuser et al. 2016). Youngsters are also fond of sharing their activities and achievements with others and to receive feedback from them which is again not true for (older) adults (Kappen et al. 2016). For the elderly, to see themselves receiving lower scores compared to their peers can have a negative effect on their motivation and can trigger negative emotions regarding their health. They do, however, strive towards community goals and want to be involved in a game where they can collaborate with their peers to achieve the common goal. Unlike youngsters, they also do not like solutions which were supposed to motivate them by collecting virtual achievements/badges (Link et al. 2014) and displaying game elements which distract them from the actual game tasks and consequently induce stress (Katz et al. 2014). For elderly people it is very important that they feel they are in control over the system and of their healthcare. This can be greatly achieved using the personalised design (McCallum 2012) and personalised reinforcements aimed at their needs (Kappen et al. 2016).

8.3 Gamification in Cognitive Assessment

While the suggested benefits of gamification itself have been presented in the introduction, the motivation of why use serious games for detection of MCI and AD is perhaps best advocated by Valladares-Rodriguez et al.: "Serious games aim at overcoming the limitations of traditional pen-and-paper methods, such as the cost of its administration being relatively time-consuming, its intrusive character, the lack of early detection capabilities, the lack of ecological validity, the learning effect, and the existence of confounding factors."

In their paper, Valladares-Rodriguez et al. (2018a) present Panoramix, a battery of serious games intended for MCI and AD screening. It assesses the main early cognitive markers, i.e., memory, executive functions, attention, and gnosis with a set of six games that are mostly based on classical psychological tests. The attention is assessed by a game inspired by the popular Simon Says game, where the player has to repeat a lengthening serious of colours. The semantic memory is probed by a gamified version of Pyramids and Palm-trees test (Howard and Patterson 1992) and working memory is probed by the gamified version of the classical Corsi's Cubes test (Kaplan et al. 1991) where a sequence of highlighted cubes has to be repeated in reverse order by the player. Furthermore, the procedural system, instrumental for the activities of daily living through its control of routines of thought and action, is assessed through the gamified version of another classical test, the Pursuit Rotor Task test (UNESCO Institute for Statistics 2012). Next, visual agnosia (the ability to visually recognise different elements and assign meaning to them) is assessed by a game where shapes, colours, feelings, and expressions need to be recognised by the player. Finally, Episodix is a game designed for assessing episodic memory. It is based on the California Verbal Test (CVLT; Delis et al. 1987). Figures 8.2, 8.3 and 8.4 show some tasks as they occur in the Episodix game.

The Panoramix battery has been tested on a pilot cohort of 16 subjects that included eight age-matched healthy controls, three subjects with MCI, and five subjects with AD. All participants played all six games and various features were measured/calculated, e.g. number of correct guesses, omissions, errors, time spent, etc. These features were used as input to various machine learning algorithms that attempted to classify into two classes: normal or impaired cognition. Leave-one-out methodology was used to estimate the success of classification, which means the algorithm learned on 15 samples and predicted the one left out. Using data from

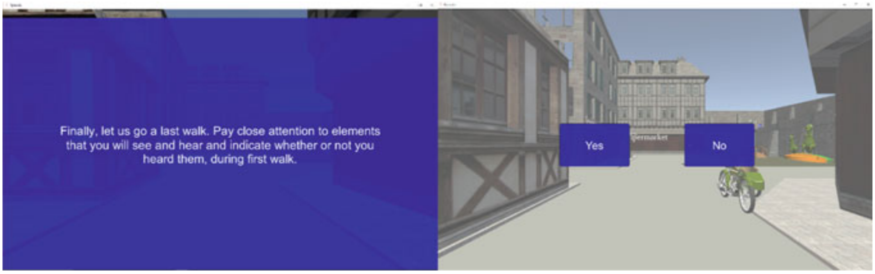

Fig. 8.2 A screenshot of a recognition task in the Episodix serious game (© Valladares-Rodriguez et al. 2018b distributed under the terms of the Creative Commons Attribution License)

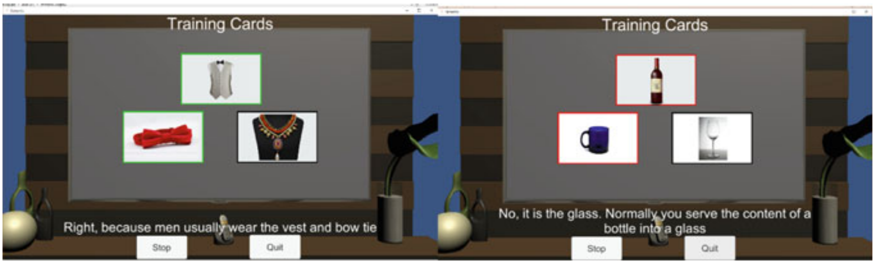

Fig. 8.3 A screenshot of a training phase for a semantic memory task in Episodix serious game (© Valladares-Rodriguez et al. 2018b distributed under the terms of the Creative Commons Attribution License)

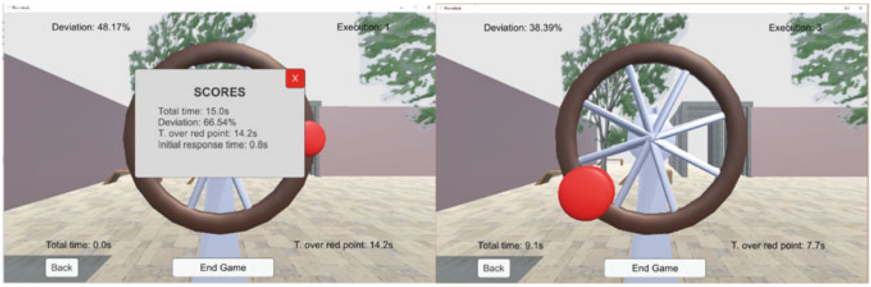

Fig. 8.4 A screenshot of a procedural memory task in Episodix serious game. The left picture shows the screen after the first execution and the right one shows the screen during the third execution (where the ball size varies) (© Valladares-Rodriguez et al. 2018b; distributed under the terms of the Creative Commons Attribution License)

three games only (episodic memory, semantic memory, and the procedural system) yielded a model with perfect separation between healthy and cognitively impaired subjects; warranting further experiments with this setup. It is also notable that good correlations with standard tests, especially for the Episodix game, were observed. This further supports the notion of games having the potential of being used in place of traditional pen-and-paper tests.

The evaluation of episodic memory is especially paramount to MCI and AD detection, as it is the most reliable indicator of the likelihood of conversion of MCI into AD. With this notion in mind, Valladares-Rodriguez et al. further focused primarily on the Episodix game. In Valladares-Rodriguez et al. (2017) they principally evaluated the usability of the game while at the same time this study served as a pilot evaluation of the game's validity. The usability of the game was confirmed and the most interesting result was that the administration of the Spanish pen-and-paper version of the California Verbal Language test took between 65 and 75 min, including the manual scoring of the test by the examiners. On the other hand, the application of the Episodix game based on CVLT took only 30 min, and the scoring was automated as part of the game itself. This supports the claim of significant time savings while avoiding potential errors present with manual scoring.

The Episodix game with semantic and procedural memory tests was evaluated to be a valid tool to discriminate among MCI, AD, and healthy individuals (HC) in (Valladares-Rodriguez et al. 2018b) and as statistically significant for the Galician population. A total of 64 individuals (28 HC, 16 MCI, and 20 AD) completed the experiment from an initial sample of 74. All participants undertook a collection of classical pen-and-paper tests and interacted with the game. Again, machine learning was used to learn a model and interpret the results of gameplay. The best classifier achieved F1 score of 0.97 signifying high accuracy of discrimination between the three groups.

Tarnanas et al. (2013, 2015) introduce the complex instrumental activities of daily living (CADL) marker and evaluates—alongside established biomarkers—its predictive power to prognosticate the advancement of cognitive decline within the next five years. The introduced CADL marker consists of two modules simulating complex activities of daily living. The first module is an immersive reality day-out task (DOT) simulating a rehearsal of an apartment building fire evacuation drill (Fig. 8.5).

The DOT contains six levels of difficulty. The user interacts with the environment with simple hand gestures and has a time limit to complete the task. The second module uses the same virtual apartment building as the DOT module and the user's task is to navigate within the building. Again, six difficulty levels comprise the module and in each level more destinations need to be reached in as short a time as possible. Both modules required coordination of information by eliciting a medium-to-high cognitive control, such as inhibition of external stimuli or processing speed, which is believed to be affected by aging. The CADL marker was captured in a virtual reality setup using a VR hardware alongside a LEAP motion sensor and a Kinect camera. The user was put on a treadmill to approximate actual movement. The setup can be seen on Fig. 8.6.

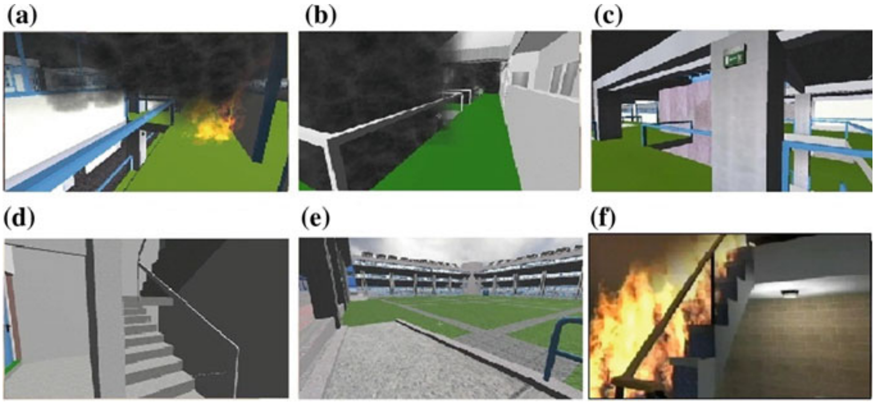

Fig. 8.5 Screenshots of different tasks and viewpoints in VR-DOT module (© Tarnanas et al. 2013. Originally published in JMIR Serious Games (http://games.jmir.org), 06.08.2013. Distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/2.0/).)

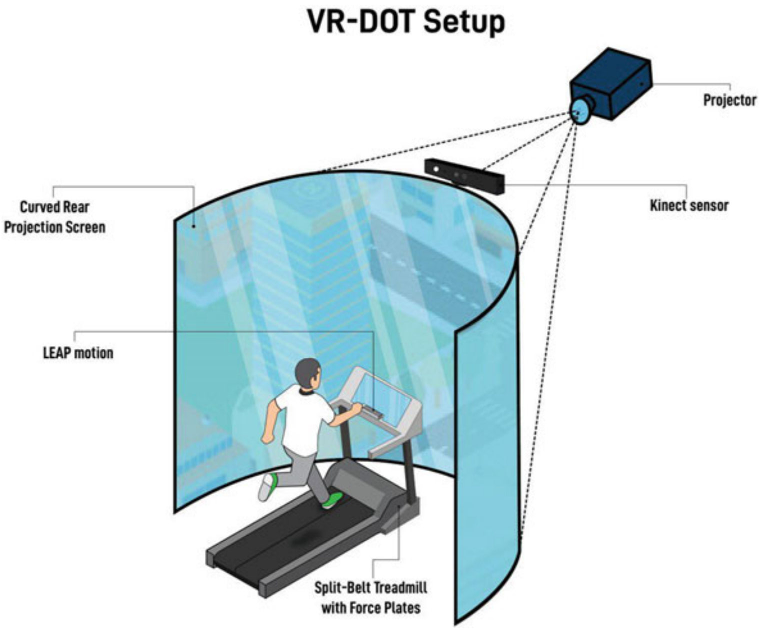

Fig. 8.6 The virtual reality setup using a VR hardware alongside a LEAP motion sensor and a Kinect camera in VR-DOT module (Adapted from Tarnanas et al. 2013. Originally published in JMIR Serious Games (http://games.jmir.org), 06.08.2013. Distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/2.0/).)

A longitudinal, five-year clinical study was conducted to evaluate the CADL marker along with the established biomarkers like fluorodeoxyglucose-positron emission tomography, precuneus and medial temporal cortical thickness for their predictive power. From a total of 350 enrolled people, 215 subjects—71 with normal cognition, 61 with MCI, and 83 with AD at baseline—completed the full duration of the study. The participants were examined (all markers recorded and a standardised neuropsychological test battery applied) at baseline and at the end of the 12-, 24-, 36-, 48-, and 60-month follow-up. The examiners observed whether subjects remained stable (within their initial group) or converted (from normal to MCI or from MCI to AD) during the study.

The Cox proportional hazards model showed that CADL marker adds independent information to the model; in fact it explained the most variability among both memory and executive function decline. The most important observation, however, is that the CADL marker could also provide predictive information for cognitive decline during the presymptomatic stage of the disease which standard biomarkers can not. This study again shows that a game (both fire drill and navigational task were perceived as a game by the participants) can be used as a long-term biomarker.

Tong et al. (2014, 2017) explored gamification in the context where a relatively frequent assessment of cognitive function is required. This context can either be preventative continuous assessments for early detection of MCI or—as in their case—to (more quickly) detect evidence of fluctuating cognitive performance hinting at delirium. The main arguments for the use of gamification are that repetitive application of a standard pen-and-pencil test is tedious for the subjects, and that such a test cannot be self-administered thus requiring significant involvement by the healthcare personnel.

They propose a well-known and popular game of whack-a-mole, initially explored in (Tong 2014), modified to be played on a tablet computer (Fig. 8.7). The objective of their version of the game is to hit as many moles coming out of the holes as possible, but at the same time avoiding to hit the butterflies. This go/no go discrimination design is aimed at measuring inhibition, an executive function important for applying attention where distractors are present and which is affected by age-related changes.

Tong et al. (2016) conducted experiments assessing the measuring validity of their approach. The first observations revealed that tablets (and/or the game design) were not necessarily a very suitable platform for the elderly population. This is an important lesson in and of itself—the user interface, including the platform selection, should be well adjusted for the target population. After the adjustments making the game easier to handle by the elderly, the validation study with 141 consenting subjects was performed. They assessed the game against MoCA, MMSE, and the Confusion Assessment Method and confirmed strong statistical correlations ($p < 0.001$) with all of them.

In a series of papers, Boletsis and McCallum (2014a, b, 2016a, b, 2017) present Smartkuber (called CogARC in its beta version), a serious mobile video game utilising Augmented Reality for the manipulation of cubes (Fig. 8.8). The main purpose of the game is cognitive screening, but it can also be used for preventative cognitive training purpose. The game is aimed at people with preclinical and early MCI

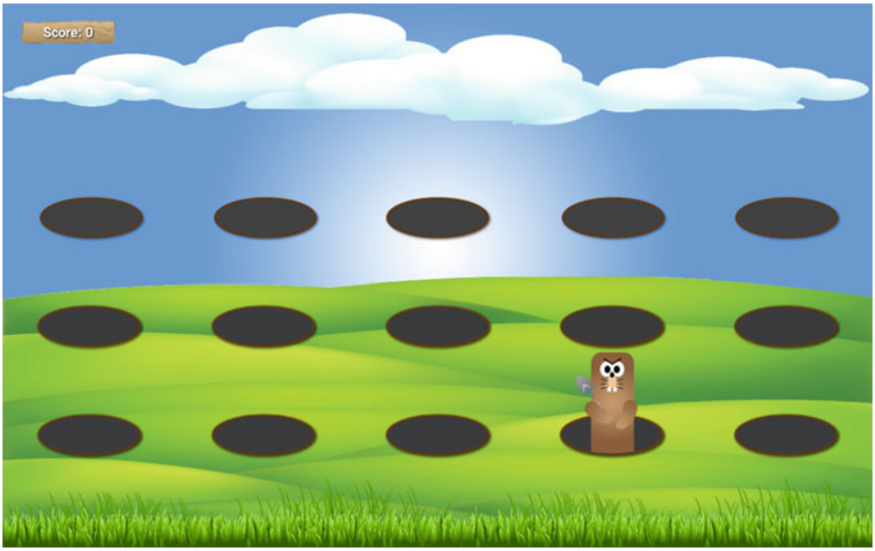

Fig. 8.7 Screenshot of a whack-a-mole game on a tablet computer (© Tong et al. 2016; Originally published in JMIR Serious Games (http://games.jmir.org), 27.05.2016. Distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/2.0/).)

stages. The game consists of several puzzle minigames for variety and for targeting different areas of cognition, including visuospatial reasoning, memory, attention, problem solving, and logical reasoning. While the paper (Boletsis and McCallum 2016a) mostly deals with the game design, in (Boletsis and McCallum 2016b) the authors evaluate the assessment capabilities of Smartkuber against MoCA in a small trial with 13 subjects over 60 years old. They report good overall correlation (0.81) between Smartkuber and MoCA, and also report on the correlations between various minigames and various MoCA's domains. Six out of seven MoCA's domains are well correlated with Smartkuber's minigames, with only delayed recall remaining uncorrelated. Also, of interest is that no significant learning effect was observed—this makes a game like Smartkuber suitable for repetitive screening application over time.

A different and interesting approach was taken by Gielis et al. (2017). They approached the problem of searching for or designing the game with which to potentially screen for signs of cognitive decline from the opposite side. Instead of defining a set of cognitive characterics a game should have, they searched for an existing game that is popular among the target population; namely, among the elderly people. Their pick was a card solitaire game, specifically Klondike solitaire game (also known as Canfield or Patience) that was widely distributed as part of the Windows OS distribution and GNOME reaching a worldwide audience (Fig. 8.9).

Once the game was selected, it was analysed by game researchers for game actions that were required to successfully complete (win) the game. The game actions represent the building blocks of a planned solution. After discarding some actions deemed

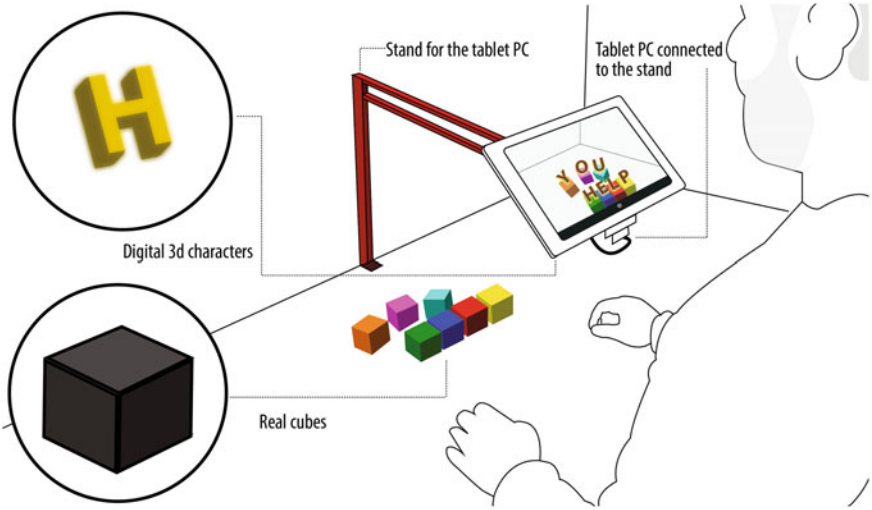

Fig. 8.8 Interaction setup of the Smartkuber system—cubes and a tablet PC attached to the base stand (© Adapted from Boletsis and McCallum 2014a; Boletsis 2016; Boletsis and McCallum 2017)

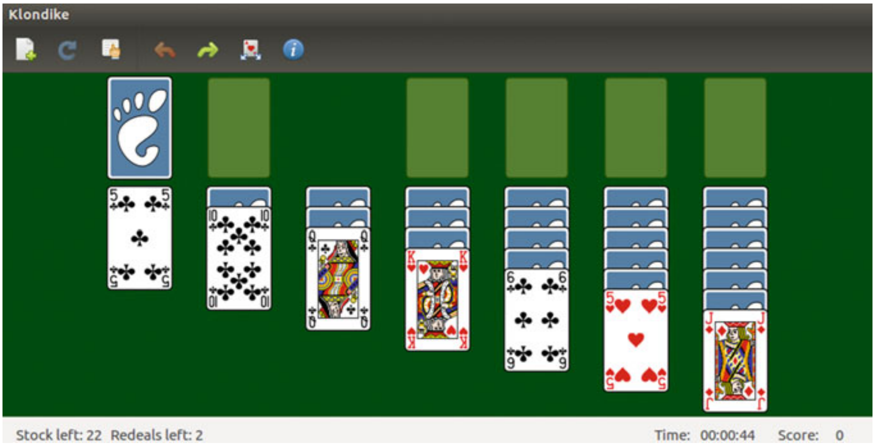

Fig. 8.9 Screenshot of Klondike Solitaire which is part of GNOME

hard to interpret, they were left with 22 distinct game actions. Next, an interdisciplinary team of three healthcare professionals mapped the game actions to various cognitive processes. The agreement between the experts was quite high for 20 out of 22 actions and the cognitive processes covered were of a wide variety. The healthcare professionals were positive in their evaluation that continuous tracking via this (or similar) solitaire game could be used to detect cognitive decline and MCI. However, no clinical study so far was conducted with either healthy controls or patients.

The position paper by Leduc-McNiven et al. (2018) involves another simple and well-known card game, namely War or, more precisely, its variant called Strategy War. In their implementation as a mobile game called WarCAT, two players are each dealt five cards and each player can play them in any order they choose. When both opponents play a card, the higher one wins and this is repeated for the other cards in the players' decks. Their idea is to observe the user's play against various computer bots, each bot designed with a specific strategy, e.g. playing their cards from low to high. The user can thus first learn the bot's behaviour (strategy) and then devise their own strategy of winning when repeatedly playing against this same bot. Observing the user's behaviour against several different bots gives a sort of 'cognitive fingerprint', or as they put it, a pattern associated with a player's actions during gameplay. The bots are of various difficulties from very bad to perfect strategy.

The authors have so far trained an artificial neural network model to predict which bot is playing; they used a large amount of bot versus bot plays to train the model. Their idea in the future is to use user's observed play and compare it with various bots using the trained model.

There have been several attempts in developing computerised self-administered test batteries for assessment (and follow-up) of MCI which effectively distinguish between the control and MCI group (e.g. Dougherty Jr et al. 2010; Égerházi et al. 2007; Saxton et al. 2009; Tornatore et al. 2005). However, these non-gamified tests do not motivate people to complete the assessments in the context of long-term monitoring. In their work, Zeng et al. (2018) introduce a gamified self-administered cognitive test battery Virtual ADL+ House for a long-term cognitive assessment implemented as an iPad application. The test includes a series of 11 mini-games covering six cognitive domains (attention, processing speed, language, visuospatial, memory and executive functioning). The games are "abstractions of many of the daily living routines, modelled after the Lawton Instrumental Activities of Daily Living Scale (Lawton and Brody 1969), including using telephone, food preparation, housekeeping, laundry and handling finances".

The evaluation of the test will be performed in three phases. In the first phase a focus group evaluated usability and entertainment aspects of the game. This phase was already carried out with the help of 13 participants (eight doctors and five healthy adults over 60 years old). The second phase will be a small scale pilot study for validity evaluation and cut-off scores adjustments. The third phase is planned to be a long-term large scale study for evaluating the disease progression and identifying high-risk individuals. The results of phase one reveal a generally positive feedback on the test. They indicate that the Virtual ADL+ House is easy to use and can keep elderly users engaged in the long-term. However, it also shows that the system is somewhat complex, that the elderly people "would need to learn a lot of things before they could get going with this platform" or would need technical support to be able to use it.

8.4 Gamification in Cognitive Training

Although the scientific literature clearly defines differences between cognitive stimulation, cognitive training, and cognitive rehabilitation (Clare and Woods 2004; Belleville 2008; Mowszowski et al. 2010) they are still often used interchangeably. The inconsistent use of these three types of cognitive interventions can explain why the scientific reports on cognitive training can sometimes be conflicting (Gates et al. 2011). We give the short explanation of the three hereinafter.

The goal of cognitive stimulation is to improve cognitive and social functioning of people with dementia by engaging them in group activities and discussions. The benefits of this kind of approach were demonstrated in a large controlled trial with 201 older people with dementia (Spector et al. 2003). People enrolled into the study showed improvements in cognition and quality of life.

Cognitive training is performed using guided practice composed of standard tasks reflecting on distinct cognitive functions like memory, attention, language, visuospatial skills, or calculation. The hypothesis is that regular training routine can maintain—or even improve—functioning in a given domain (Clare and Woods 2004). Cognitive training can be performed in the form of group sessions (Kesslak et al. 1997; Moore et al. 2001), individual sessions (Davis et al. 2001; Farina et al. 2002) or performed with the help of family members supported by a therapist (Quayhagen et al. 2000).

The aim of cognitive rehabilitation is to improve the functioning of people with cognitive impairment in everyday life (Wilson 2002). Its advantage is the individualised approach where the health care specialist adjusts the rehabilitation programme to tackle those difficulties considered most relevant by the person with dementia and their family (Clare and Woods 2004).

Episodic memory training programme Game Show was developed in collaboration between healthy adults, patients with agnostic MCI (aMCI), psychologists and game developers (Savulich et al. 2017). The game included stimulating music and visually appealing displays and was run on an iPad. Participants of the study attended eight supervised one-hour trainings. The game motivated participants by rewarding them with virtual gold coins every time they correctly solved the task. The player had to associate different geometric patterns with spatial locations. To keep the players motivated and engaged, the game automatically determined the number of different geometric patterns to be shown based on the player's performance. The results of the study performed on 42 patients with aMCI (healthy controls were not included in the study) showed improvement of episodic memory and enhanced visuospatial abilities in patients with aMCI.

Mora et al. (2016) echoed the sentiment of Tong et al. (2014) regarding gamification and frequent application of the same assessment or training procedure over and over again. In their own words: "Common therapeutic strategies rely on participants regularly completing diverse tasks in a monotonous way, which may get tiresome as they become routine, tempting participants to drop out after a short time. According to the motivational outcomes of the strategic use of game design elements, gamification arises as an effective technique for user engagement in non-leisure contexts like healthcare and well-being."

They present Preventive Neuro Health (PNH), a gamified suite for cognitive training. The suite contains 42 exercises for cognitive stimulation covering attention, memory, executive functions, orientation, gnosis, and praxis. Their work is especially interesting because of careful attention given to the breakdown of which gamification principles are suitable for the older population (target user group) and which are not. For example making direct comparisons between the user results and competition-based gamification are two examples of principles not liked by the elderly while peer reinforcement and personalised reinforcement are principles liked by the elderly. Their work is also notable for the use of crowdsourcing-inspired gamification elements, e.g. community purpose (their personal training result contributing to the group score) or notification that a given amount of other users have already completed their daily training.

Continuing in the same vein as the work of Mora et al. (2016) above, a similar and very relevant observation regarding gamification is made by Tziraki et al. (2017). In their own words: "The field of serious games for people with dementia (PwD) is mostly driven by game-design principles typically applied to games created by and for younger individuals." Specifically, they argue that serious games aimed at people with impairments should be designed in such a way as to be of appropriate difficulty level for such users and to offer cues or other guidance to allow the users to successfully complete the game. They argue that while making errors is the way people usually learn, for PwD the effect of mistakes can be mostly negative and that is why guidance and cues should be used to avoid errors (errorless learning). With that in mind, they designed a game for PwD target group aimed at enhancing their self-efficacy in regular daily activities.

The game was used in a pilot study with 24 PwD (of which only 12 finished the study) and 14 healthy adults over 65 years old (control group) enrolled. The participants played the game for 10 weeks with two sessions per week. It was observed that healthy controls completed the game much faster than PwD. However, a more interesting result was that both groups experienced a similar decrease in game tasks completion time during the trial, implying that both groups improved their processing speed with practice. PwD also self-reported an improvement in their self-efficacy with regular daily activities.

An idea of including automatic assistance during the games is explored in a pilot study by Phan Tran et al. (2016). The reasoning is along the lines of the work by Tziraki et al. described above, namely that cognitively impaired people can have problems with gameplay due to e.g. forgetfulness and without assistance they get discouraged and lose motivation to continue. When it comes to cognitive training using serious games, people stop playing them because they feel discouraged due to different reasons. Phan Tran et al. have developed an interactive system to provide assistance to the players during the game. The assistance was given using a 3D animated avatar which can move and give verbal guidelines. There are many benefits of using a virtual avatar: providing a feeling of a companion to the elderly (Morandell et al. 2008), boosting attention and sympathy (Vardoulakis et al. 2012),

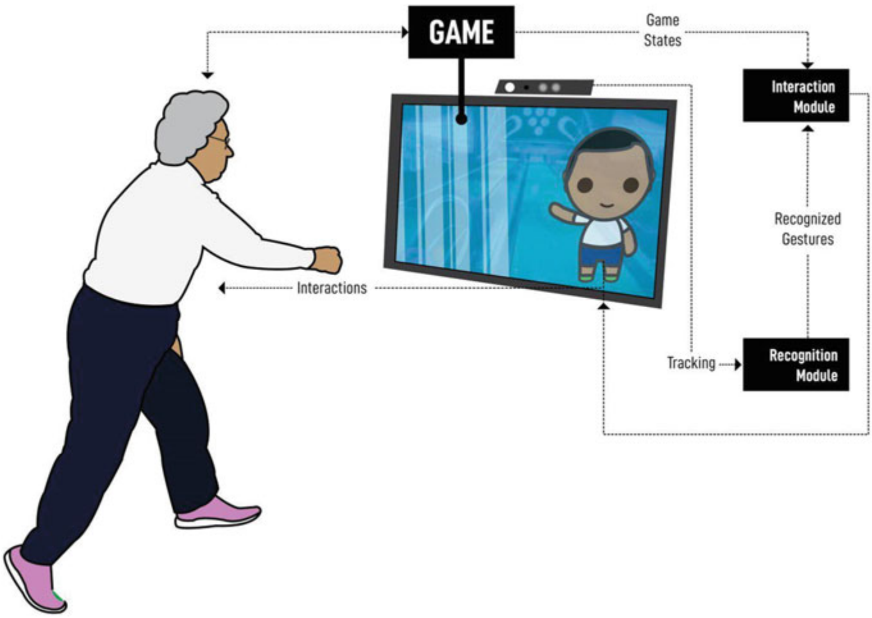

Fig. 8.10 Setup of an interactive system to provide assistance to the players during the game (based on description from Phan Tran et al. 2016)

and improving the interaction with the system (Ortiz et al. 2007). The system has two modules (Fig. 8.10). The Recognition Module recognizes the player's gestures using Microsoft Kinect and its SDK. The gestures are then sent to the Interaction Module which collects these gestures and uses them in combination with the game states to determine the interaction type. In the game, the users could play the game by only raising hands.

Phan Tran et al. set up a pilot study with three groups of ten subjects with different cognitive impairments: Mnesic plaint, MCI, and Alzheimer's disease. The participants played a concentration-focused serious game and each session lasted about 20 min. After initial introduction to the rules of the game by the therapist, the participants played the game once without the system's assistance and once with the assistance; the order of these two sessions was randomised. The assistance offered by the system was quite simple: (1) when the system detected inactivity, it reminded the player about the game and gave some guidelines as per the game state, and (2) if the system detected player making a lot of mistakes, it recalled the rules of the game for them.

The results are very preliminary, but they hint that assistance of this simple type is a welcome addition to the games designed specifically for such target population. In all cases, not surprisingly, participants performed better (quicker and with better scores) when assistance was offered. The important result, however, is that some people tended to abandon the game in the run when no assistance was offered, while no such abandonments happened when assistance was offered to the players. Some other systems for elderly utilising cognitive assistants are described in a survey by Costa et al. (2018).

Zając-Lamparska et al. (2017) developed the GRADYS training software, a computerised VR-based cognitive training system, working with the Oculus Rift, and consisting of separate game scripts to stimulate four different cognitive domains: attention, memory, language, and visuospatial processing. GRADYS is intended for cognitively healthy older adults and those with MCI to milder dementia. The authors argue that a VR-based cognitive training can provide an experience (much) closer to everyday situations than either standard computer interfaces or even pen-and-paper training, thus providing better ecological validity of the training. The gameplay revolves around similar tasks as already seen in several applications surveyed in this chapter, e.g. a number of elements to memorize in the memory module, pointing out a correct target object in the presence of distractors of varying similarity to the target in the attention module, correctly positioning objects of increased visuospatial complexity in the visuospatial module, and training with increasing syntax complexity and vocabulary difficulty in the language module. Three levels of difficulty are provided for each module, again in line with previously described works pointing out that adjusting the level of difficulty to the player is an important gamification element to keep the player interested and motivated. Other gamification elements include tracking results in a given session, improving them in subsequent training sessions, and comparing results with other users of the software—the last one deemed controversial (for elderly population) in some of the works previously mentioned.

8.5 Discussion

It is hardly possible to give an absolutely exhaustive overview of the current research in almost any field and that was also not the primary intention of this work. We strove to give an interesting and broad enough snapshot of currently still budding, but nevertheless already very active research field. This is suggested as most of the surveyed works are very recent, many still in or just past the pilot phase. The discussion focuses on the most interesting points raised or demonstrated by the surveyed studies.

Many surveyed papers raise the point of the user's motivation. This is usually not a problem when considering a one-off medical examination or one that is administered with long time intervals (e.g. yearly or longer) in between repetitions. However, in situations when a shorter time span is desired between tests for detecting the condition as soon as possible and even more so when repetitive cognitive training is in question, then the motivation issue can—and usually does—become one of the most critical aspects. The situation is akin to that of physical training. If one looks at the contents of fitness or bodybuilding magazines, he or she quickly realises that they are filled with articles on new possible exercises or combinations of training regimens. While an important point is to 'attack' the muscle from a different angle and not let it get too used to the training regimen, the main point is actually to keep motivation. And humans are naturally inclined to be interested in new things, new exercises, new combinations. The situation is exactly the same or perhaps one can argue even more accentuated with cognitive training as the mind quickly adapts (the learning effect) and becomes bored with anything too repetitive. Thus, new cognitive training exercises or some new tweaks of the same exercises are constantly needed. This is where gamification can really excel at. It is usually much easier to tweak, randomise, or upgrade an existing virtual game than a pen-and-paper exercise. And this comes on top of being able to seize the other advantages of gamification with respect to keeping the user motivated, e.g. comparing the scores across the community, contributing to the community goals, automatically keeping history, etc.

Another important aspect concerning user motivation raised in several papers—and another one hardly possible with pen-and-paper exercises—is to offer (in-game) assistance to the player. The underlying point is that some users tend to get discouraged and demotivated when continuously unable to reach the game goals. Sometimes very little help is enough to help the player, especially with the elderly and MCI users; this is e.g. seen in (Phan Tran et al. 2016) where they offer some simple game state related advice when inactivity is detected. Even just reminding the players about the game can be useful as these are players with memory and/or concentration problems.

The level of play difficulty can be viewed as a complementary feature to in-game assistance in the sense that for some users it is just the opposite, the game being too easy, that discourages them. Levelling up is an inherent gamification feature. At the risk of sounding repetitive, it is also much easier to detect and adjust the level of difficulty with virtual games than with pen-and-pencil ones. An interesting idea is discussed in (Leduc-McNiven et al. 2018). It is often possible to detect the player's level of play automatically. Even more, certain characteristics of the user's play can be continuously observed and used to produce a sort of cognitive fingerprint of the player. Observing the performance through this fingerprint (or user profile or some attribute description of the player) over a longer period of time can detect changes in the player's (cognitive) condition. Such reasoning was confirmed as useful in (Tarnanas et al. 2013, 2015) when the gaming 'biomarker' proved independently useful for predicting the cognitive state of the player.

Yet another interesting aspect of combining the adjustment of the level of play difficulty and in-game assistance was demonstrated in (Tziraki et al. 2017). Their results hint that even patients with AD can exhibit learning and improving at the game if the level of difficulty is suitable for them. They advocate the so-called errorless learning as a way to keep the AD players' motivation. While perhaps inconclusive as many patients dropped out and the participants numbers were small, it still warrants and interesting direction worth repeating or exploring further.

The ecological validity, i.e. the study's close approximation of the real-world setting being investigated, is another important point potentially very much benefitting from the AR- and VR-based immersive systems. Such systems can recreate real-life scenarios relatively realistically if enough care is given to its design and implementation. The activities of daily living (ADL) is a good example of tasks that can be quite realistically simulated and where such realism might be even more desired than with other games since it simulates and measures the performance at real life tasks directly. An example of this is the apartment building fire drill task from the work by Tarnanas et al. (2013, 2015). The authors went into real detail to recreate the scenario as far as adding the treadmill to simulate movement around the building. While perhaps seeming as an exaggeration, such attention to detail can often make the difference. Just to give an example, consider two older men walking. Then, one of them stops when he starts talking to his friend. This can often be seen with patients having Parkinson's disease. If such an activity would only be simulated on a screen, this effect could be completely overlooked.

More a point of digitalisation or automatisation than gamification itself, but nonetheless worth mentioning, is the potential to reduce manpower workload and the mistakes stemming from it in scoring pen-and-paper results. This notion was practically demonstrated in (Valladares-Rodriguez et al. 2017) where they observed that a gamified test administration took less than half the time of the equivalent pen-and-paper version of the test. Since the scoring is usually based on some concrete measured features (e.g. number of false responses, total or reaction times, etc.) it can also eliminate mistakes from manual scoring of the tests once the automated scoring model is well validated (this being the hard part). We, the authors of this survey, can attest from personal experience that administering tests can be monotonous and very tiring also for the tester not just the examined user. This leads to a larger susceptibility of errors and/or lesser productivity.

The surveyed papers demonstrated various approaches of how to come up with games for cognitive assessment or training. Probably the most standard approach is to gamify the existing neuropsychological (pen-and-paper) test directly or to come up with a game that is similar to one of these tests. In both cases, never mind how closely the game follows the original test, validation is required. Going from paper to the screen and into virtual reality can (and usually does) introduce some differences and these have to be accounted for. A good take away lesson from one of the studies is that one has to be very mindful of target population—in this case elderly people, usually with at least some cognitive impairments—when selecting the game platform and the game's design. For example, Tong et al. (2016) discovered (after the fact) that while the game itself was well designed, tablet computers as a platform were problematic simply because the elderly had trouble with the game controls due to limited size of the device.

An interesting alternative to this approach of selecting or creating games was shown by Gielis et al. (2017). They turned the selection process around and searched for a game that is already widespread and popular among the target population—in their case this was Klondike solitaire freely distributed with the Windows operating system. Then they analysed in detail how the game is played and how single game actions map to cognitive processes. If the latter are deemed appropriate for cognitive assessment or monitoring by the healthcare community, the game can become an assessment tool and its game actions take the role of biomarkers.

The last point we would like to discuss in this overview is about the nature of most reviewed works and likely the field itself. The works are in the large majority of the cases very recent. While undoubtedly screening for works containing the keyword 'gamification'—which came into practice only within the last 10 years—focused the search towards mostly very recent works, this is not the only reason. The field is actually quite young; in our belief the reasons are something along these lines: (1) gamification itself is actually relatively recent; (2) focus on neuropsychological disorders is a direct result of observing the population aging in most developed countries and this also happened only quite recently as evidenced e.g. by it becoming the focus of European (and worldwide) project calls only in recent framework programmes and by recent interest from big industry (pharmaceutical, healthcare, etc.); (3) the technology, mostly sensors, coming of age (getting cheaper and widespread, reliable enough, and smaller and lighter) in recent years (the era of smartphones, smartwatches, etc.); (4) widespread acceptance of data acquisition (e.g. self-tracking of physical activity) and data analysis approaches (like machine learning). We share the sentiment of Zając-Lamparska et al. (2017) who wrote "In the era of aging societies, research into methods of cognitive rehabilitation in clinical populations and cognitive enhancement in healthy older adults has soared recently. The growing interest in this area has stimulated the development of technologically advanced computerized training…".

The field of gamification for neuropsychological assessment and training is inherently very interdisciplinary as testified by the wide variety of different conferences and journals the surveyed papers appeared in. While, as stated above, most works are in or just past the pilot phase, other works like e.g. Tarnanas et al. (2013, 2015) that report very positive results of a five-year long clinical study into a gamification-based biomarker, we believe this field is a budding one, benefitting from research in many fields, and will likely expand in the near future.

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Chapter 9
The Healing App: Augmented Reality and Art for Pediatric Patients with Chronic Pain

Olivia Davis and Claudia Hart

Abstract Healthcare is a large and ever-expanding industry affecting millions of people every day. Therefore, it makes sense that the medical community is already discovering the benefits of augmented reality (AR). Training, live surgical guidance, and therapy are already popular areas of AR in medicine. However, what if we also harnessed the power of augmented reality to influence pain management with art? In collaboration with artist Claudia Hart, the Montefiore Health System is creating a new project that explores the combined power of art and technology in a healthcare environment. By commissioning Claudia Hart for a specific area of a hospital, in a situation where she is an intimate part of the planning, a magical and meaningful space emerges that could directly affect overall patient experience and even the need for pain medications. We believe our work together in art, design, and technology is the future of healthcare and patient environments.

9.1 Introduction: The Virtual and Augmented Reality Fine Art Program at Montefiore Health System (by Olivia L. Davis)

For more than a decade, researchers have studied the value and promise of using virtual reality (VR) and augmented reality (AR) in healthcare. It has been found that VR and AR improve patient well-being and decrease fear and anxiety during hospital visits by taking their mind off the pain experienced during procedures and rehabilitation (Donovitch 2018). However, no studies or programs to date have explored fine art experiences to further a patient's pain management or drug reduction throughout their treatment and been able to quantify the results. Today, the Montefiore Health System is doing just that.

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The Montefiore Health System is a premier academic medical center and the University Hospital for Albert Einstein College of Medicine, New York City, USA. Combining a population health perspective that focuses on the health needs of the local Bronx community with nationally recognized clinical excellence, MHS delivers coordinated, compassionate, and science-driven care where, when, and how patients need it most. Montefiore consists of six hospitals and an extended care facility with a total of 2,059 beds, and state-of-the-art primary and specialty care provided through a network of more than 150 locations across The Bronx, Hudson Valley and Westchester counties in New York State.

Montefiore's goal is to diminish anxiety, pain and opioid addiction through stimulus-rich and curated artistic environments. Several specialties in pediatrics including cancer, sickle cell, rehabilitation, bone marrow transplant, and even simple injections often come with a varying degree of pain and other side effects. The opportunity for physicians and therapists to provide artistic VR and AR experiences could change how patients react to medicine for life.

This new concept asks artists of all media to create artwork solely in virtual and augmented reality. To do this, the Montefiore Health System finds and partners with artists, academic institutions and media labs to allow those who have never used this technology to experiment with tools such as *Tiltbrush* (www.tiltbrush.com) or provide equipment and resources to those with digital art backgrounds to create all new experiences for the benefit of healthcare.

The overall success and primary objective of this program is to prove the effectiveness of virtual and augmented reality experiences to decrease patient anxiety and opioid use as compared to other activity options for the patient. To do this, we are working with state-of-the-art equipment that can read a patient's neuro-responses i.e. thoughts to prove that VR/AR is successful in impacting patient experience during treatment and beyond.

Following our preliminary tests with patients, we have already seen results proving that VR and AR change the neuro-responses of a patient during treatment and time in the hospital towards a more calming effect. With further results, artistic technology could become a standard of excellence in all practices and for all ages at Montefiore. It will also create an ongoing library and museum of original artwork in our hospital as part of a growing collection for the Fine Art Program and Collection.

9.2 Why Fine Art?

The concept of virtual and augmented reality in medicine is not new. However, the combination of fine art with VR and AR in healthcare is. Since Summer 2017, the Fine Art Program and Collection at Montefiore Einstein has worked to build a platform that brings in fine artists to create works of art in VR and AR that can inspire patients and distract them from their pain and suffering while in the hospital. This concept stems from the restorative power that art has proven to have in healthcare environments alongside our society's constant use of new technologies.

The concept of art curators working full-time in a hospital is also not a new concept in medicine but it is a rare one. In 2006, the Cleveland Clinic established an Art Program responsible for selecting new art acquisitions and today holds over 6,500 works of art (The Cleveland Clinic 2018). In 2010, NYU Langone Medical Center, as part of their capital expansion, sought to begin a fine art department separate from interior design that specializes in finding contemporary works of art that can appreciate in value overtime. In 2014, the Montefiore Health System created the Fine Art Program and Collection, in order to build a collection that reflects the standards and values of the hospital and the local community. We remain one of only two in-house art collections in the New York City tri-state area.

What sets Montefiore apart from other hospital collections is our site-specific and humanistic approach to art collecting. We treat each department and sub-specialty individually and consider the everyday lives of the patients, family members, caregivers, and staff to ensure the art can have the most powerful impact possible. For example, when purchasing art for our Stroke Center, we spent several weeks speaking with the physicians and patients to get a better understanding of the conditions people are waiting in. Considering the mental trauma that occurs and the repairs the brain is attempting following a stroke, it is very important not to place wording or photo-realist artwork on the walls. Abstract forms are the best opportunity so that patients can allow their brains to piece together their own stories inspired but not driven by the art. Another example is a Neurological Intensive Care Unit. Patients waking up from comas should not have hard lines or be overtly figurative. They need soft lines with just enough of a hint at reality so that their minds can slowly focus on the scene. We commissioned a pastel artist to create 24 original works of art for each patient room that depict our local Hudson Valley landscape but with the softness of pastel that is welcoming yet calming to patients.

The same principles are applied to fine art and technology at Montefiore. This idea came to The Fine Art Program when looking at a project in the Pediatric Oncology wing and the individual patient rooms. Each time when considering what to place on the wall and speak to the patient, the more we saw children looking at cell phones, Ipads, and the television screen meaning that any artwork chosen would just create more noise in the space and basically serve no purpose to a patient so engrossed in today's technology. That is when the program realized that by combining a site-specific and humanistic approach with the most immersive technologies on the market, we could have a chance to positively influence pediatric patients with contemporary art and move away from the many violent and inappropriate gaming opportunities that exist today.

9.2.1 Finding an Artist for the Collection

In January 2018, a walk by Transfer Gallery on 14th Street led to seeing an exhibit called "The Flower Matrix" (Fig. 9.1). The work involved both augmented and virtual realities (Figs. 9.2 and 9.3), along with nature, two strong components to our preferred

Fig. 9.1 *The Flower Matrix* curated by Kelani Nichole and Transfer Gallery in collaboration with Wallplay, at Gallery 151 in Chelsea, 245 West 14th Street New York, NY 10011, November 30–January 28th 2017–18 (*Photography* Walter Wlodarczyk)

content in the hospital. Downstairs in the gallery there was a completely transformed space of color, objects, and a VR headset hanging in the center. One suddenly found themself lost in an 'Alice in Wonderland' like world created by artist Claudia Hart. This world resonated with the core values and goals of virtual reality fine art at Montefiore. On January 20, 2018, Curator Olivia Davis and Claudia Hart herself were introduced with the intent to discuss VR and AR opportunities for her art at the hospital.

On January 24th, Claudia visited the Moses Campus at 111 East 210th Street. After looking at both inpatient and outpatient areas in the Children's Hospital at Montefiore (CHAM), we could see several possibilities for her work to help enliven and distract patients and families at Montefiore. That is when a project was born.

9.2.2 The Project

In Summer 2019, Montefiore will open a new state-of-the-art infusion space for pediatric patients suffering from cancer and sickle cell disease. There will be 25 rooms and a large playroom to allow ambulatory patients and family members to escape the often long hours they sit receiving treatment.

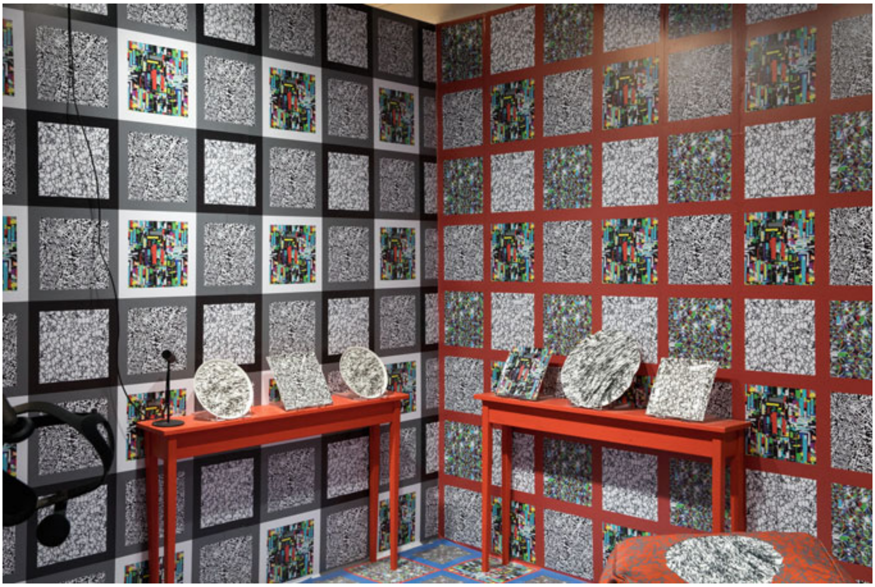

Fig. 9.2 *The Flower Matrix* curated by Kelani Nichole and Transfer Gallery in collaboration with Wallplay, at Gallery 151 in Chelsea, 245 West 14th Street New York, NY 10011, November 30–January 28th 2017–18 (*Photography* Walter Wlodarczyk)

Fig. 9.3 *The Flower Matrix* curated by Kelani Nichole and Transfer Gallery in collaboration with Wallplay, at Gallery 151 in Chelsea, 245 West 14th Street New York, NY 10011, November 30–January 28th 2017–18 (*Photography* Walter Wlodarczyk)

Fig. 9.4 Claudia Hart, *The Montefiore Playroom*, 2018, 3D visualization, courtesy of the artist

The playroom is where Claudia's art is the perfect answer to a space in need of calming and tranquil distraction while simultaneously being stimulating enough to engage children (Fig. 9.4).

9.3 From the Artist's Point of View (by Claudia Hart)

The installation that Olivia saw on 14th Street in New York was the first iteration of the a complete *Flower Matrix*, a concept that I'm only now calling a "virtual chamber for chamber music." *The Flower Matrix* slowly evolved over a period of a year, 2017, during which I produced four installations at different cultural institutions (see Figs. 9.5 and 9.6).

These four projects allowed me to beta test the concept and to personally experience how different people in different cultures experience it, tweaking variant sequentially. I think of *The Flower Matrix* as a physicalized computer interface. To build it, I combined different augmented-reality objects—meaning objects of design that are covered with graphical patterns that are actually computer codes, triggering *The Looking Glass*, my custom augmented-reality app (Fig. 9.7). *The Looking Glass* permits users to view animations embedded in these trackable decorative patterns. *The Flower Matrix* environment is a lounge specifically designed for viewing virtual realities, through the ubiquitous VR headset.

My VR world uses the same elements that users can see in the form of looping animations through *The Looking Glass*, in the AR chamber. With this construct (an AR chamber designed in relationship to specific VR environments), I have designed

Fig. 9.5 *The Flower Matrix*, curated by HyeIn Jeon, at the Nabi Center in Seoul, Jongno Jongno 26 SK 3/1/18–4/15/18 (*Photography* Art Center Nabi)

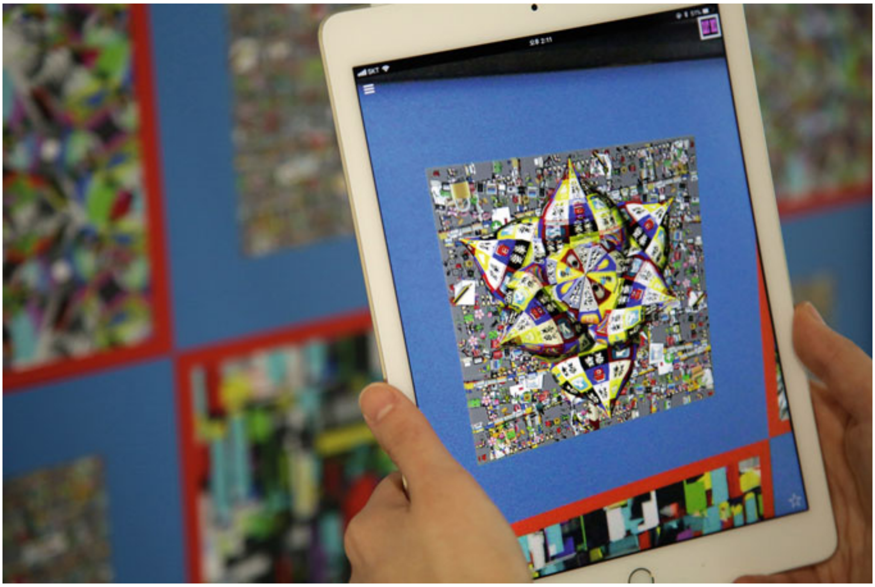

Fig. 9.6 *The Flower Matrix*, curated by HyeIn Jeon, at the Nabi Center in Seoul, Jongno Jongno 26 SK 3/1/18–4/15/18 (*Photography* Art Center Nabi)

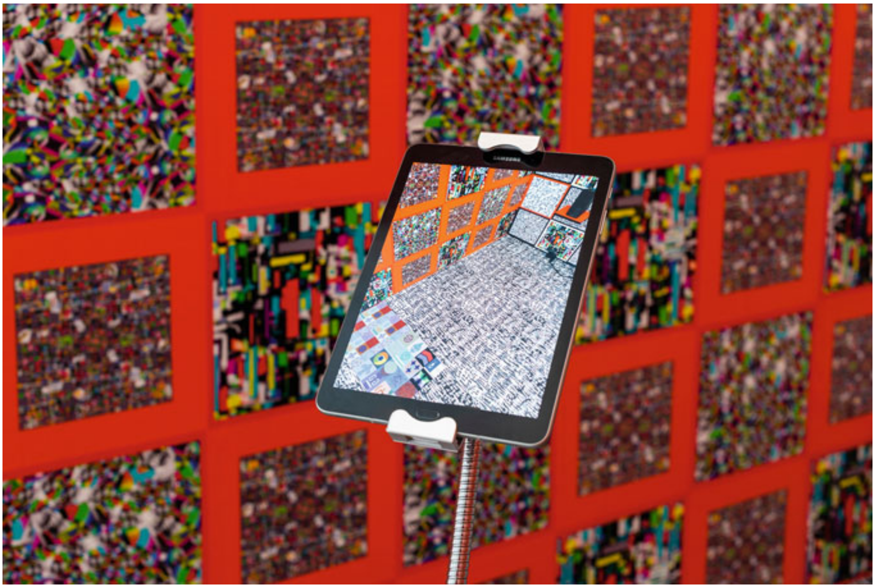

Fig. 9.7 *Out of Body*, curated by Susan Silas and Claudia Hart, bitforms gallery, 130 Allen Street in NY, October 27–December 2, 2018 (*Photography* Emile Askey)

a frame for experiencing and employing successive levels of immersion (Fig. 9.8). While my AR chamber is one kind of interface, they are meant to soften the harsh transition into the VR world through headsets, actually another kind of computer interface, albeit a very awkward one. Because a user occupies my AR chamber with their entire body, it heightens user-experience because they phenomenally experience their bodies as having entered an immaterial, artificial VR world rather than just their head and eyes.

The Flower Matrix mashes 3D animation, motion-captured live performance, and recorded music. It feeds-back the virtual and the live, blending them together in a liminal, uncanny mix. I have been inspired since the 1990s when I produced my first 3D animations by the technology theorist Donna Haraway, whose *Cyborg Manifesto* (Haraway 1985) imagined a Utopian future in which advanced bio-technologies would liberate human culture from the constraints of gender binaries. So, for *The Flower Matrix* environment, following Haraway's cyborg paradigm, I imagined blending together the physical real world and the ephemeral virtual one in an uncanny cocktail. Part of this experience is audial so acting in parallel, my collaborator, the composer Edmund Campion composed the music for live drummers who are bound to computer generated click-tracks and mixed with the disembodied sounds of an invisible improvising cellist. Both my structural, architectural strategy in relationship to my virtual worlds and Campion's music, define a new chamber-music experience. It is obliquely referential to the 19th-century salon for chamber music and the time in

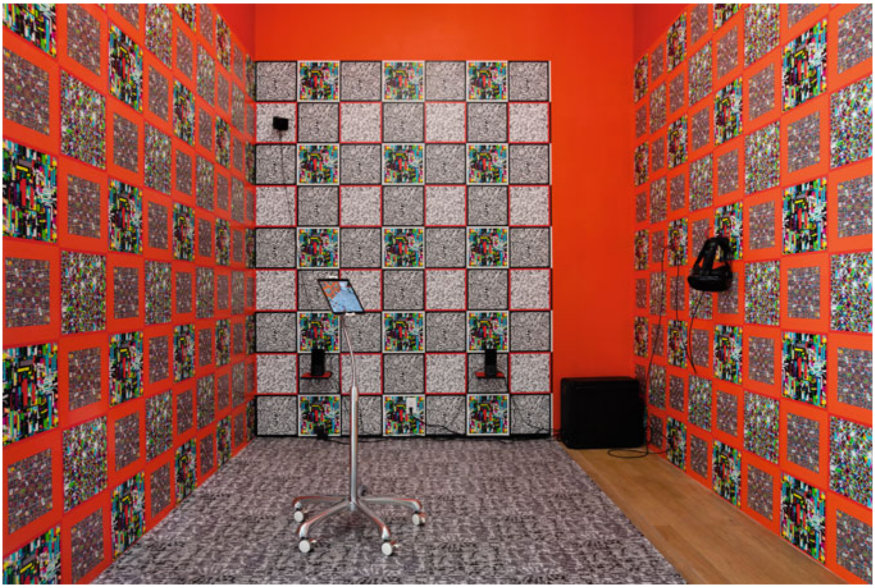

Fig. 9.8 *Out of Body*, curated by Susan Silas and Claudia Hart, bitforms gallery, 130 Allen Street in NY, October 27–December 2, 2018 (*Photography* Emile Askey)

which the original *Alice's Adventures in Wonderland* (Dodgson 1865) was written, but only now existing between the real and the digital.

Because of the virtual Chamber's uncanny sense of liminality, its effect on people is hypnotic, it induces a contemplative state. Users' experience is trance-like. When they finally don the VR headset, after spending some time exploring the AR decor with a computer tablet in hand, they seem to me, as I regularly observe, to be in a state of ecstasy. They feel good! They walk around stroking each other and the physical elements in the room, breathlessly, unsure as to whether the things they are touching are physical or ephemeral. This has something to do with the subject matter of *The Flower Matrix*, as reflected in its visual esthetic and related music. Inside *The Flower Matrix*, a mixed-reality architecture becomes fantastical (Fig. 9.9). It is embellished by decorative elements embracing an aesthetic of the fake in which technology has replaced nature: sugary sweet and chemically toxic in equal measures. It's like eating candy, but without the calories and unhealthy additives.

In *The Flower Matrix* environment, I reinterpreted the "labyrinth of the minotaur," a mythological maze from which there is no escape. As its source, an appropriated computer model taken from the free-online digital repository *3D Warehouse*, then covered graphical patterns made from an edited selection flashing emojis. These are the icons of power, money, addiction and control, symbols of casino-capitalism, creating imagery that is both seductive and oppressive. The immersive audio score plunges visitors into an intensely embodied and incessantly unfolding narrative of signs and symbols, as they navigate *The Flower Matrix*.

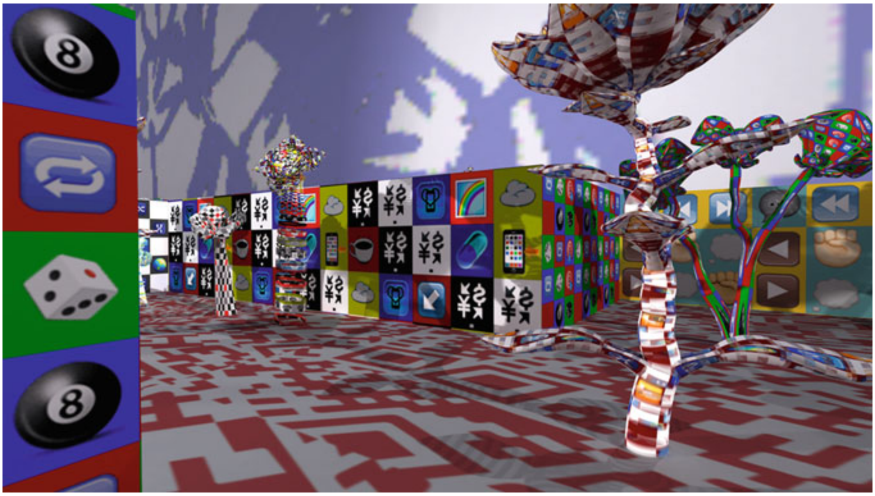

Fig. 9.9 Claudia Hart, *The Flower Matrix*, 2017, computer-generated VR environment for Oculus Rift

The Flower Matrix is, in its totality, a Haraway "cyborg," a hybrid environment using a custom augmented-reality application made for physical installation in the real world. This real-world environment is a prototype for a new kind of computer interface, taking the form of real-world architecture by means of augmented-reality embossed decorative elements designed for hyper-immersion in virtual-reality (Fig. 9.10). On a parallel platform, *The Flower Matrix* is a VR software world, created for Oculus, that pushes into the real world as hand-thrown ceramics, floor coverings, fabrics, furniture and wallpaper—decor harvested from the imaginary *Flower Matrix*. Its augmented-reality decor is coded to trigger my *Looking Glass* augmented app, which when loaded on a smart device, allows users to view animations culled from the *Flower Matrix* embedded in its surfaces. Inside *The Flower Matrix*, viewers dwell in a disorienting loop of modalities where the rational order of reason and technology has turned in on itself. It is this very feedback loop that was the theme of an exhibition curated by Elizabeth Chodos, that included my third iteration of *The Flower Matrix*, at The Miller Center For Contemporary Art, at Carnegie Mellon University. Here, my design became more optical and more artificial in its heightened pallet than previously (Fig. 9.11). The chamber was also more monumental in scale. I was more emphatic in mimicking my *Flower Matrix* virtual environment within the parameters of the real world. Viewers were delighted. My design transformations had a visible mood elevating effect on viewers.

In her exhibition statement discussed the Moravec Paradox, she (Chodos 2018) discusses a concept evolved by Carnegie Mellon University cognitive scientist, Hans Moravec. At this juncture of the narrative it is particularly relevant:

Fig. 9.10 Paradox*: The Body in the Age of AI*, curated by Elizabeth Chodos, The Miller Center for Contemporary Art, Carnegie Mellon University, Pittsburgh PA, Oct 5, 2018–Feb 3, 2019 (*Photography* Tom Little)

Fig. 9.11 *Paradox: The Body in the Age of AI*, curated by Elizabeth Chodos, The Miller Center for Contemporary Art, Carnegie Mellon University, Pittsburgh PA, Oct 5, 2018–Feb 3, 2019 (*Photography* Tom Little)

> In the late 80s, artificial intelligence and robotics scientists had promised huge developments that they then struggled to deliver. The Moravec Paradox was one the many challenges delaying progress. It showed that high-level reasoning and logic problems required only little computation, whereas basic sensorimotor skills like walking, or seeing, required enormous amounts of computational resources…Hans Moravec, theorized that this paradox could be explained by the process of human evolution. He writes, "Encoded in the large, highly evolved sensory and motor portions of the human brain is a billion years of experience about the nature of the world and how to survive in it. The deliberate process we call reasoning is, I believe, the thinnest veneer of human thought, effective only because it is supported by this much older and much more powerful, though usually unconscious, sensorimotor knowledge." This paradox reveals that there is fundamental information stored in the dialogical relationship of the mind and body; its unconscious nature belies its critical role and its levels of complexity.
>
> …Society tends to privilege reason and logic because it is conscious and quantifiable. But beneath this thin "veneer of human thought" is a deeper, more complex knowledge system within the body. As technologists imagine the potentials of merging humans with AI…Before we enter a generation where cyborgs are as ubiquitous as the internet, in a time when we still inhabit human bodies, the urgent questions to ask are what lessons can our mortal vessels teach us and what unknown paradox might we contain?

9.4 The Montefiore Playroom (by Claudia Hart)

My proposal for the *Montefiore Playroom* brings together Donna Haraway's Cyborg with cognitive scientist Hans Moravec's "Paradox" from the point of view of a maker producing exhibits for an adult audience. In the *Playroom*, my audience consists of children, but children confronted with very adult realities: the fragility and vulnerability of the body, the inevitability of death, and a daily confrontation with pain. In the *Playroom*, my goal is to lift these children out of the real world, into a liminal halfway space (Fig. 9.12), so they might float above their bodies and detach from their pain and anxiety, yet still engage actively with another world. This is the world of literature—canonical fairy tales culled from an international array. The Bronx, where Montefiore is sited, is one of the most diverse in the world, including African, Asian, and Latin Americans. The children using the playroom also suffer from a range of diseases, including cancer and Sickle Cell Anemia, typically spending 1–6 months in the hospital.

The playroom uses 5 data sets as source material, fairy tales from five different cultural traditions: African, Chinese, Latin American, Eastern European, and the fifth, *Alice Adventures in Wonderland*, the paradigm guiding my augmented and virtual reality works between 2013 and 2018, the time of this writing. The stories will all have a consistent theme, all about little girls and animals.

Each of these stories is then synopsized, broken into condensed sentences, then animated and marked by distinctive color schemes (Fig. 9.13). Five sentences and three iconic illustrations will be the means of telling tale. In total, 40 animations, eight from each of five international tales, come together in a single "healing" augmented-reality app.

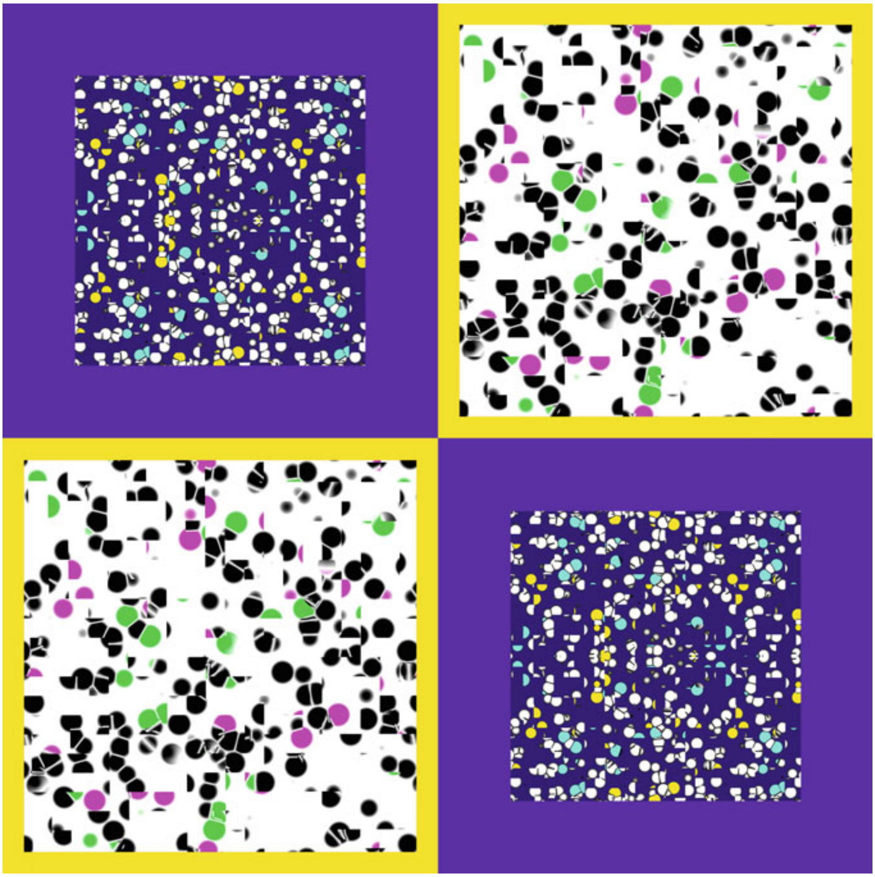

Fig. 9.12 AR trackables, viewable in *The Looking Glass App* found on generic *Laya*r applications downloadable here: https://www.layar.com/mobile-download

The *Healing App* requires forty trackable patterns triggering forty story animations. Marked by the same five colors that distinguish the five stories, these decorative patterns are the basis of the *Montefiore Playroom* design. Forty augmented patterns will surface vinyl floor coverings and the fabrics upholstering *Playroom* furniture (Fig. 9.14). The furniture will also evoke fairy tales, take the form of beanbag "pouffes," suggesting stuffed animals, in "parent," "child" and "toy" sizes (20-in., 12-in. and 6-in. upholstered cubes). These patterned pouffes scatter randomly around intimate play areas, activating children to find their own hidden patterns within (Fig. 9.15), either conjoining elements of the same hue or, like a cross-cultural puzzle, recombining them into international, meta-tales by mixing and matching.

Claudia Hart
November 17, 2018

Fig. 9.13 Claudia Hart, *The Montefiore Playroom*, 2018, 3D visualization, courtesy of the artist

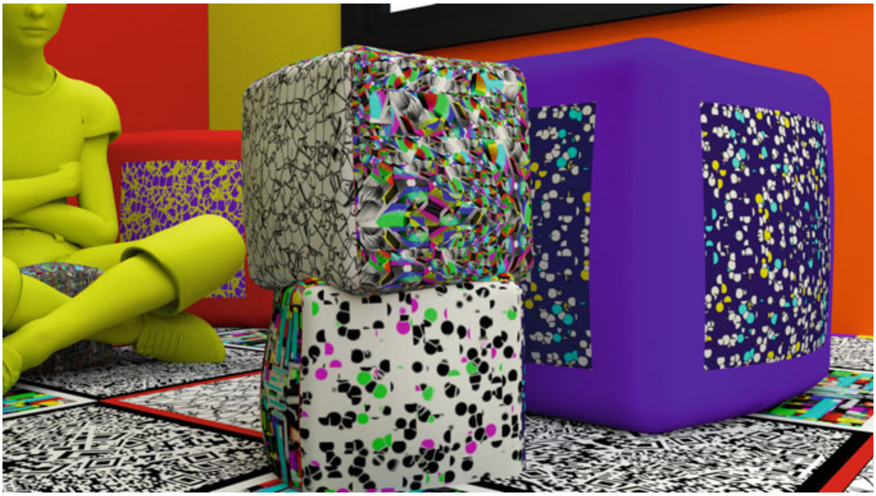

Fig. 9.14 Claudia Hart, *The Montefiore Playroom*, 2018, 3D visualization, courtesy of the artist

9.5 Concluding Curator Notes

Combining fine art, literature, storytelling, and wonder in *The Montefiore Playroom* is a turning point for healthcare. If augmented reality environments created by artists such as Claudia Hart could become the new standard of patient experience in hospitals, then we have the potential to change the way people look at medicine entirely and for the rest of their lives (Fig. 9.16).

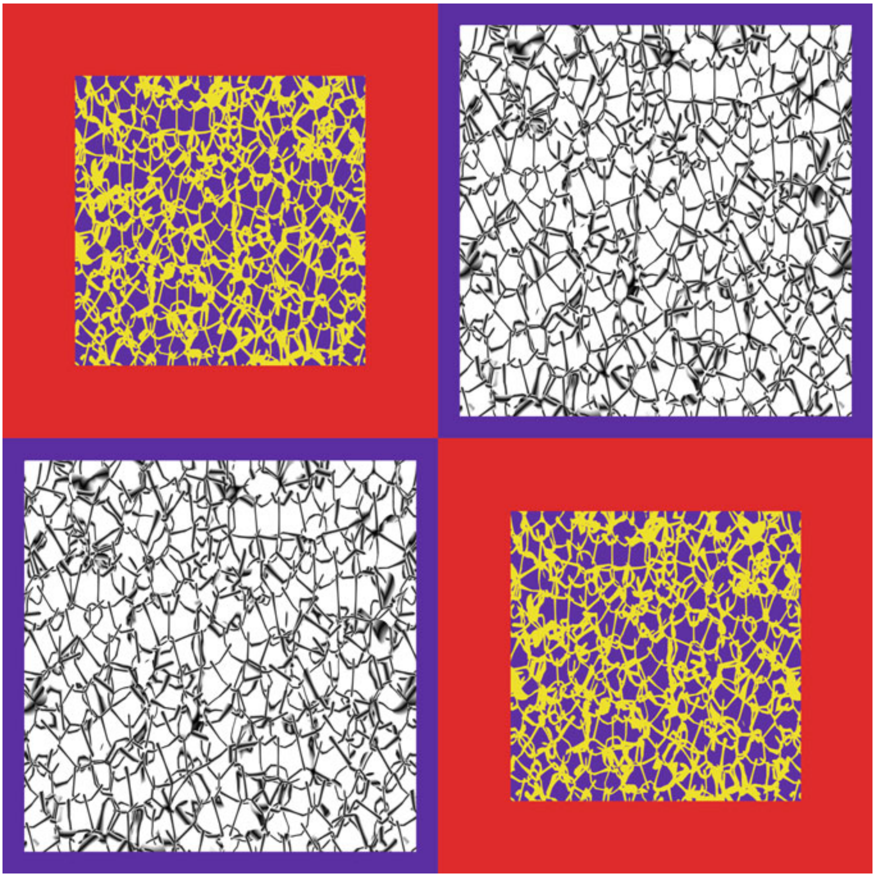

Fig. 9.15 AR trackables, viewable in *The Looking Glass App* found on generic *Laya*r applications downloadable here: https://www.layar.com/mobile-download

Right now our country is battling an ever growing opioid and heroin epidemic. Hospitals, in addition to fighting the current contagion, need to stop the next generation of users. This begins by changing how pediatric patients manage and mitigate their pain the moment they enter the hospital. Programs such as the augmented reality *Healing App*, created site-specifically for our diverse population of Bronx patients, breaks down walls and allows children to transcend the confines of the hospital and therefore their own pain. Giving pediatric patients the latest technology that unveils an entire world outside their own, renews a sense of power and courage that are stripped away the moment you enter the hospital. In *The Playroom*, you are no longer a sick patient, you are the hero or heroine of the story.

Ultimately, by working with artist Claudia Hart to create a space of wonder and safety for our patients, we embark on a new era of healing where humanism, culture,

Fig. 9.16 Claudia Hart, *The Montefiore Playroom*, 2018, 3D visualization, courtesy of the artist

and technology unite to become the new first line of defense for pain management in healthcare.

Olivia Davis
November 21, 2018

9.6 Flower Matrix Production and Author Credits

The Flower Matrix, by Claudia Hart. Music Composition: Edmund Campion
Cello Improvisations: Danielle DeGruttola
log drums: Loren Mach and Dan Kennedy
vocals: Claudia Hart and Mikey McParlane

Paper Porcelain Ceramics: hand-thrown by Kimi Kim
Porcelain *Nue Morte* dishes: Produced by SEEK-ART + mOsantimetre, Istanbul
Live performance: Kristina Isabelle and Isaias Velazquez

Motion-capture and sponsoring: Game On, Montreal
Post processing and sponsoring: Hectic with Compiègne University of Technology, Paris
Unity Programming: Andrew Ajamian, Andrew Blanton and Jonatan Martinez

The Flower Matrix was commissioned by TRANSFER and presented by Wallplay.

It received additional support from The Center for New Music and Audio Technology, UC Berkeley and New York State Council on the Arts in Partnership with Wave Farm Media Arts Assistance Fund (MAAF).

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Part III
Augmented Reality Games in Art

Chapter 10
The Gamification of Augmented Reality Art

Patrick Lichty

Abstract Augmented Reality (AR) and its applications are being used in many applications, including gaming, education, industry, research, and art. Gamification refers to the merging of games with interactive media (video games, Virtual and Augmented Realities, for example) to allow for the completion of difficult digital labour of research in a more fun, intuitive fashion. In this chapter, the merging of gamification and Augmented Reality-based art is discussed, its impact in terms of digital labour as well as examples of Augmented Reality that exhibit gamification or elements of it. Speculative design fictions of gamified Augmented Reality are examined to determine possible future outcomes of this genre. Lastly historical experiments in user interface design are mentioned to propose future solutions for Augmented Reality applications, artistic installations and gamification scenarios.

10.1 Introduction

As the genres of Augmented Reality expand, they will eventually proliferate to serve any number of cultural functions, including that of *gamification*. One of these is to place Augmented Reality-based art into the service of performing certain serious and purposeful tasks, such as the solution of complex visual/spatial problems, sorting, etc. while interacting with an Augmented Reality/Mixed Reality artwork. Gamification comes from this impetus in the form of taking a task/problem and subjecting methods of solutions to game-based constraints. There are a number of screen-based examples of gamified problems like the protein folding game, *Foldit*. Darf Designs' *Hermaton* architectural installation also hints at task-based artistic Augmented Reality through its specific formal qualities of being a task-based game. Conversely, games like *Pokemon GO* integrate task completion in terms of gaining experience to ascend game levels, much like RPGs like *Warcraft* and *GO*'s predecessor, *Ingress*. But why are there not more applications/artworks that address the notion of gamification in the realm of Augmented Reality? In this chapter, the cultural effects that lead into

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the practices of gamification, such as STEM (Science, Technology, Engineering and Math) and STEM to STEAM (Science, Technology, Engineering, *Art*, and Math) curriculum, screen-based gamification will be examined, as well as the notions of digital labour and how it may be placed to the service of performing certain tasks, like education, problem solving, etc.

One of the key issues when thinking about gamification in its application to Augmented Reality Art, is that there simply is not a great deal of it to date, or at least not as much as other genres, such as screen-based games and gamified Virtual Reality. This essay, while seeking models that could qualify as part of the conversation, will also point toward future models where gamification could be applied. There are instances in which one can argue for task-based interaction in Augmented Reality Art (Darf Designs *Hermaton*) or certain sorts of labour (*Pokémon GO).* But few Augmented Reality art-based applications have instances in which tasks are "usefully" being put in services of finding solutions to a given problem defined by the game/art/experience. Most are in service to a metaphor, interact as spatial installation (as in *Fantastic Contraption* in Virtual Reality), but rarely are the interactions being placed in a role that is accomplishing a given set of labour that is outside the interaction with the work. For this study, works will be selected that fit general models of gamification and then that study shall expand on the possible instrumentalization of the tasks involved.

10.2 Considering Gamification

The core notion behind the rise of Gamification as a cultural trope comes from models of user engagement to make subjects more pleasant that are not considered pleasurable or accessible and ascribe labour to experiences that generate some sort of practical use value. To understand some of the thought behind gamification and its application to Augmented Reality Art, one must create a context for our subject, where it comes from, and frame the artwork that falls in this category. While there are multiple strategies to discuss, the idea is that there is a common thread; the invitation to engage with subjects considered difficult or mundane as a form of play, as well as where these impulses come from. It is important considering initiatives behind gamification that many of these come from U.S. educational initiatives or ideas related to increasing productivity in technology-based businesses.

For example, a strategy related to gamification is STEM, then STEM to STEAM, a set of imperatives developed by a 2006 declaration by the U.S. National Academies, and then formalized by the America Competes Act of 2007 sought to improve underperforming U.S. standards in Science, Technology, Engineering and Math. Over the first two to three years, STEM programs did little to improve flagging scores, so in 2009 the Next Generation Science Standards (NGSS) were created. The problem is, as with many U.S.-based educational initiatives, these programs have been poorly funded, with the assumption that initiatives alone would result in solutions to the problem. But as Sousa and Pilecki suggest (Sousa and Pilecki 2018), the introduction of arts-based components into the STEM programs provide inspirational methods that give context, application, and meaning to learning science and technology. In this case, STEAM attempts to place the arts in the litany of buzzwords like innovation and creativity, and place art as an incentivizer, as play does in gamification.

Even though a deep discussion of STEAM may seem peripheral to the notion of gamification of art in Augmented Reality, doing so reveals much about the cultural scaffold that evinces the phenomenology of these regimes of thought. For instance, another aspect of the STEM to STEAM impulse (the "A" denoting Art) is the preservation of arts and humanities-based curricula in an increasingly instrumentalized educational system in the United States. While STEAM as such is considered a incentivization strategy in terms of education, gamification is used in a number of modalities, including problem solving and data processing as well as education. Part of gamification's usefulness is the creation of media which is "sticky" or invites repeat usage.

The notion of media's "stickiness" or its habit-forming (habitual) qualities is essential to gamified media. In *Hooked, How to Build Habit-Forming Products*, Nir Eyal describes the mechanics behind the creation of addictive media. Eyal and Shiv discuss what they call the "Hook" model (Eyal 2014), that incorporates four elements: Trigger, Action, Variable Reward, and Investment. Where this model differs from a basic feedback loop is in the last two elements. A variable reward creates intrigue; in the case of gamified environments like the *Foldit* protein folding game, the task is always different and novel as the problem gets solved. This leads to the next step of investment, where the system is improved or develops based on the actions of the last action or user. This creates a sense of progressive reward as the process continues. The case of gamified task, the user gets an idea that meaningful work is being produced. Perhaps in models of gamified Augmented Reality Art there would be evidence of progress with the work regarding persistence in construction, evidence of communal contribution in public spaces (as in *Membit*) and so on. This is different from Augmented Reality experiences like *Pokemon GO, JC GO*, or *Niantic* in which only the player develops and the environment stays the same unless there is a global "Season" change. Non-game online environments like *Second Life* used the stickiness of user investiture to enhance its user experience by centering that environment on user-generated content, and the "seasonal" nature of games like *Fortnite* (and the sandbox nature of its Creative mode) bring a fresh take on the MMO. However, gamification strategies have also been used to critique these methods, with Ian Bogost's *Cowclicker* being a prime example.

10.3 Stickiness and Critique: *Cowclicker*

Ian Bogost's *Cowclicker* (Tanz 2011) was a critical game commenting on Facebook games like Zynga's *FarmVille*, but could also be construed to be a criticism of gamification as a whole in terms of monetization and habituation. In it, players clicked on a sprite of a cow every six hours. That's it. The game allowed certain actions, where players could let friends' cows onto their pastures, collecting extra "mooney" for each click (Fig. 10.1). Bogost created Cowclicker for a presentation on social gaming in 2010, using it as a deconstruction of social gaming, monetization of "freemium" games, poorly designed educational games, and gamification. The fact that it went viral, reaching nearly 50,000 users at one point reveals the relevance of Bogost's critique. *Cowclicker* was developed and continued until its end in 2011 one year later with the Cowpocalypse (Burgess 2018). This led an anticlimactic game to an anticlimactic end. When answering one user in that the game itself wasn't very fun, Bogost replied that "The game wasn't that fun in the first place." (Leigh 2013). His reflection that monetization and social gaming being built into the Facebook infrastructure suggests intrinsic abuses of these genres through stickiness and monetization, and suggests potential abuses of gamified AR, as seen in Matsuda's *Hyper-Reality* video explored later in this text. However, one application of gamification in desktop gaming that revealed gamification's positive potential, and this is the protein folding game, *Foldit.*

Foldit (Ponti et al. 2015) is an online game created by the University of Washington Center for Game Science, in collaboration with the University of Washington Department of Biochemistry to solve certain protein folding solutions in regard to biochemical problems. Created in 2011, *Foldit* is a multiplayer online game in which players know little or nothing about the actual biochemistry except for the rules of docking molecules and thus creating "recipes" which are shared with other players. In the first year, over 5000 recipes were created, and according to Scientific American in September 2011, users solved critical issues in enzyme production in enzyme sequencing in the replication of HIV viruses within three weeks (Coren 2011).

The strategies employed by *Foldit* use the human brain's 3D-processing capability, and tie this to communal strategies of problem solving through online social space and represents a highly effective solution for solving these spatial problems. Research by the *Foldit* team suggests that the crowdsourcing of gamification evidenced itself as one of the most effective strategies for solving this genre of problems, and is more efficient than brute computation. What is important about *Foldit* to this writer is the application of this environment to basic research, as opposed to the direct extraction of use value for financial profit, in the case of the pay-to-win games critiqued by Bogost. This brings our discussion to the notion of labour, non-labour, and playbour in terms of digital media, the model of labour and extraction of use value would translate into gamified AR Art.

10.4 Labour, Non-labour, and Playbour

As gamification ostensibly deals with task completion as part of game play, the mention of the task brings into question the involvement of labour, and with that labour, the conferral of use-value (Gebrauchswert). The engagement with this subject opens a discursive space which is a continuum in game-play of vectoralist labour, non-labour, and "playbour". This requires a reflection on the notion of games, play,

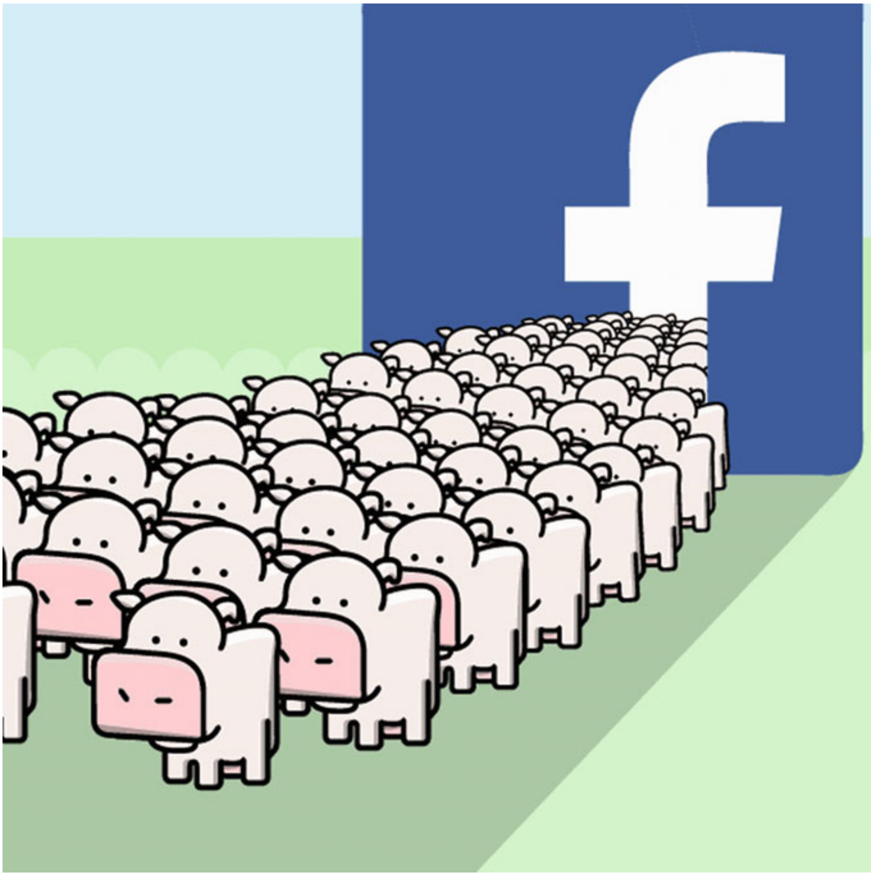

Fig. 10.1 *Cowclicker* (2011), *Courtesy* Ian Bogost

labour, use value and their relationship to gamification and digital interaction, as well as extraction of value from digital media.

A good method of determining this relationship is to draw an epistemic arc from game to labour in relation to gamification. Definitions of what constitutes a game vary from Wittgenstein to Salen, all of whom define various models/families of rules, interactions, and/or conflict. However, one of the simplest definitions of a game is by Kevin Maroney, who stated a game is “a form of play with goals and structure” (Maroney 2005). Conversely, play, as defined by the Oxford English Dictionary, is to “engage in activity for enjoyment and recreation rather than a serious or practical purpose” (OED Online 2018).

Considering practicality in distinguishing gamified tasks versus games proper, which the OED connotes as connoting frivolity is also key in the notion of gamification. The mention of ‘seriousness’ as in opposition to the notion of gaming calls into question notions such as ‘applied gaming’. This genre, coined as “Serious Gaming” by Clark Abt in 1970 in his book, Serious Games (Abt 1970) and popularized by Ben Sawyer by the Serious Games Initiative in the mid-2000s (Sawyer 2007), proposes alternative problem solving through the competitive, associative, and ludic strategies of gaming. Educator James Paul Gee also championed gaming, especially computer games, as instrument of literacy. Gee reminisces that one of his first experiences with gaming in long sessions with the game *Time Machine*, resulted in, "confronting what was, for me, a new form of learning and thinking was both frustrating and life enhancing." (Gee 2003, 118). What Gee was doing in the early 2000s was some of the early (not only) popular articulations of the use of computer gaming for the engagement of difficult mental labor, such as learning.

Gee's articulation of novel forms of learning and thinking as applied to the solution of complex problems is a precursor of Sawyer's notions of Serious Gaming. The center of the difference between Gee and Sawyer is that of interactive design, or the direction of the rhetorical vector; where Gee is learning from his new discovered environment, Sawyer is intentional in terms of proposing games that are intended as tasks for the explicit solution of problems. Learning from solving *Myst* or *Oblivion* is fundamentally different from making the folding of proteins in DNA segments, although either could constitute a challenging, enjoyable task. While one creates a space where the individual learns, adapts to, and completes difficult tasks in finishing a difficult game, gamified tasks have specific outcomes which are used for the solutions which they were designed for. The user may learn and execute difficult problems, but the important difference is that with gamification, the outcomes are *applied.*

Hence, the application of gamification, or its instrumentalization of play to the performance of intellectual tasks shifts the gamified space from that of pure entertainment to enjoyable "useful" task. Returning to our previous definition, the gamified task adopting the role of "practical" play leads us to the question of the use-value of the solution of that task and the value assigned to the labour to complete that task. This leads to a discussion of vectoral labour, and the notion of "playbour" coined by Julian Kücklich in 2005 in his article *Precarious Playbour* echoed in Wark's thought on labour in the digital age. To consider this is to look at how degrees of labour could be valued in games such as *Pokémon GO*.

In the *Hacker Manifesto* (Wark 2004), Wark proposes the addition of an expanded model of digital capital and class dynamics. This includes the addition of two classes, the Hackers and the Vectoralists, and their respective systems of capital. In Wark's model, these new classes exist in opposition in their relation to intellectual capital. The Hacker class is the epitome of Stewart Brand's motto, "Information Wants to be Free" (Levy 2014). The Hacker is the generator of free intellectual property, music, code, *art*, data, knowledge. A key point to understanding the Hacker Class' relationship to intellectual property is "We do not own what we produce - it owns us." This notion of ownership places the Hackers in the position of endless Long Tail (Anderson 2004) abundance and free value, not scarcity.

Conversely, in contrast to the Hacker model of digital abundance are the Vectoral Class, or the corporatists whose goal is the extraction of value from intellectual property. Conventional examples of vectoralism are content providers like Netflix, Amazon, Hulu, as well as major dotcoms that extract value from the means of informatic production. For the sake of this discussion, it might not be useful to include social media, from Facebook to YouTube, WhatsApp, etc., as they intersect on this essay's discussion of playbour, but do not address the specific modalities, and thus a distinction is intended. This is where a jump from Serious Gaming and game-based learning paradigms to digital Marxism when considering the gamification of Augmented Reality, Augmented Reality Art, and even games such as *Pokémon GO* are not such abstract leaps. To consider the differences between these concepts is linked to labour, use value, and an interpretation of Kuchlich's "playbour", especially in terms of deriving value from interactions with augmented content, art, or gaming. In *Precarious playbour: Modders and the digital games industry* (Kucklich 2005), Kuchlich initially framed the term to talk about certain practices in game culture, like modding. Modding is the practice of taking pre-existent content, as with games like *Skyrim*, and changing designs/substituting content to change the experience of the game. Famous examples are *Doom* and *Quake*, but others include *Skyrim*, where users substituted the model of the ancient dragon, Alduin, World-Eater, Bane of Kings, for a model of Thomas the Tank Engine in the game mod, *Really Useful Dragons* (Lambo_96 2013). So, at the point in Skyrim where the player is about to be beheaded, and the great dragon is about to appear, the "toot" of the engine is heard in the distance. Thomas appears, breathing fire, and laying waste to the village.

Kucklich's point that this would be writ large through social media culture is that of the fans doing unpaid work for the company by developing the game further for their own enjoyment, amounting to playbour. This also happens with other fan cultures, as in the case of science fiction programmes like *Star Wars* and *Star Trek* through the generation of fan media. What results from the fans is an enhancement of the intellectual property through a sort of hacker-class labour, which creates a vectoral use value.

The next step in the understanding of playbour is that of social media, and especially platforms such as Facebook and YouTube, where user media generation is a direct example of vectoral labor creating use-value for the platform, and is extracted through advertisement revenue or pay services. Keep in mind that the model for playbour discussed here is related to the extraction of value from user content and user interaction, which may differ slightly from others'. The connection between *Foldit* and Bogost's critiques of vectoralist social games like *FarmVille* (which offer in-game purchases that allow for a much greater ease of advancement) relate to the notion of extraction of capital.

The concern here is the ability to extract capital, whether financial, intellectual, or other from a gamified interaction, and whether this is a beneficial transaction to the designer and the user. In Augmented Reality environments like *Membit*, user engagement qualitatively adds value through the collective aggregation of memory through the insertions of photo-based augments in public space. But as of this writing, no extraction of value through ads or the like are evident. In social media, such as the case of Facebook, scandals like the Cambridge Analytica case (Confessore 2018) make clear that the relationship between Facebook and the user is currently akin to a sort of Stockholm Syndrome, where the user becomes so dependent upon the use of the platform, that abuses in value extraction are met with little recourse.

Fortunately, there are few or no Augmented Reality apps, art, games, or otherwise that create this sort of relation, but Google Glass, with its potentially "always on" gaze created a possibility for surveillance-as-playbour situations with Google. The issue is whether there is an ability to extract vectoral capital from a gamified task in augmented public space. Although personal spatial (augmented) computing such as the Hololens and Magic Leap are still relatively new, Keiichi Matsuda's *Hyper-Reality* shows a model in which living in augmented space could result in ubiquitous extraction of labour from any form of attention. Before discussing this example, let there be a comparison between the notions of interactions and tasks.

10.5 Interaction and Task

Gamification implies the performance of an interaction with the media that generates a useful outcome or task. A detailed exploration relating to User Experience Design pertaining to task flows, types of tasks and decompositions are beyond the more qualitative nature of this discussion. In our case, the gamification of art, Augmented Reality or not, returns to the OED definition of play as having no purpose, and as art and games frequently have the quality of not being instrumentalized, and gamification places the gamified artwork at the service of a *purpose*. For now, the definition of a given interaction set to a task will be considered as a product of labour. The question is, in the case of gamification, what is the use-value of the labour?

10.6 Tasks and Labour in Augmented Reality Games/Art, from Screen to Space

Gaming certainly has genres based around fictional labour; Blizzard's *World of Warcraft* has levelling that players "grind" through, consisting of killing ten Razorbacks (or whatever monster, for that matter) to get a certain amount of experience points. This is straightforward labor with a given use value which converts into exchange value in the form of experience points. When this is translated into AR-based art, whether gamified in terms of education, monetization, or knowledge production (among others) brings into question what models can be used for progressive social models of gamification in augmented space. For this discussion, we will consider some Augmented and Mixed Reality experiences (a mix of game, art, and design) as possible examples, then look at two near-future fictions that take critical stances towards gamification of augmented space.

Pappenheimer, et al.'s *skywrite* (Pappenheimer 2012) employs a collective experience of skywriting in Augmented Reality for the potential signalling of desire for

Fig. 10.2 *Skywrite* (2011), Pappenheimer, et al. *Courtesy* the artist

political change. Users using the app write their desires in the sky (Fig. 10.2), ostensibly to communicate them to others. But what other uses could it have? For example, in the case of natural disasters such as the massive fires in California, could this technology be used to mark areas under that part of a sky? Or, drawing a more direct line to gamification, could image recognition be used along with the *skywrite* technology to crowdsource meteorological research, or verify the accuracy of weather prediction? Suggesting the instrumentalization of an activist app not the intention of Pappenheimer and company, but on the other hand, using the produced data could have positive social benefit as just mentioned.

Membit, a photo-based geolocative public app created by Jay Van Buren et al. (Hills-Duty 2017) allows users to place photos of moments at certain places and spatial orientations, or the placement of an image in space. The user goes to a place on the Membit map, takes a shot, and the app records the image, place, and also orientation of the image. To recall the image, the user accesses a channel or searches the area for media, and then reorients to the image in space to the point that it reconstitutes. This is a fairly unique use of Augmented Reality in that it largely creates asynchronous experiential windows into the past of the site. For the AWE

2016 conference, Van Buren placed banners depicting Augmented Reality pioneers in the Santa Clara Convention Center, suggesting illustrative uses for the platform.

Taking this spatial/photographic form of Augmented Reality into consideration, gamified Augmented Reality art utilizing this schema could include education, wayfinding, or possibly even landscape notation. For example, Van Buren's initial example of documenting memory resembles a scavenger hunt, suitable for historical documentation, with the potential for basic scoring, competition, or research-based collaboration. This documentation could record longitudinal studies of change over time in a landscape, which could be useful in times of climate change, in cases like sea encroachment on coastines due to climate change. In some ways, this software's application could reflect that of *skywrite* in sharing relevant information about the landscape. However, *Membit's* application to models of stickiness like Eyal and Shiv's concepts of variable reward and investiture seem less clear, with variable reward being the most difficult to resolve, as the problems may be generated by user-created contexts. The next example of spatial Augmented Reality that could adapt to gamification is a spatially-oriented puzzle, Darf Designs' *Hermaton.*

Hermaton, a "buzz-wire maze" 2013 game from London-based Darf Designs (Lichty 2014), creates a gaming environment that is designed to fit inside the built environment. Hermaton is located by large-scale printouts in the room being used as augment targets for a large, multi-faceted machine that players have to activate (Fig. 10.3). Players of *Hermaton* move a digital ball through a maze, activating parts of the machine that are part of the installation. Parts are machinic, with intricate mechanisms in the modules to others that are more about the movement of the ball. *Hermaton*, as seen at the Augmented World Expo 2013, was an example of an excellent architectural visualization with a game component, but still limited itself to that of the game format and did not extract any performance metrics.

If turned into a gamified model, *Hermaton* could be instrumentalized in several ways. One is a form of physical therapy, where movement of the ball is done to accompany movements, and progress could be quantified longitudinally through multiple trials. A user could be seen as perhaps moving the ball though the space slower at first, then measure cognitive function as they learned the space, or require the user to reach high or low. Another could be a training aid, where the Augmented Reality conceit can be an orientation device, helping the user learn some spatial task, such as dis/assembly, which is one of the first applications of instrumentalized Augmented Reality. The use of Augmented Reality linked to a device in the hand and pushing the need to move the device in ways that challenge the body or the conception of interaction could be a key aspect of gamification. One other spatial puzzle/device game that hints at gamification strategies is *Fantastic Contraption*. Although *Contraption* is originally produced as a Virtual Reality game, it could be deployed as an Augmented Reality title in platforms like the Magic Leap headset.

Fantastic Contraption (Allain 2017) is a room-scale physics-based Virtual Reality game in which players use various materials to create machines that overcome certain obstacles (Fig. 10.4). This could range from navigating a room to moving a pink ball to a wall. To accomplish these tasks, the player has only a few materials: a cylindrical motor, a wooden beam, and a balloon beam. From these objects, one can make robots,

Fig. 10.3 *Hermaton* (2015). *Courtesy* Darf Design

Fig. 10.4 *Fantastic Contraption* (Mixed Reality), *Courtesy* Northway Games

vehicles, even trebuchets (for the ball). Like other physics- based games (like *World of Goo*), the solutions can vary, but all have a fairly well-defined range of solutions based on the physical properties of the constituent parts. Motors turn, but can reverse when placed in an opposite orientation, wooden beams give hard machinic linkages, and balloons stretch, cushion, and can even be popped. YouTube documentation has even shown *Fantastic Contraption* as a Mixed Reality experience (Romaine 2018), giving this author the notion of considering it as applicable as a gamified Augmented Reality STEM educational experience.

The educational/STEM possibilities of *Fantastic Contraption* are clear when placed in an Augmented Reality context, as it deals with creating physical solutions for machinic problems. Manipulating machines in physical Augmented Reality contexts makes sense, but where the environment is defined in the case of Virtual Reality, the actual context of the surrounding environment must be taken into consideration. Several options as to how to contextualize the task are evident, with two main decisions having to do with using the physical environment as a context for the solution, or merely using an open space. In the latter case, the game can work as in the Virtual Reality version, but when taking the physical environment into consideration the situation becomes more complicated, when considering gamified STEM education. For example, does the exercise limit itself to certain structural constraints ("Find a wall and a clear area of floor"), or will it place itself into a dynamic context with the surrounding environment and define problems on the fly using the parameters of motion, height, etc.? Secondly, how would metrics (score) be determined in such a case; would points be assigned for speed, height/number of obstacles, number of elements, etc.? This use of context-driven Augmented Reality for the solution of gamified physics problems would present infinite challenges but would also present difficulties in ascertaining metrics.

Expanding on the physical construction notion, Mel Chin's *Unmoored* (Selvin 2018) has little to do with gamification per se in an overt sense, but points at elements of it. In this piece, onlookers use a Microsoft Hololens to observe a Times Square transformed by climate change. Boats sail and bump around one another in a flooded Square. Created in partnership with UNC Asheville's STEAM Studio students, Chin created this work, and *Wake*, a large-scale animatronic sculpture of singer Jenny Lind and a 20-m ship hull situated at Broadway Plaza (Fig. 10.5). While not indicative of gamification in themselves, the piece's situation in this context suggests gestures towards education, simulation, and construction. The use of spatial computing in large public areas like Times Square and Broadway Plaza prove the viability of public augmented computing. It also shows the potential for gamified interaction with the larger constructed human environment. While this is a speculative scenario, the potential for smart city paradigms/Big Data combined with crowdsourced interpretation of this data could spell a symbiotic human/AI relationship in urban spaces, and this could be a place for a larger conversation. On the smaller end, *LEGO Augmented Reality Studio* offers direct potential for application in this study.

Lego AR Studio (Kobie 2017) presents a direct but unrealized opportunity for gamified learning in Augmented Reality paired with the proper conceptual frame, this application is a logical progression from *Fantastic Contraption*. The ARKit-based

Fig. 10.5 *Wake+Unmoored*, (2018) *Courtesy* Mel Chin

app allows for scenarios to play around various constructions. However, *LEGO AR Studio* (Fig. 10.6) consists only of simulated blocks and narratives surrounding them. For example, users can play with pirate ship, a hospital, a robot, a man on a dragon, a police station, a truck and a train. Different combinations cause various behaviours, such as moving the dragon overhead causing people underneath to move around. If this app were tied to construction and AI, to track blocks and act as a play partner of sorts using automated strategies of LEGO construction (Kozaki et al. 2016), the app would be far more interesting, and block tracking metrics could offer insights in cognitive science and spatial construction for LEGO building.

Given the theoretical considerations and examples which point towards a gamified AR/Art, apps like LEGO AR are glorified advertisements for the plastic bricks. However, there are short films which clearly indicate an Augmented future, and the argumentative stretch here is for that of gamified Augmented Reality Art is in the form of science-fiction based speculative design stories. Two short films, *Hyper-Reality* and *Sight* offer dystopian insights into the future of ubiquitous AR, with gamification being central to living under this particular ontology. As with many dystopian Sci-Fi near future stories, technology is seen as the threat to individual freedom.

Fig. 10.6 *Lego AR Studio*, *Courtesy* Lego

10.7 Synthesis: Sight and Hyper-Reality

Keiichi Matsuda's 2016 short, *Hyper-Reality* (Matsuda, 2016) depicts the logical extreme of gamification of Augmented Reality in a video artwork. It depicts the journey of a hapless Medellin, Colombia teacher turned courier, Juliana Ostrepo, and a day in her life. As we enter the first scene, she is on a bus playing a cat-themed matching game, earning "Loyalty points" (the currency in this scenario), when she is called by her AI-based boss, the Job Monkey Motivation Guru (Fig. 10.7). She plaintively asks that as she is trained as a teacher, isn't there a better job than being a shopper? He informs her to trust the app, it always gives the best jobs. She swipes him out of sight in frustration, then considers wiping her online account in disgust before deciding that she would lose all her loyalty points in doing so.

As Juliana's day progresses, it shows more social commentary on the future- Augmented Reality scenario. She is harassed by a hacker, where she turns to the grocery store's AI service department for help. They restart her device, briefly revealing the bleak fiducial marker reality that Medellin has become, and her headset restarts. However, her AI helpers show her a blue line that leads to a biometric identification center. As an aside, at this level of sophistication, her device not having iris scanning is a plot hole… She follows the blue line into the street, only to find that it's all been a hack. She is confronted by an attacker who is cloaked in augments and stabs her in

Fig. 10.7 *Hyper-Reality*, by Keiichi Matsuda. *Courtesy* the artist

the hand. Apparently, this allows the hacker to steal her biometric information, and her device is wiped clean. Despondent, she looks around as her now defaulted device restarts, and she sees a shrine to the Virgin of Guadalupe, asking her to make the sign of the Cross and become Catholic. She does, and her life begins anew, with the irony being that the Catholic app is run by Bully Entertainment, the same one that ran all her apps before the attack. Such a commentary hints at the ubiquity of corporate interests in online space and evolutions of their algorithms in their manipulation of users' desires and even lives. Jaron Lanier points this out in his 2018 interviews and articles on how corporate algorithms are evolving and shaping our desires in real time (Kulwin 2018). Would the gamification of public glasses-based Augmented Reality result in the commodification of our conscious time, as Facebook and Instagram do for so many, as Matsuda seems to suggest?

Arguably the most direct media-based depiction of gamified Augmented Reality as everyday life is the short film *Sight* (May-raz and Lazo 2015) by Eran May-raz and Daniel Lazo. *Sight* depicts a day in the life of Augmented Reality developer Patrick.s, a systems-level programmer at Sight Systems, a fictional company that has created Augmented Reality audiovisual contact lenses. As *Sight* begins, Patrick is playing a more Virtual Reality-like flying game in an almost empty room, leaving an important point as to whether our future display devices will be Augmented Reality, Virtual Reality, Mixed Reality, or merely changing based on the context on whether one's eyes are closed. Secondly, the idea that decor and all but basic living structures will be depicted question whether a Sight-like augmented experience could result in decreased consumption of consumer goods, optimization of food use, etc. as we will see. Patrick's day continues, more interestingly when he prepares his lunch using an app called *ChefMaster*, which encourages the player to optimize cucumber

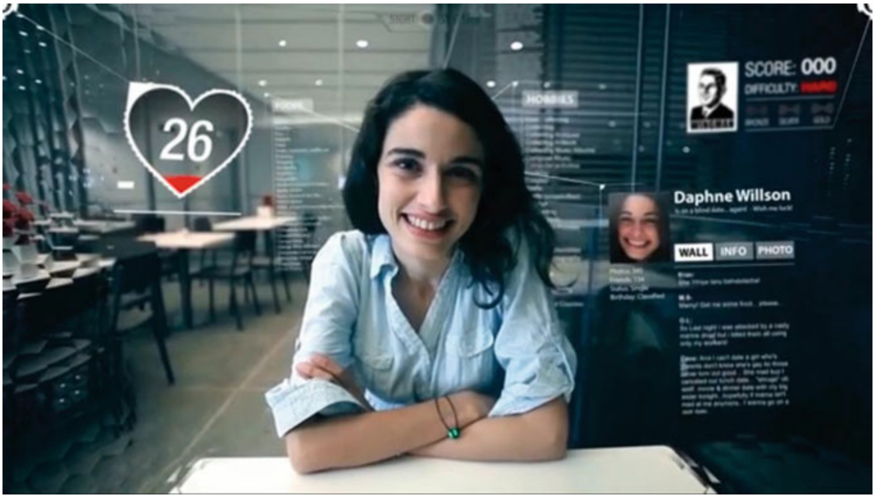

Fig. 10.8 Sight (2015), *Courtesy* Robot Genius Films

slicing and fry an egg based on gamified models. When he mis-slices a cucumber, he sweeps away the vegetable, to "restart the level"; showing that the program suggests wasting the cucumber rather than taking a point deficit. What would a gamified life like that which Sight provides be like; would it create positive social effects like decreased material consumption, or also rote adherence to the normative models of gamification? Would you be a better chef, or just a really good cucumber slicer/egg frier?

The dystopic notes in *Sight's* vision of Augmented Reality gamification increases as he prepares for his date with Daphne (Fig. 10.8). His helper app, called *Wingman*, helps him dress for the occasion, and then using AI, context and voice recognition, does everything from suggests conversational subjects, food choices, and relational timing. When Patrick finally gets Daphne home, they sit and toast what Patrick calls "a perfect night", as Daphne notes his augmented decor. This is when she notices his game board, and more importantly, his score marker for the *Wingman* dating app. Realizing she has been merely a pawn in a sociopathic dating theatre, she gets up furiously, and turns to leave; Patrick, However, has other plans. Daphne's concerns about Sight Systems actually creating mind altering implants proves true, as Patrick commands "WAIT!" and she stops mid-stride, as command-line interfaces pop up in Patrick's display, implying that he has just hacked Daphne at the root (deepest) level. This is also similar to the *Black Mirror* episode, "Playtest" (Seara 2016) in which the protagonist of the episode is also controlled by a neural/Augmented Reality interface. The tired trope of media of technology's control of the individual is un-needed in this film as *Sight* shows a number of harbingers of near future scenarios.

In the case of ubiquitous gamified AR, what would the ultimate outcome result in as far as a user experience is concerned, and how would this translate to art, or even design? In the case of Matsuda, corporate driven AI agents might seek to extract every second of attention, day or night, being a not-so-subtle metaphor for social media. This might be done by gamifying *everything* at subtly layered means, from amusing ourselves with tasks when not engaged with a pressing task, to trying to suggest purchasing/patronage choices when involved in "useful" work, and by translating physical jobs to fungible game points. In the universe of *Sight*, every task and aspect of lie is quantified and gamified, from monitoring the contents of one's refrigerator to using predictive AI to seduce prospective mates. Although for some an environment that is "winnable" might be preferable as global media depicts a more unstable existence, *Sight* bluntly makes its social critique evident in suggesting the medium being more than merely the message, but an instrument for direct neural control. In either scenario, the metaphor for gamification being a metaphor of control by hegemonic/capitalistic scaffolds is a bit of a tired trope, but is also a pointer at the recurrent dreams of the abuses of power extant in current social media and a warning against the same in ubiquitous AR.

10.8 AR, Art, Gamification, and Formalist UI Design

After a theoretical consideration, examples of potential models, and speculative design scenarios, what are some possible explanations for the relative absence of the genre, that is, gamified Augmented Reality Art? In that Augmented Reality is certainly an artform by 2019 is proven in many texts and most notably in the Geroimenko's previous anthology (Geroimenko 2018). So, given that Augmented Reality is a long-standing genre for art which is expanding into the 2010s, what are some rationales for the lack of gamification in this area? I will argue a small amount in terms of novelty, but also paradigmatically in terms of the creation of the form, availability, and its terms of expression. This may sound slightly Greenbergian in terms of formalism/minimalism regarding art, but in terms of Augmented Reality and art, the notions of essential form may be crucial here. This study will conclude with suggestions on formal user interface as aesthetic experience that could be taken into creative Augmented Reality applications.

The novelty of AR's popularization/democratization as an art medium is certainly a consideration. Although practitioners like Berry/Poupreyev have made expressive Augmented Reality in the 1990s with works like *Augmented Groove* (Lichty 2014), the issue is more of the critical mass of production stemming from the expansion of core technologies for handhelds in the late 2000s. Platforms like Metaio, Hoppala, and the free sections of platforms like Layar allowed for a great deal of creative exploration in the late 2000s that was not available before in public space. With the buyout of Metaio by Apple in 2016, and the increase of paid services on other platforms, Augmented Reality as art slowed slightly until platforms like Unreal Engine, Vuforia, and ARKit allowed greater freedom once again.

Secondly, and it is arguably the technologist's excuse, Augmented Reality as an art form is *less* explored than some, and relatively speaking, is a younger genre than

Virtual Reality. This is a response in other genres like virtual worlds like Second Life, that 'We're still in our adolescence", which, after 20+ years if the social virtual platforms Traveler Onlive and ActiveWorlds are considered, is a position which increasingly cannot be supported. But if we see the emergence of creative Augmented Reality in the late 90s to the expansion of the field in the 2010s with groups like Manifest.AR. Therefore, while a great deal of work has been done in Augmented Reality -based art, the genre is new enough that sufficient maturation has not taken place to allow for the exploration of things like gamification to any large extent, and this text points toward its potential.

Lastly, one of the issues with the creation of Augmented Reality-based art is that it is a form based on a fundamentally new form of Human-Computer interaction (HCI). For example, a seminal example of spatial computing, the Microsoft HoloLens, uses the surrounding architecture as a extension of the desktop metaphor as a place to place 2D browsers. While this essay lacks scope for the exploration of the UI/UX of spatial computing, it is this writer's contention that we simply have not developed spatial paradigms of computing. The evidence of this is that the Microsoft HoloLens, although masterful in its use of gestural computing, still uses 2D browsers and menuing. Likewise, the Meta and Magic Leap interfaces still use "Billboard" interfaces with icons. In short, if we are to operate in 3D, our operating system interfaces need to be 3D.

In popular culture, a couple visionary User Interface designs point at what immersive interface design could emerge in Augmented Reality. The movies *Johnny Mnemonic* (Longo 1995) and *Minority Report* (Spielberg 2002) both proposed haptic interfaces for the embodied manipulation of data and could be used for interfaces in space for gamification solutions similar to that of the *Foldit* game. The difference between the two interfaces is notions of the UI; for *Johnny Mnemonic*, the UI is still set into quasi-physical metaphors such as a triangular widget, keypads and so on. On the other hand, the *Minority Report* interface, developed by John Underkoffler at MIT, deals with the problem of "Real World Geometry" (Underkoffler 2014) in terms of a practice of process-based gestures, much as the Apple interface paradigm expresses itself not as a technology, but as set of gestures. Underkoffler's gestural interface translate to general models for the manipulation of informatic objects. This reduction of UI to sets of gestural processes for the manipulation of experiential objects could be the spatial paradigm for ubiquitous Augmented Reality interfacing using hand tracking without the need for a "air-mouse" as with the Magic Leap and Oculus Go.

In the late 1990s, UK-based interactive designers, including Roy Stringer and Roger Harnden, and later Danny Brown through the firm Amaze, and Stephen Holtzmann in the USA questioned the two-dimensionality of the World Wide Web though radical UI designs. *Noodlebox* (Digitalarchaeology 2011) was Brown's attempt at describing online informatics in terms as a set of nested cubic boxes that would express the spatial structure of an online space's informatics. A unique part of the Noodlebox interface was the fact that the interface components were *moveable*, allowing the user to reconfigure the structure of their interactive space to suit their personal organizational style. *Navihedron*, (Hutton 2014) imagined by Roy Stringer, would expand on this metaphor by using nested sets of platonic solids to structure information by arranging along the lines of edges and vertices on each solid, and allowing each vertex to be an interactive node for the expansion of a new solid/topical space. Steven Holtzman, creator of the *Perspectaview* hyperbrowser (Dunn 1998), allowed for a hierarchical tree of information to be flown through in space, similar to Ted Nelson's Xanadu interface. These technologies would generally scale back to forms of mindmap/hyperbrowser platforms *Thinkmap* and *The Brain.com*, which structured themselves on traditional spider-like mind-map cognitive maps.

10.9 The Dependence on Space

One last issue that constitutes a challenge to Augmented Reality-based artists is the dependence of Augmented Reality to the geometric context of the physical environment. This is a matter of conceptual frame as can be seen through examining the spatial computing frame of the Microsoft HoloLens, and then of a brief text by the American author Terrence McKenna. Perhaps a challenge to a variable reward and investiture (Eyal 2014) may be related to the use of variable spatial context and persistence of media in that environment, which is preserved in the interface methodology of the HoloLens. When activated in a given space, the HoloLens uses structured light to create a scan of the area, and places holograms, browsers, etc. within the user's view which is congruent with the user's spatial field. Each of these spatial databases are stored, and then accessed as the user re-enters the space, with the persistent elements of the workplace in position. This dependence of computational space to the environment constitutes a physical context that is meaningful to the given space and paired with the proper problems/content a site for solving meaningful/useful interactions like spatial puzzle solving, object recognition, and the like. This leads us to consider novel forms of meaning construction though task completion in AR.

Considering a speculative model for a gamified space in Augmented Reality which would create a unique gamified experience, the writer Terrence McKenna gives a model in the radio programme, *Virtual Paradise* (Earwax Productions 1992) in which he discusses a real-time form of concrete interaction in virtual space. *Virtual Paradise* was an experimental documentary by Earwax Productions in San Francisco featuring luminaries of the time (Terrence McKenna, Brenda Laurel) who were part of a 24-hour event focusing on Virtual Reality. During this documentary, McKenna spoke about his ideas on concrete language in Virtual Reality. His Virtual Reality (Augmented Reality) "fantasy" (sic) is about structural elements of language, such as the grammatical elements, and defining them as geometric elements, having colour and form in space, forming a "tinkertoy-like construction" constructing itself based on the rules of grammar and syntax. He argues that "language is a topological manifold, a set of interacting rules that come down to being perceived as a surface." (Earwax Productions 1992). He wonders then whether his idea is more than a linguistic gimmick, in that if you could concretize language into a form of post-symbolic communication, you could swap one's point of view, and actualize virtual empathy. As with many of McKenna's brilliantly seductive arguments, his description of this scenario as some sort of revelation of Chomsky's universal "deep grammar" is probably a gimmick when thought of practically. But when considering the arbitrary, subjective nature of language, there is no universal sense of subjectivity. However, when taken structurally, if we take this schema, assign rules, apply rules of speech-to-text, as well as rules of construction in synthetic space, McKenna's fantasy, in a headset like the Hololens or Magic Leap, could be a model for persistent speech-driven concretist sculpture in virtual/augmented space. Placed within the scope of other rules (types of object/time, structural analysis) could be a poetic game of sort, and therefore subject to gamification. Closing this discussion of Augmented Reality art as a small genre, the proposition for realizing McKenna's fantasy as a sculptural game of concretized language is a provocation for the development of the form.

10.10 Conclusion

Although the genre of gamified Augmented Reality Art is small as of 2019, my contention is that it will come. This is not to say that gamification in art or creative media does not exist, or certainly not that Augmented Reality art or design exists. And games such as *Pokémon GO* or augmented star charts with recognition games all have the potential for the generation of use value from augmented interaction, whether for analysis, education, knowledge generation, or monetization. Given the sensitive nature (e.g. Bogost along with Wark's models of labour in the digital age) of the possible abuses of monetization, my thoughts for the futures of gamified Augmented Reality art are centered in the other three categories. The uses of gamified Augmented Reality Art, as discussed above, could have ready entry points in STEAM education, visual coding, design, spatial problem solving, play, therapeutic experience, and environmental notation/information sharing, as mentioned above. The issue, as Matsuda asks in his film, is what value/meaning is being generated, who is it useful for, what are the questions being solved/asked, who owns the value, who does it benefit, and who controls it. These are only technical design issues, but social design issues/human factors. And most relevant, what is the artist's role as investigator of gamified space, and who is their research partner, again asking the questions above. The examples we have explored, from *Fantastic Contraption* to *Membit*, and on to the media fantasies *Sight* and *Hyper-Reality*, offer models and warnings about the future of augmentation and how they could/might be applied to our subject. And lastly, the basic issues of interface, whether entirely spatial as in the case of Mel Chin's work (intrinsic to the HCI design of the HoloLens) to the potential for object recognition that *LEGO AR Studio* hints at hints at. This, when thought forward through spatial interface metaphors developed by Stringer, Brown, et al., one might develop potentials for objective interfaces or the embedding of meaning in visual structure such as those suggested by McKenna. The issue for this writer is the meaningfulness (rather than usefulness) in the experience and the value of interaction with the gamified AR artwork.

Using the language circumspectly, the potential usefulness of gamified Augmented Reality art and the uniqueness of problems it could solve is evident from the relatively short histories of both genres. However, the question is whether to do it is as an exercise of the instrumentalization of art in Augmented Reality, which would be a disservice to the notion. It is my hope that when this genre of interactive media arises its usefulness can be directed that are meaningful, inspirational, helpful, and a tool in the aid of the current global condition.

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Chapter 11
Unintended Consequence: Pervasive Games and Public Art

Daniel Della-Bosca

Abstract Games such as Niantic's Ingress and Pokémon GO have demonstrated that Pervasive Games can be highly engaging for their audience by creatively combining location-based data and augmented content. This research asks how Pervasive Games using Augmented Reality can contribute to a changing perception of Public Art through a playful exploration of place. By unintentionally discovering Art whilst playing games, new meanings are seen to emerge and are explored from new perspectives through the surprise of discovery and re-negotiation with art in public places. This chapter is a semiotic exploration, through analysis and interview of some of the signs and symbols of Public Art and particularly the ontological shifts arising from the re-contextualisation and revisitations of symbols in augmented frameworks. The analysis of semiotic change seeks to explore the shifting interpretations of Public Art afforded by playing games with augmented technologies. Pervasive Games such as Wayfinder Live, and even Pokémon GO and its precursors unravel an evolving set of rich discourses in which to investigate the recursive correlations of Art and Place. The outcomes of this analysis of Pervasive Games reveal the ontological implications not of intentional design, but of the unintended consequence of playing Games through Art.

11.1 Introduction: *The Game*

It is a given, that as soon as you are introduced to *The Game*, you are a player. *The Game* is everywhere and nowhere, it is simultaneously beautiful and infuriating in its simplicity. If you have never heard of *The Game* before, the rules are simple. 'Everyone is always playing the game, you lose the game when you remember that you are playing it, and you must announce your loss' (Haywood 2007).

The Game is one of the simplest examples of pervasiveness. It requires no technologies, but in actuality, thrives upon the use of mobile and web technologies to communicate its existence. Some players go to great lengths to reveal their loss to

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their social network. Some experience their loss as a time of quiet reflection, and in that moment enjoy the absurdity of it all. In that moment; work, routine, seriousness and rules are all forgotten and the fun of life becomes important. It feels good to stretch that moment, to keep losing to the game.

The Game is wonderfully pervasive and infectious. It is infectious because as a loss is announced, the network of players that the loss is announced to, grows as each recipient remembers *The Game.* Losses are successes, they illustrate that the minds of many people are thinking about games and playing, and enjoying life. Hearing about losing *The Game* is as infectious as a smile or a laugh.

The ideas of pervasiveness need to be discussed first before we are to move on. It may seem obvious that *The Game* is pervasive but there is something really quite special about the grand stage that this game is performed in. The first agreement entered into, is that everyone is playing the game and that neither awareness nor consent is required to play (Haywood 2007). This radical idea breaks with Huizinga's rules of the playground as separate from ordinary spaces. Huizinga describes these play grounds, inclusive of the term magic circle, as 'temporary worlds within the ordinary world, dedicated to the performance of an act apart' (Huizinga 1955). Katie Salen and Eric Zimmerman confirm that 'the magic circle of a game is where the game takes place. To play a game means entering into a magic circle, or perhaps creating one as a game begins' (Salen and Zimmerman 2003). Separating *The Game* from the ordinary world is an impossible task as the rules are so encompassing of time and space. Eric Zimmerman resolved the argument in 2012 by stating that, 'Huizinga never took the view that games are ultimately separate from everything else in life or that rules are the sole fundamental unit of games. In fact, Huizinga's thesis is much more ambivalent on these issues and he actually closes his seminal book with a passionate argument against a strict separation between life and games' (Zimmerman 2012).

Markus Montola's definitions of pervasive games are helpful here to provide a formal position as to just how encompassing a pervasive game can be, as it necessarily permits the inclusion of reality (whatever that may be). Montola states that, 'Pervasive games consciously exploit the ambiguity of expanding beyond the basic boundaries of the contractual magic circle. This often leads to the point where the game interface is completely ambiguous: Any action could be a game action, and any sensory observation by any participant could be seen as part of the game' (Montola 2005). Using *The Game* as our illustration, Montola's reasoning holds true. *The Game*, ontologically speaking, challenges us as players and participants to explore what it means to play with reality as we would like it to be (Hawthorne 2018).

Montola's definition of the pervasive game as only requiring temporal, spatial or social expansion, presupposes that the pervasive game does in no way require any technologies. Any pervasive game may be enhanced, augmented or mediated by various technologies but it is not a priori. The Game in order to encompass the globe however, exists quite appropriately in the 21st century as socially, a loss (or gain) can be communicated to a network of friends. Players can be informed and reminded of the game temporally and spatially using web and mobile technologies. Montola concludes with this simple statement. 'To say that pervasive gaming is not limited to the contractual play space of the traditional magic circle of gameplay means that participating in a pervasive game influences the ordinary life of the player quite directly' (Montola 2005). This idea of direct influence is no less than ontological change, the player is changed.

Adam Rafinski and Markus Zielke support this ontological shift when claiming that pervasive games also shatter borders between a playful and serious state of consciousness because they are staged in the real world and are driven by both uncertainty and ambiguity (Rafinski and Zielke 2014). Rafinski and Zielke offer, that in relation to technologically mediated experiences, experiences augmented by digital media; these new games, new experiences shape reality by their design (Rafinski and Zielke 2014).

This last point concerning design is important. The concern is that a game and particularly a digitally mediated game is a *designed for* experience, and that the design of the experience itself may be structured through the lens or driven by narrative. The simplicity of the design of *The Game,* is perhaps an exception, it helps shape reality through its omission of rules rather than the imposition of story. Rafinski and Zeilke write about their research as focusing strongly on the ontological shift away from game design as experience design (Rafinski and Zielke 2014). This is perhaps the crucial point of the successes of pervasive games, that the experience is not rigidly engineered for the user, but rather the player is engaged in the aesthetics of the experience.

Games such as Troy Innocent's *Wayfinder Live* (Innocent 2018a, b), reshapes reality as well, but through an augmented frame. The aesthetics of the game are carefully constructed for a codified engagement with the audience, whilst permitting a new and playful (ludic) engagement with location. The problem concerning the design of Pervasive Games using augmented technologies are how the audience can interpret the new rules and symbols of the game, in tandem with the already understood rules and symbols of the urban environment they are located in.

This is the semiotic challenge, especially when concerned with the ever-changing affordances of new technologies. The technical considerations require effort, dedication, planning and testing, in short; Design. The design of a structured engagement with game elements and narrative, and the space to permit aesthetic engagement with elements and environment on the audience's terms.

11.2 The Design of Public Art

Crafting a game has its correspondences in the processes and methods of producing public art. It is also unfortunately easy to complicate a work of art for a public location. Public Art from inception to installation and beyond is a negotiation. It is a negotiation with many people, with committees full of stakeholders all of whom have an interest in what this 'thing' should be. The process of designing art for public places can be a frustrating challenge as the disciplines of art and design may intersect in very pragmatic ways, but may contradict conceptually. Careful design methods are necessary for the safe, considered and timely production of public art and subsequently the process is very much about designing for experience in functional terms. If that was it, if design was the sole consideration of public art, then all of its products would be risk managed outcomes of purely functional urban furniture. Public art is expected to be more, it is expected to tell stories, to challenge its audience, to change mindsets, to be what art should be, philosophically motivating and challenging.

Public Art does not need to be serious to challenge, it can be playful. Pubic Art can now also be a game that is played in public spaces, and that game constitutes art. We are conscious of cities full of public works that are perhaps too serious. They exist still, and they have merit but they are static things in urban, suburban and regional spaces and their engagement with their audience is what we once knew public art to be, not what it has evolved into now. Public Art now has altogether new potential.

The intersection of design and art using digital media, particularly mediated experience (within the context of public spaces) represents that new potential. It is successful because it is a complex engagement, a complex experience, not a simple one defined by the paradigms of one discipline at the expense of another. It has been previously argued that complexity is perhaps a defining feature of the success of mediated realities (Della-Bosca 2018). To clarify, complex experiences are not complicated ones. A mash up of experiences and technologies is complication. A careful integration of disciplinary strengths and purposeful uses of technologies for meaningful experiences at multiple spatial and temporal levels constitutes complexity.

Patricia Phillips writes of the potential of public art, it is not necessarily a definition, but perhaps an ovation. 'People generally experience public art when they are doing something else. Rather than a distraction or dilution of an art experience, this coupling of art with daily life can produce an enrichment of a pure, idealised, and increasingly rare concept of aesthetic contemplation' (Phillips 2003). Phillips' idea of experiencing public art whilst engaged in everyday activity makes sense. The object, the experience that we encounter in a public place is not understood as art until it is separated in some way from its background. The considered design of public art locates it carefully within its context, its background, but it is the encounter that organizes and activates the audience.

In Alva Noe's view, 'Design, the work of technology, stops, and Art begins, when we are unable to take the background of our familiar technologies and activities for granted' (Noe 2015). Noe states that Art is an engagement with the ways in which our practices, techniques, and technologies, organize us (Noe 2015). The complex engagement with mediated experience as public art, demonstrates the recursive and layered potential of this rich aesthetic experience. It is an aesthetic experience that is, according to Patricia Phillips enriched by lived experience. Patrick Lichty speaks of the aesthetic experience as liminal (Lichty 2014), and this is crucially important for interrogating the technological mediation of reality, as the aesthetic experiences are not tethered to one reality or another, nor are they solely understood according to one cognitive framework. The experiences are best navigated in the merged spaces between domains. The domains here to clarify, are rational and formal domains (designed objects, environments and experiences) in respect to

Fig. 11.1 Auguste Rodin, “The Burghers of Calais” in the Memorial Court of the Main Quad, on the Stanford University campus (Introvert 2004)

their structuring according to design intent, and sensorial domains (visual and haptic particularly) crafted to elicit and permit aesthetic engagement.

In regard to the conventions of public art, two examples of a rupture in negotiated engagement with static sculptural work in public space are offered. The first, *The Burghers of Calais* (see Fig. 11.1), represents a grouping of historical figures commissioned and completed by Auguste Rodin in 1889. Rodin desired that it not be installed on a plinth as was the norm for civic sculpture. He wanted contemporary townsfolk to “almost bump into” the figures and feel solidarity with them (Laurent 1989). This is perhaps best realized by the extended placement of casts at Stanford University a group of figures that permit physical interaction with its audience.

The second illustration (see Fig. 11.2) is a work by George Segal completed in plaster in 1991 and cast in bronze and installed at the FDR memorial in 1999. This work although physically similar to Rodin’s sculptures, is important because it is representative of ordinary men. Segal devoted his career to sculptures of everyday persons and allowed them to exist in galleries and importantly public places so that they could be representative of their audience.

These two illustrations may seem dated in regard to a discussion concerning pervasive games and public art, but they are offered as contextual landmarks for the ontological considerations that particular artists and their works have advanced our understanding of how we negotiate design and aesthetics for public space.

There are of course many more examples of art in public places as influenced and changed by land art, installation, performance and graffiti, but the particularities of public space, particularly civic space, require a special kind of negotiation. We are much more accepting as an audience now of many influences of artists and art movements but the acceptance by a broad community base is slow and the implementation

Fig. 11.2 George Segal, “The Breadline” FDR memorial, Washington DC (Highsmith 2018)

of it as required by the commissioning bodies still require strict design adherence to even permit novel adaptations to what public art can constitute.

Rodin’s wish for an integration of artwork and audience was not realized in his lifetime. George Segal did realize, the often poignant and sometimes playful integration of artwork with audience. Could it be seen that Rodin and Segal played games with their audience? Perhaps not. Rodin and Segal *played* with the formalities of space and form and with narrative. Playing a game is something else, and that is what will be discussed later in terms of the potential public acceptance of ephemeral works. In Rodin’s time the ideas of ephemeral art did not yet exist so design considerations were framed by the conventions of producing civic sculpture in durable and lasting materials, bronze or stone, media that were known to be aesthetically accepted by their audience. The placement, location and separation from audience using architectural structures such as plinths and pediments and so on, were also agreed upon design conventions

The semiotic disruption of signage as artwork produced by a poet, may stand as an absurdist link between civic public sculpture and pervasive games. Richard Tipping’s artworks as they are located in public space, qualify as public art but philosophically they represent much more. They engage the audience through cognitive play as all good poetry does, but deeper than that they disrupt the *narrative* that signs and public art generally are concerned with. Traffic signs in particular, present us with multilayered categories of semiotic rules. They operate as temporal and spatial networks of learned, applied and accepted symbols. The rules take a lifetime to learn, but Richard Tipping spent a career elegantly breaking them. The Art Gallery of New South Wales classifies the work illustrated, as an *artsign* a type of work that evolved from interventions of changing and obscuring text on traffic signs, into purposely and skillfully executed guerrilla visual poetry (Tipping 2012, 2014). The word *artsign* however does not help to elucidate their full potential. Their careful constructions demonstrate the accepted design language of signs that we would ordinarily heed,

Fig. 11.3 Richard Tipping, "Artwork Ahead" 2014, Sydney, Australia (Whiteghost.ink 2016)

but render into the background, as Alva Noe states. But the poetic disruptions are Art. Together they are perfectly packaged, internally and externally referential designs and aesthetic objects. They challenge the audience to shift between ontological positions, to consider whether we are engaging with a narrative, with known rules and conventions (as shown in Fig. 11.3). Or whether we are being immersed in a game. And more, to be sensorially manipulated to alternate between states of being.

Richard Tipping's works, disrupt, mediate, and ultimately alter reality for their audience. They are profoundly playful, serious augmentations to their environment, in a physical, literal and conceptual sense.

Graphic works similar to Tipping's *artsigns* are the kinds of things that are currently now easier to deliver in augmented frameworks but that belies the point of the experience. The artworks are beautifully crafted material objects and as such, are expertly designed to permit aesthetic experience. Richard Tippings work evoke the playful seriousness of Guy Debord and the Situationists (Debord 1956). They are societal ruptures that quietly, poetically change reality. One of the Situationist's practices, according to Debord was the *Dérive*, a drift through and across the landscape which involved playful-constructive behaviour and awareness of psychogeographical effects (Debord 1956). The idea of the *Dérive* was to free oneself from the constraints and monotony of everyday existence and simultaneously let go whilst engaging with terrain and ecology. The precise ideas of psychogeography are that the practice of it, incorporate the observations and analysis of the effects on individuals, of the consciously and unconsciously ordered urban environment. But it is this mix of order and disorder, of design and sensorial aesthetic recognition, of ecologies both

Fig. 11.4 Urban codemakers in action, 2010, Melbourne Australia (Conway and Innocent 2017)

natural and social that affect the human physiologically, intellectually and emotionally, that proves useful in understanding complex interrelated systems and ultimately doing something with it.

Readapting the system for other purpose, such as playing a game is a perfect opportunity to engage in play not just for plays sake but for using games to unravel past, and create new meanings. It is imperative here to historically link the Situationists and the critically acclaimed location-based games of Troy Innocent. Troy is a Melbourne academic lecturing in Games and Interactivity, and the creator of a series of expansive location-based games designed and run in cities around the globe. His games evidence the curious potential of The *Dérive*, of strangely structured play (see Fig. 11.4) which he and Hugh Davies offer, might therefore be understood as a playful decoding of infrastructure (Davies and Innocent 2017).

Troy Innocent and Hugh Davies reference Guy Debord when writing about location-based games. 'The *Dérive* and the opportunities afforded by psychogeography connect to the role of play in creating alternate realities—those imagined by appropriating elements of the urban environment and associating new meanings with them—and play as decoding infrastructure as the player becomes more aware of different layers and systems that make up the nature of cities' (Davies and Innocent 2017).

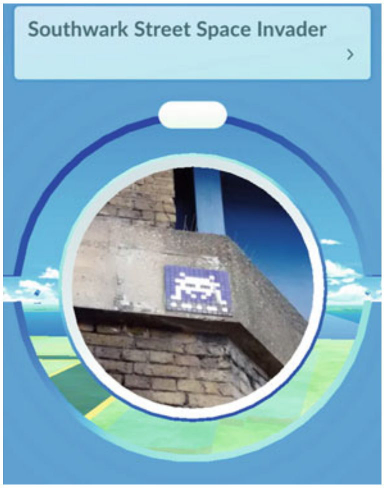

Fig. 11.5 LDN_130, London, 2013, Invader (Woods 2016)

11.3 Pervasive Games and the Augmentation of Reality

This chapter includes text from an interview between the author and Troy Innocent for the express purpose of understanding the depth and consequence of constructing and delivering Pervasive Games from the creator's point of view. Some of that interview will be woven into the proceeding sections as the fusion of Art, Design and Game in public space is explored. It is essential here though, to discuss a partial history of location-based games and what augmented reality can offer public art.

Invader, is a street artist known for producing 8-bit mosaic artworks and cementing them into the urban landscape. *Invader* describes these installations as Invasions. In a non-digital fashion, *Invader's* work augments its landscape. Curiously the works are physical interpretations of digital originals, so the augmentations are contrary to what we understand now as technological or digital augmentation. The recollection of a game is a wonderful thing, and a chance encounter with the graphic symbols themselves are enough to re-frame an everyday experience to help feel as if you are back in the game. The foregrounded encounter with an *Invader* on the street corner is an engagement with the circular dialogues of art, where art references game and game references art. *Invader's* Invaders are also re-referenced as augmented markers (*PokéStops*) within the game of *Pokémon GO* adding to the circularity of game, art and place (see Fig. 11.5). Invader himself is presumably happy about that as he accepts the description that his work is street art, graffiti and game (Invader 2014a, b).

In regard to the circularity of game, again there is a curious history to how landmarks surfaced within *Pokémon GO,* and that is because of a previous game called *Ingress* that amassed a global database of images submitted by players as they were asked to contribute locations for *portals* to be used within the game (Weigel 2016). These *portals* were reused as *PokéStops* within *Pokémon GO.*

The question is, what attracted a game player of *Ingress* to provide the locations of *Invader's* artworks? Was the attraction of aesthetic concern, reminiscence, in respect to games once played? Or were the considerations more formal, evidencing familiarity to place or having strategic purpose, hidden and providing depth and purpose to the puzzle of finding.

The answer, probably is yes to all of these concerns. That is the negotiation of art/place/space and being are considered at least subconsciously, as rich interconnected and complex scenarios. The role that technology plays in this, is especially interesting as the internet-based location maps and recomposed artworks as augmented markers consciously reframe each other. It is possible that '*Invader's'* web-based location maps inspired some *Ingress* players to visit certain locations which in turn inspired *Pokémon GO* developers to frame gameplay in a particular fashion. It is possible, because the technological domains of personal and mobile computing and real-world environments as accessed using GPS are merging, especially in the minds of the player and certainly in the minds of developers. The game or subsequent games are possible because of these affordances. This means in turn that the players themselves through their actions have afforded new possibilities to the ideas and practices of public art.

Troy Innocent is adamant that a definition of public art is inclusive of the digital space. As Troy has been making, coding, teaching and researching games for decades, he should know. His games are well received by their communities, councils and academics. In contrast, public art of a conventional static nature usually upsets more people than it pleases, at least in the short term. It seems that most everyone loves a game, especially urban planners and civic leaders. Troy currently works with 5 inner city and 2 suburban Melbourne councils as part of the Smart Cities Research Institute, and in 2017 he was awarded the Melbourne knowledge fellowship to research playable cities around the globe. Urban planners are taking play seriously partly because games like Troy's *Wayfinder Live* demonstrate repeatedly, that it engages community and it changes people's relationships to place, as public art should. The independent games and game-makers are also in turn validated by the commercial success of games such as *Pokémon GO*. Urban planners and policy makers can easily see now that location-based games can function effectively, permit communities new ways of exploring their cities and ultimately make people happy.

11.4 The Aesthetics of Augmentation

Central to the function and success of Troy Innocent's games are fiducial markers, which are the physical objects, or graphic elements located in spatial terms and visible to both machine and humans. Fiducial markers are not used in *Pokémon GO*. The game relies upon geolocation and it may seem that markers appear as *PokéStops,* but the appearance of the embedded images are only coded to co-ordinates. The fiducial markers within Troy's games are quite complex and highly integrated aesthetic objects that tether a cloud of data to its location (Innocent 2017). The markers are

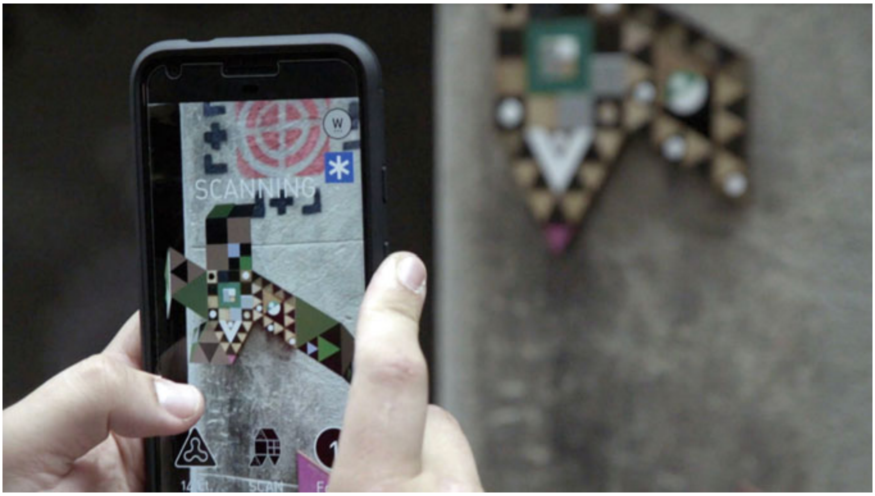

Fig. 11.6 Troy Innocent, 'Wayfinder Live' (Innocent 2018a, b)

much more than simple QR codes, they are compositions of shapes and textures and colours, crafted in ways to be read in conjunction with the mobile application giving specified outcomes at varying times dependent upon the game and player state (see Fig. 11.6).

Troy describes the markers as glyphs, units of language, complex signifiers that reside in mixed realities. To someone external to the game, the markers are illegible, they demand inquiry, and psychologically they are obviously puzzles waiting to be solved or components to be assembled into a larger whole. Sometimes that is the case, in *Wayfinder Live,* 16 glyphs fit together physically and virtually to complete the puzzle.

In terms of machine processing, pattern recognition algorithms can be configured in many ways to read images and objects for extended purposes, but that only constitutes a set of components of the game. The experience as a whole is about the interrelationship of pattern recognition by machine and human in a recursive dialogue.

In the essay, *A Framework for Cloud Aesthetics in Mixed-Realities,* Troy explores, referencing Galloway, that which precisely constitutes the diegetic and non-diegetic act (Galloway 2006). Troy speaks of the contributions of Human and Machine agents 'Operator acts are those of the player, while machine acts are those of the software system. The latter is made up of machine vision that has decoded the markers, rules for connecting these to images and sounds, and the overall operational context of the iPad. Diegetic acts are those embedded into this system and that cannot be changed; non-diegetic acts are those that happen outside the system; in this case, mostly through interaction between players' (Innocent 2017). The intention of games such as *Wayfinder Live* and Noemaflux, is to carefully craft the machine acts for the experience to function well and the narrative to be explored, whilst permitting room for social connections to grow through dialogue and interpretation, as this in turn modifies the public space.

What is of specific interest here is Unintended Consequence. What occurs outside the narrative and game space that permits a change in behaviour due to location or technologies or perceived connection to the player?

The image illustrated (see Fig. 11.7), constitutes a good example of what could potentially affect and change players experience in an extra-diegetic sense. I have written previously about the experiences of re-engaging with public art through *Pokémon GO* through the purposed act of looking through the compositional frame of the smart phone, the device that is reframing the environment to bring forward what the game intends but also what was unintended (Della-Bosca 2018). Discovering or even re-discovering Banksy's *Girl with a Pearl Eardrum,* whilst immersed in an aesthetically rich urban game makes for an amazing experience. Everything within the environmental contexts of a location-based game has the potential to be extra diegetic, and it is that potential which makes it reality altering. Street Art, Graffiti, prior commissioned Public Art, everything is reframed and repurposed and has the potential to speak to the game. Everything external to the game in a non-diegetic sense can become meaningful in new ways as well.

An unintended consequence of crafting Pervasive games emerged in a review of businesses and galleries on Guildford Lane in Melbourne. Presumably, after perusing a marker, following a link and scanning the Urban Codemakers site. This was revealed to the author of the Broadsheet.

The review reads 'Urban Codemakers, Commissioned by the City of Melbourne as part of the Laneway Commissions for 2010, their activities range from community consultations, advising councils on city planning and researching the role of the increasingly dominant and interactive media into shaping our urban space. Using an experimental approach that draws upon game design, semiotics and generative systems for urban planning' (Adams 2010). Troy Innocent and his colleagues seem to have been bestowed with the extra-diegetically appointed roles of urban planners. Perhaps this is a great unintended consequence that Pervasive games using Augmented Reality have created new, (albeit unofficial roles) in planning for the city of Melbourne.

Troy Innocent's narrative context for *Urban Codemaking* actually was; *what would happen if Game designers were to redevelop the city?* In the years since 2010, that has happened. The game designers are redeveloping the city by encouraging play in public spaces. The audience, including policy makers and urban planners are beginning to see the potentials of place in an entirely different way. The augmented frameworks driving the games are maturing, and as a result of commercial successes of Augmented Reality Games, play is serious business. It is evolving because of the affordance of augmented frameworks developed by large game companies who are investing in the technologies. It is shaped in turn by artists and independent game makers who reshape reality and help their audience become something new.

Fig. 11.7 Troy Innocent, 'Wayfinder Live', Bristol, 2018 (Innocent 2018a)

11.5 Conclusion: The Mediation of Reality

Finding Invader's invaders, is as much a Game as it is Art, and yes there is an app for finding and collecting Invaders invasions through photographing them. Nearly 63 000 players had downloaded and used the app and uploaded their images.

Patrick Lichty reminds us that the introduction of mediated experience, to include and deliver pre-existing artistic content within the augmented experience, offers it up for investigation as a frame for mediation which in turn provides the opportunity for discussion on novel modes of becoming (Lichty 2014). Art always mediates reality, but it is through structural, spatial and temporal complexities that we engage in the recursive loops of becoming and understanding, which is perhaps the game of art.

How else could ones being, be so transformed in drab suburban Melbourne, by the simultaneous recall of a wonderful English film, the obsessions of a French street

Fig. 11.8 MLB_09, Melbourne, 2002, Invader (Invader 2014a, 2014b)

artist bent on global domination, the purpose of public art and the pure stupid fun of trying to defeat aliens in a Japanese arcade game (as illustrated in Fig. 11.8).

Designing Augmented Reality Games carefully to permit an engaging aesthetic experience is a difficult task. It requires the design team to be understanding of psychological and philosophical implications, expert in semiotics and phenomenology, and urban planning it seems.

Invader is persistent enough to get his tiles in cities all over the globe. His augmentations of the urban landscape require real tiles and real adhesive, but the play is in association, in memory and reminiscence. Playing with memories of playing games. Invaders Art is mediating reality quite successfully because it is a careful negotiation of symbol and space. Niantic's augmentations on the other hand, began with reasonably arbitrary images of sites uploaded by players of *Ingress* and those sites have gone on to serve as the growing location database for their games and more, as Niantic is now happy to sell its platform to others. Millions of people are still playing *Pokémon GO* and rightly so, as *Pokémon* is very much a part of the collective consciousness of generations of game players.

We happily give ourselves over to new realities as we become something else through play. What Augmented Reality is offering the disciplines of Art and Design through Public Art is something quite wonderful. Every aerosol spatter, purpose made fiducial marker, architectural feature, graphic sign and much more has the potential to be meaningful new symbols in the language of games played in public spaces. As with all visual discourse though, the semiotics of Pervasive Games using Augmented Reality requires attention and critique. *Pokémon GO* is successful because we, the audience want it and permit it. That doesn't mean it is helping us understand and interrogate our environments any better. In some respects, *Pokémon GO* is too structured, it does not allow us to see past the tasks at hand. Only when something comes into frame such as a *PokéStop* that we have an aesthetic and cognitive engagement with, are we prepared to allow our mindsets to shift. These are the unintentional but meaningful moments of playing *Pokémon GO*.

Games such as *Wayfinder Live* may help us re-invent our urban spaces through complex semiotic engagement resulting in attentive play. Troy Innocent describes the act of playing his games as always in the process of coming into being. That is what playing games are about, it is about involving people in those processes.

Pervasive Gaming presents significant challenges to what we understand Public Art to be. Pervasive Games using Augmented Reality affords new potential and purpose to Art in public places and the games played in public places can have social and cultural significance in ways that we may not understand yet, but room must be left for play and discovery for those opportunities to emerge. If Public Art continues to be a structured and designed for experience, the audience does not retain a stake in re-imagining and re-inventing public space.

If urban planners see potential, the commissioners, curators and managers of public art should actively be immersed in playing games. The stakeholders of existing and emerging opportunities for public art, by playing, may get to sense what their audience does, that actively interacting with art and space is much more fun and perhaps meaningful than passively looking at static works.

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Chapter 12
Defacing the 'Balloon Dog': Art, Algorithmic Culture and Augmented Reality

Rewa Wright

Abstract This chapter examines gamification through selected artworks that deploy augmented reality (AR) techniques. Gamification is approached as a form of 'algorithmic culture' in which algorithms can be, to varying degrees, both positively guiding or negatively coercing a user. After analyzing examples of gamification in the mobile entertainment industry, such as Snapchat and Pokémon GO, examples from contemporary media art that blend augmented reality techniques with algorithmic structures and tendencies are investigated. This research considers AR as a processual entity, rather than a discrete form or technical medium. Its interfaces are not simply dynamically engaged across the physical and the digital but entangled with social and cultural forces.

12.1 Introduction

When Snap launched their AR art platform using a giant geo-located augment of Jeff Koons' *Balloon Dog*, placed in iconic Central Park, New York, they were certainly not expecting any controversy. Within days, the artwork had been hacked by Sebastian Errazuriz, a media artist from New York, who had built an AR graffiti app. to deface Koons' masterpiece. Seemingly motivated by a desire to speak out against the increasing corporate control of AR space, the artist made a political statement against the privatisation of the virtual public sphere. At the same time, he was speaking out against gamification, in terms of Snapchat's playable media experiences such as dogface and the vomit rainbow, images which have to date appeared in tens of millions of user-generated selfies.

Koons' Balloon Dog appeared in Central Park through the World Lens filter, a physically non-invasive software generated means of geo-locating visual content at a specific physical site. The placement was part of Snap's art programme, and subsequently Koons' Popeye has been placed virtually in the steps of the Sydney Opera House (17 October 2018) causing no controversy of note. So, why especially

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does the placement of a famous sculpture as virtual ignite the debate on AR and public space? And can a playful low-brow social media ‘game’ become art, even with the help of one of America’s most iconic and widely revered artists? Snap contends, yes, with the launch of their new art platform for ‘lens’ creator’s asserting AR art’s right to gamify. In this context, the notion of gamification also extends to products which entice consumers to participate in their ethos through the deployment of game-like elements. In the Central Park location chosen for the display of Koons’ sculpture as virtual, it would be entirely illegal to erect a billboard advertising for Snap or any other company: Yet, it is the confluence of proprietary software and virtual space that has produced this unique and somewhat opportunistic marketing paradigm. However, it is this same ability to insert virtual objects into public space that has fuelled quite a different paradigm, that of the AR intervention, now a well-known technique in emergent artistic practice.

In a video posted to Instagram, Mr. Errazuriz explained why he had questioned Snapchat’s collaboration. “For a company to have the freedom to GPS tag whatever they want is an enormous luxury that we should not be giving out for free,” Mr. Errazuriz said. “The virtual public space belongs to us, we should charge them rent.” The idea of privatising or monetizing virtual space is also something Forbes magazine picked up on. For companies like Snap, a space where no rent is paid is a clear opportunity for free marketing. However, it is the overlay that is owned, as well as the means to access it—in the case of the *Balloon Dog* virtual sculpture, via the Snap proprietary platform, and in the case of Errazuriz’s artful intervention, his own proprietary app. The space itself remains in the public domain, free to use by all, even corporations in pursuit free exposure to fuel their privatised profits. Here, virtual public space is a resource that can be extracted and harnessed for whatever purpose.

12.2 AR/MR Commercial and Technical Development

In a widely accepted technical definition from Ronald Azuma, AR is any technological system which combines real and digital elements, is interactive in real time, and registers in three dimensions (Azuma 1997, p. 355). AR experience is generally framed by a display screen, often either held by or attached to human users: for example, as a smartphone or head worn display. These range from screens on smartphones, through to heads-up displays (HUDs), or large screens designed to reflect human scale and capture human movement. A sample of recent games and entertainment applications from the commercial world illustrate how AR continues to be confined to informatic overlay design. Wikitude (2008), for example, was the first application (app) for smartphone and tablet to use a Simultaneous Localization and Mapping (SLAM) algorithm to overlay three-dimensional coordinates in geographical space, through alignment with the accelerometer and gyroscope sensors. Cartographic and geo-locational information was held on a web server and transposed to appear as localised information on the screen space of the user. Another popular and commercially successful example from the mobile game industry, the massive multiplayer game Pokémon GO (2016) invites players to collect virtual avatars (Pokémon) which battle one another, and eventually cooperate to take over virtual bases called 'gyms' geo-located in real space. In the game's AR mode, 'trainers' attempt to capture Pokémon that are visible as a layer on a smartphone screen. The game uses geo-location to spawn and track the Pokémon (Juhász and Hochmair 2017), in combination with an informatic overlay approach. In another context, Snapchat (2016), overlays novelty augments on the faces of users, such as dog, a dancing elf, or a rainbow. The application uses a 'features point detection' technique to precisely locate augments—called 'lenses' by the company—over the faces of users (Pawade et al. 2018). A user's face is captured through the front-facing camera of their smartphone, placed in a 'mirror,' adapted through the addition of an augmented overlay, then re-presented in the screen display as an altered image stream.

In limited ways, these more recent examples of AR engage aspects of a user's corporeality. It could be argued that applications like Snapchat provide new senses of embodiment for the participant by shifting the relation between the camera's image stream and a second augmented image stream. Yet bodies here are highly delimited by their interaction with a screen. Captured in this 'magic mirror,' the body is reconstituted via a technical apparatus as components of computational vision, where a digital replica of an area of the user's corporeality endlessly loops without variation. Additionally, many of the designs currently deployed in the mobile AR industry proceed from the assumption that the digital screen functions like as an analogue to a window. Wikitude is literally a map overlaying physical space; in Pokémon GO, the smartphone screen becomes a 'portal' to look through. Others, such as Snapchat, function through the trope of the magic mirror. Playful media, such as Snapchat's world lens' products have shifted our perception of what 'art' might be in the context of AR as a commercial enterprise. At the same time, more high-brow precursors such as serious art games, have expanded our understanding of what AR might do in the public domain. In each of the apps mentioned above, AR is focussed on what happens within the frame of the screen. The following section will elaborate on the engineering techniques that make the informatic overlay possible and indicate how—in the design of commercial products—those techniques also flow into MR as an emergent field.

The apparatus that started the HMD/HUD research trajectory in MR, was invented by Ivan Sutherland: his Sword of Damocles (1968) took up an entire room, had functional vision from one eye, could only be comfortably worn for a few minutes, and showed wireframe line drawings (Sutherland 1968, pp. 757–759). Yet its radical concept—that human vision might combine with digital content through a display worn on one's head—established a research trajectory for AR/MR/VR that is proliferated today across many devices. Fundamental for this research trajectory is a pragmatic approach that aimed for greater efficiency in task completion, helpful in military and industrial contexts that embrace the notion that the human body would be enhanced by augmented vision. Current commercial and industrial approaches incorporate the latest sensing technology to convey sophisticated situated and highly contextual data aimed at adding clarity to the digital experience (such as Ohta and Tamura 2014).

Engineering handbooks are replete with a wide range of tracking techniques for AR/MR, including marker-based and image-based tracking, model targets stored in the Cloud and geo-locational information (Carmigniani and Furht 2011; Kent 2012; Craig 2013; Peddie 2017). These techniques have facilitated a plethora of AR games for smartphone, with mobile AR being the largest category of commercial MR use (as in the gamified examples mentioned above). Product launches attach data, such as a new car, to real-world objects such as cubes, while QR codes on supermarket cereal boxes aim to tempt buyers with embedded links to product websites.

12.3 AR/MR Through Media Art Practice and Scholarship

The approaches described in this section, are neither engineering-based nor confined by earlier media concepts. Artists involved with AR/MR have manifested different techniques for augmenting space, many of which pre-date the current thinking in computer science and engineering such as that encapsulated by the Reality-Virtuality RV Continuum and other similarly restrictive models. We will be examining artistic interventions that complicate both the informatic overlay approach and the notion of a ‘seamless’ connection between ‘real’ and ‘virtual’ in MR spaces. The experimental artworks surveyed in this section are sympathetic to what I will later analyse as a materialist approach to MR that focuses on relations, intra-action and the agential reality of all elements of the software assemblage. It is not intended to be a comprehensive selection of artwork in the field: rather, the artworks mentioned here reveal an interest in processes that encourage self-organisation, emergent relational forces, iterative re-assembly, and an aesthetically expanded role where audience members becomes participants/artists.

Inquisitive writers/practitioners from the avant-garde of media art practice have drawn attention to the need for an alternative formulation of MR. In an analysis of the collective Blast Theory’s augmented and mixed reality artwork, Steve Benford and Gabriella Giannachi note that Milgram and Kishino’s Reality-Virtuality Continuum might be more useful if it was ‘more rhizomatic’, since the classification system tends to place physical and virtual in opposition to one another rather than fostering a more relational system (Benford and Giannachi 2011, p. 3). They describe the Reality-Virtuality Continuum as a ‘largely mathematical and technology-centric’ method of ‘constructing virtual spaces’ in order to align them with physical space (2011, p. 43). In response, they offer the notion of ‘trajectories’, where the participant enacting an artwork moves experientially through real and virtual online worlds that are partially pre-scripted, and partially self-generated. The pioneering MR participatory performances *Uncle Roy All Around* (2003), and *FlyPad* (2009) by Blast Theory weave together theatrical performance, online and real-world environments, audience participation, role-playing, and data extraction in complex arrangements that unfold mutually across the digital as well as the physical (Benford and Giannachi 2011). Carving out a new genre of MR performance, Blast Theory’s contribution to a performative MR, advances a less digitally privileged mix of realities, where participants are given cues by the artworks that send them off on exploratory trajectories that pass through 'hybrid space'. Referencing Gilles Deleuze's notion of the 'fold' they describe hybrid space as:

> composed of different, adjacent, "enfolding" spaces, simultaneously occupying different points on the mixed reality continuum, which remain, however, in a heterogenous, discontinuous, unsynthesized, and changing relationship with one another (Benford and Giannachi 2011, p. 45).

For example, in *FlyPad* (2009), a camera placed over a gallery's atrium framed a wide orthographic view of the space below. In this frame—a 'flying area'—visitors were able to take on the identity of a winged avatar (a brightly coloured insect), whose movement they controlled using a footpad. Flying across and through the atrium, the flyers could join together, performing new movements by melding their avatars, or remain separate but fly with less vigour. Prior to playing the game, as they walked around the gallery, data was extracted from participant's movement by way of a Radio Frequency Identification Device (RFID) tag, and this data was added to their digital avatar in the *FlyPad* game. Incorporating a participant generated trajectory with pre-figured elements, produced an iterative artwork that could never unfold the same way twice (2011, p. 138–141). While Blast Theory's work does not directly relate to my practice-based approach since it relates more to the potential of MR as a transmedia storytelling medium, it illuminates the need for more performative versions of MR, influenced by relational assemblages rather than technocentric formulations.

Following the thread of dissent toward technology driven methods that occlude the body and align corporeality with a pre-figured data system, leads us to artist generated approaches that use different techniques to combine corporeality with augmented digital worlds. In John McCormick and Adam Nash's *Reproduction*—an artificially evolving performative digital ecology (2011), autonomous agents helped to generate embodied relations that re-sited image/colour data from human interactors to an adapting digital 'life-form'. Extracted using motion capture technology, the results of the results of these hybrid reproductions—as they adapt in real time in response to feedback—were presented as a full-scale projection in an immersive room. The impact of this mutation on the visitor is discussed as provoking a multi-sensory state of 'contemplative interaction' (Riley and Innocent 2014; Riley and Nash 2014), and it is noted that this understanding differs from conventions that frequently situate MR as either 'reactive or distracting' (Riley and Nash 2014, p. 260). Contemplative interaction offers itself as a method that examines 'notions of affect that relate bodies, locations, spaces and codes across the physical and virtual' (Riley and Nash 2014, p. 263). Again, a much more complex figuration than offered by the Reality-Virtuality Continuum, and one that allies itself with Deleuzian notions of affect and embodiment (Riley and Nash 2014, p. 261).

Sandbox: Relational Architecture 17 (2010) by Rafael Lozano-Hemmer, used augmented projections to form spontaneous visual connections between people at Santa Monica Beach. An area of 740 m^2 of the beach had been prepared in advance with a tracking system, surveillance cameras, and projectors that caste real time images of giant hands across its surface. These giant hands were magnifications of human hands playing in one of two 69 × 93 cm sandboxes nearby. At the same time, participants on the beach were captured by the same tracking/surveillance/projection system, with their full body images shrunk to a tiny scale. Re-projected into the sandbox, people there were able to play with human miniatures using their hands. Choices emerged: participants could join the sandbox and see their own hands projected as giants; or, they could remain in the expansive beach space and have their own full body images recorded, and shrunk, then projected back to the sandbox for hands there to explore.

As physical bodies passed by one another—in the illuminated darkness of the tactile and tractional sand—they passed over and against digital augments as light projections of the bodies of others. This relay of projections formed a recursive loop where new relations of overlapping bodies spontaneously and temporarily emerge, in oscillation between media environment and natural environment, corporeal bodies and projected bodies. Light gave these augmented bodies presence, through the relations it formed with other surfaces: the augmented sandbox, the participant's skin, the luminous projection system, the tracking and surveillance software.

This is not Lozano-Hemmer's first installation leveraging AR technology in a complex relational system. Indeed, it is clear that Lozano-Hemmer was a pioneer in the creative use of augmented material in media art. In *Underscan* (2007) as well as *Body Movies* (2002), an earlier version of the same tracking system used in Sandbox was deployed to track participants and activate augmented video that passed under their shadows as they walked. Ulrik Ekman has analysed emergence and embodiment in relation to *Underscan*:

> This happens via the virtualization of their bodies, but also via the emergence of a complementary interplay, in their embodiments and the real environment, among locative media, signaletic telepresence, and ubiquitous computing (2012, p. 18).

Ekman notices a blurring of distinctions, such as between public and private space via the virtualization of bodies. Like *Sandbox*, the technical operation of *Underscan* involved luring people into a pre-prepared space embedded with sensors and surveillance equipment, where their movements would be tracked and used to trigger corresponding movement image sequences. In the case of *Underscan*, the projected sequences were from pre-recorded films, deployed on the pavement as augmented overlays. In the case of *Sandbox*, the projections on the sand unfold in real time, reflecting advances in tracking technology made in the seven years between these works. Looking over to the sandbox from the sand, participants could see others playing with their images, and they could do the same with the large-scale hands projected on them.

Sandbox's project description lays the power relations and affective conjunctions of bodies (human and non-human) embedded in this artwork bare:

> The project uses ominous infrared surveillance equipment not unlike what might be found at the US-Mexico border to track illegal immigrants, or at a shopping mall to track teenagers. These images are amplified by digital cinema projectors which create an animated topology over the beach, making tangible the power asymmetry inherent in technologies of amplification.

This 'animated topology' approached power relations as matters of scale: where giant hands manipulated tiny people, yet the tiny people were also able to overturn that relation and become the giant hands. Spaces are alluring and carefully composed, drawing humans toward their dynamism—such as movements of light and data—latent with affective potential. DeLanda (2007) suggests that human experience in Lozano-Hemmer's artworks, is largely produced through 'expressive spaces' activated by underlying nonhuman energies. In such spaces, code is not simply executable but is affective, 'long series of ones and zeros that ultimately embody the software animating the hardware' (DeLanda 2007, p. 104). Establishing a giant structure populated with surveillance cameras, a bespoke tracking system, and ultra-high power projectors, Lozano-Hemmer generated an expressive space for humans to affectively perform within.

All the artist-led approaches described above convey the idea that the physical and digital spaces of MR are actually not separate but meet through oscillatory movements of bodies and data. In such assemblages, the materiality of the digital is not only affective, but further suggests that senses of embodiment operate between human and nonhuman. this affords the broad perspective that data and the corporeal might mutually co-constitute one another. Clearly, such approaches are markedly different from the engineering and computer science paradigms discussed earlier in this article, that would fix MR as a matter of technical arrangements on a display screen.

Lanfranco Aceti's and Richard Rinehart's (2013) edited special edition of Leonardo Journal, *Not Here Not There*, was the first comprehensive survey of AR/MR as an artistic category. Framing a quote from the Manifest.AR collective, Rinehart summarizes some of the provocative issues raised by mobile AR:

> Sited art and intervention art meet in the art of the trespass. What is our current relationship to the sites we live in? What representational strategies are contemporary artists using to engage sites? How are sites politically activated? (Aceti and Rinehart 2013, p. 9)

This collection focussed on mobile AR deployed through geo-location, since this was a popular artistic movement at the time. Soon after Aceti and Rinehart's collection, *Augmented Reality Art: From an Emerging Technology to a Novel Creative Medium* (2014) edited by Vladimir Geroimenko, became the first book to systematically analyse the artistic threads coming out of AR as a new medium. Contextualising that study, Geroimenko reproduced in full the Manifest.AR manifesto (Freeman et al. 2012), leading him to argue that what differentiates AR from other emergent media forms such as 'virtual reality, Web art, video, and physical computing' is that it is bound up with an activist politics that re-purposes technologies like mobile phones as radical artmaking devices (Geroimenko 2014, p. vii). Moving away from the restrictions imposed on AR as medium defined by the informatic overlay or by remediating older media, artists working with mobile AR have forged new critical pathways, such as those described in Geroimenko's collection. Mobile AR—popularized by commercial products such as the smartphone games described earlier—in media art takes geo-location to activist contexts.

Mobile augmented reality art (MARt), emerged as cultural force in AR from about 2010, with the influential Manifest.AR group founded on January 25th, 2011, following their ground-breaking guerrilla exhibition/intervention in the Museum of Modern Art, New York, We AR in MoMA (2010). There, organisers Mark Skwarek and Sander Veenhof conspired to stage an exhibition of augmented art without the permission of the gallery, and got away with it. Holding tours of their artworks, the show went under the radar of the gallery authorities, and inaugurated a new movement in activist and interventionist installation. Subsequently, the group staged other interventions where geo-location was used to surreptitiously place augments at canonical and politically loaded sites, such as outside the New York Stock Exchange during Occupy Wall Street (Skwarek 2014, p. 3), and at the Venice Biennale 2011 and 2013 (Thiel 2011, 2014). During Occupy Wall Street, the area in front of the New York Stock Exchange was off limits for protestors, yet the Manifest.AR group were able to stage a 'flash mob' waving smartphones rather than obvious signage (Skwarek 2014, p. 17). While augments still operate as informatic overlays, they are skewed to critical ends by an activist culture. A deeper knowledge of how information operates via layering in AR, also featured in some of this work. For example, by hosting their work on private 'layers' in the app Layer, Manifest. AR avoided the marketing noise made by commercial mediatic assemblages. Such strategic uses of augments in conjunction with mobile devices, not only encouraged a critical turn in thinking about the informatic overlay, but also implied a more extensive concept of embodiment.

Moving around a site to discover augments on a smartphone involves a trajectory through physical space that engages meanings that are both pre-existing and inscribed. Space is not inert waiting to be written on by the artist/activist: space can be considered as expressive, as will be examined shortly (DeLanda 2007). Rethought as affective toward its human inhabitants, space can be conceived as a force of the nonhuman that makes connections with embodied actions, generating affects that adapt behaviours and practices. Artworks using mobile AR that likewise imply space might be expressive, and that work alongside the embodied actions of participants to co-compose the experience, are Tamiko Thiel and Will Pappenheimer's Biomer Skelters (Liverpool 2013 and various iterations), and Janet Cardiff and George Bures Miller's the City of Forking Paths (Sydney, 2014–2017).

In Tamiko Thiel and Will Pappenheimer's Biomer Skelters (Liverpool 2013 and various iterations), a participant walks around a pre-determined area of a city with their smartphone. As they move the camera sensor, they see an array of digital plants appear on their phone screen. The participant holds a Zephyr heart rate monitor to connect a bespoke smartphone app to their heartbeat. The frequency of the signal generated by the beating rhythm of their heart is converted into the augments—virtual plants—that populate the 'biome', a term borrowed from biology that describes a community of plants and animals living together in a 'congruous ecology' (Woodward 2009, p. 2). In this case, the biome is an urban landscape populated by data, plants and bodies.

The concept of combining an art-game form, an affective computing network, together with algorithmic botany produced through AR, marks a physiological turn toward embodied action in mobile AR. Operating as a self-organising system tethered to the physical activity of walking—hence conjoining physical world with digital via enactment—the participant of this art-game becomes a vital part in speculatively generating a 'natural' rejuvenation of the city. As the game never unfolds the same way twice, each experience is highly differentiated and multiple meanings layer on top of one another at the same geographical sites. During this active movement across an urban landscape, tangible changes are made by the participant, and each player is involved in a lively botanical re-inscription of the city (Wright 2018a). Members of the public are accorded a meaningful role as ecological change makers in their own community. Beyond the game, Thiel and Pappenheimer's real time re-assembly of a digital biome across the topology of urban physical space perhaps contributes to a shift in thinking urban design, introducing new design possibilities for a somewhat homogenous urban ecology of the contemporary city.

In opposition to the more mainstream uses of augmentation, Lev Manovich has cited artist Janet Cardiff's audio walks (dating back to 2005) as an exemplar of the poetic deployment of ubiquitous technology:

> Their power lies in the interactions between the two spaces—between vision and hearing (what users are seeing and hearing), and between present and past… (Manovich 2006, p. 226).

By directing the participant toward conflicting perceptual zones, Cardiff's work shifts conventional preconceptions about that space, transforming relations between participant and site. Janet Cardiff and George Bures Miller's *the City of Forking Paths* (Sydney, 2014–2017) places the participant in a situation where they must follow the audio-visual logic of an AR embedded video, along the exact cartography set out by the narrative. Participants play a video on their smartphone and follow along with the artists' shamanic audio-visual narrative as it meanders through The Rocks district in Sydney. Required to trace multiple narrative flows at the same time, the participant must attune to the work as it unfolds: the video stream playing constantly on the phone's screen; the binaurally recorded narrative that played through headphones; and, the parallel 'reality' of the street experience during the walk (Wright 2018b). These nuances are less narrative than embodied: they must pause and sit, walk, take multiple turns, follow a tunnel under a street, and so forth. Confronted with at times startling imagery on-screen—a phalanx of office workers dimly lit with mobile phones, a gagged man with duct tape over his mouth wearing a straight-jacket in Miller's Point—the participant must perceptually negotiate a parallel flow of experience between physical and digital. If they deviate from the 'forking paths,' they lose their place; for example, by taking a turn down the wrong street, they are cut adrift from the artwork, and the co-emergent experience of physical and digital experience is broken. In this way, the work operates alongside each person's sensory apprehensions and habits, foregrounding the role of the body in producing a MR experience rather than being framed by technical constraints such as screen, transmission and resolution.

In these mobile AR artworks, the movements of and between participant and smartphone work together to extend the augmented space into geographical space. Highlighting the embedded physical entanglement between mobile device and user, physical and digital mobilities extend the augmented experience toward a more complex and heterogenous material assemblage that does not exclusively reside in screen space. Art experiences that interpolate the performer or participant in extensive (outside the frame) and intensive (sensorial) compositional modes, explore AR from the standpoint of an embodied intra-action engaging participant, augments and ecology.

However, as I have argued, the application of categories, taxonomies or criteria to delineate and create inclusions or exclusions, would restrict MR discourse and practice in media art. Such an approach would offer limited chances for new senses of embodiment, restrict a participant's sense of agency in digital space, and overly program the shape of the MR experience for participants/performers. The informatic overlay approach was traced through diverse examples and revealed as a specific design approach where augments convey informatic content, shaped by Milgram and Kishino's taxonomy in co-operation with other programmatic mechanisms. The problems caused by a taxonomic understanding of MR were not solely concerned with the informatic overlay. They also related to the hardware devices that materialized digital augments—such as the HUD and the smartphone—as well as the design practices applied to the deployment of augmented material.

Closer to the interests of this study are MR experiences as bespoke relational arrangements or assemblages, manifest in the work of the artists discussed here, such as Blast Theory, Rafael Lozano-Hemmer, McCormick and Nash, Thiel and Pappenheimer, as well as Cardiff and Miller. Through attention to the various modes of augmented interfacing expressed in these new artistic paradigms, we have explored AR's capacity to generate interesting arrangements with code and bodies, encouraging experiences that beckon new modalities of embodiment.

As we saw through the analysis of *Sandbox* (2010), for example, augments must be given due consideration as nonhuman forces that prehend affect and beckon human bodies toward senses of embodiment that are spontaneous and emergent with a computational, algorithmic, and augmented network assemblage. Such a network assemblage has been configured using software as a responsive agent that co-creates in hybrids spaces and blended time scales, with human interlocutors. Furthermore, I have argued that the 'media assemblages' (Fuller 2005, p. 13) that have spawned the contemporary approaches to AR/MR discussed on this chapter, are always part of broader technosocial shifts; for example, the re-purposing of the phone as an entire medial space and a space for the emergence of new social behaviours. If we only see AR/MR as an information layer, we miss its capacity to provoke multimodal perceptions, and we miss the affective new senses of embodiment that emerge via the nuanced shifts in user/participant behaviours. Considering AR/MR as an aspect of algorithmic cultures in general, rather than as a purely technical medium for delivering overlaid content via a technical device, affords an approach that examines AR/MR beyond the informatic overlay. In fact, AR/MR is a kind of software assemblage that co-composes a set of evolving cultural behaviours and actions, taking a defining role in the shifting materiality of algorithmic culture.

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Chapter 13
Circumpolar Gamifications in the Age of Global Warming: Ice Levels, Anxiety and the Anthropocene

Nathan Shafer

Abstract From Frostbite to Never Alone, videogames have included tropes from Arctic cultures and biomes of the circumpolar north. The chapter looks at the representations of both culture and nature from the circumpolar north in mixed reality and videogames. This is explored through an historical analysis of videogames set in the Arctic, focusing mostly on Alaska, with a few works from media outside of mixed reality and videogames discussed. The chapter illustrates a history of games set in the Arctic, paired with how polar cultures are or are not accurately represented, what effects the global discussion on climate change has on these representations as well as the role of Indigenous sovereignty and justice. These issues are all compounded by a global anxiety associated with climate change/global warming, that leads to eschatological perseverations. The videogame Never Alone is the quintessential example of how northern culture and environmental issues can be used in a videogame without the follies of vestigial colonialist thinking. Augmented Reality (AR) works from the Dirigibles of Denali project by Nathan Shafer and Patrick Lichty, are discussed in these new contexts, with an emphasis on biomes, anthromes, and a new hybrid concept, the infome, which is a digital anthrome. Conclusions drawn are that Indigenous communities in the circumpolar north need to retain the control over their own infomes, which would include knowledge of their biomes and cultures, and how those are represented by the outside.

13.1 Introduction

> We are very much aware of the climate change, and it's been for many years, even before climatologists were noticing this change, Inuit were already saying, "Siḷa alaŋŋuqtuq." ("Our climate is changing.")
>
> —Ronald Aniqsuaq Brower, Sr., from "There Is No More Thick Ice", one of the Cultural Insights videos from Kisima Inŋitchuŋa (Never Alone)

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This chapter is going to look at a very specific way of participating in augmented reality videogames, by situating them in Alaska. To do this better, much of the chapter looks at the history of videogames set in Alaska, or the greater Arctic. Most of these games are not augmented reality, but are rather traditional videogames, which are completely virtual, even though they are not normally considered to be Virtual Reality. Regardless, classic videogames inform both Augmented Reality as well as Virtual Reality videogaming, and in the Mixed Reality Continuum, videogames can occur anywhere, as they are not specific to any one region of Mixed Reality. Meaning, videogames can be produced using Virtual Reality, Augmented Reality, Augmented Virtuality and in the Real World.

For further examples of videogames produced in all four realms of mixed reality, go to Sect. 13.5 'Somethings Everywhere' in this chapter and scan the image of the Mixed Reality Continuum using the HP Reveal AR app. Follow the Shared Universe channel to get the augments on your device.

13.2 Nuna and Siḷa

Ice levels have been a gaming trope since arcades began housing videogames for the general public to play in the late 70s and early 80s. Not long after videogame arcades appeared, home consoles revolutionized videogames by bringing them into the home. Today videogames are mobile, can be played virtually anywhere and are integrating mixed reality—inserting geolocations, and live video recordings into the experience. Augmented reality games at the moment are struggling to find their footing in this expanded space, harkening back to the early arcade games by bringing people together in social spaces. These social spaces where mobile videogames are being played harbor a significant amount of anxiety in the larger media ecology in that they are redefining our experience of the real world. People are spending more time looking at screens, because they have uninterrupted access to them. Futurists are predicting the eventual embedding of screens into our biology, via lenses on the eyes or screens networked into our brains. Whether this scenario may play out or not, the notion itself, has a significant portion of the global population worried about an end of the real world. This anxiety of a simulated world built onto our collective experience of the real one is creating a speculative space that is a digital extension of the anthropogenic biomes, which we currently inhabit.

Ice levels are a simulation of the cryosphere, the sphere of the Earth that is frozen fresh water, slowly moving on top of the continents. In 2012, the author began a project called *Exit Glacier*, which recreated five of the former termini at Exit Glacier, outside of Seward, Alaska. Exit Glacier (Fig. 13.1) is one of the poster children for global warming and glacial retreat. It is also one of the world's most popular drive-up glaciers. *Exit Glacier* was built on location using augmented reality using a now obsolete third party AR platform, Junaio, which is fitting because at the time of the creation of *Exit Glacier*, there were more pixels standing in for the real life Exit Glacier on location than there was actual glacier. When Junaio went down, the AR

Fig. 13.1 Exit Glacier (2014) (Photo by Patrick Lichty)

Fig. 13.2 Ice Level in Sourpunk, Cyberdough (Nathan Shafer, 2015), geolocation based augmented reality videogame situated across the Kenai Penninsula (Photo by Nathan Shafer)

simulation was lost as well, just like the real glacier, so now there is an archive of the simulation that was recreating the original glacial faces. Soon, with the rapid retreat of this once enormous glacier, we will have only an archive of all that it once was. It will be an ice level that users can 'play' and in 2015 the author built a site-specific AR videogame at the same location called *Soupunk, Cyberdough* (Fig. 13.2), where players collect magical items like time-traveling ingots, moose nuggets and fireweed. Using the same Junaio platform, *Sourpunk, Cyberdough* was turned into a target-based AR game built on top of a series of independently published Alaskan comic books entitled *Sowsear V/Wintermoot V* organized by Alaskan artist Jimmy Riordian (Fig. 13.3).

As global warming is encroaching more and more into the cryosphere in the real world, we are left with several unique problems in the representation of the Arctic and other frozen parts of the world in our virtual realms. Here it is important to

Fig. 13.3 Sourpunk, Cyberdough (Nathan Shafer, 2015), target based augmented reality videogame as part of Sowsear V/Wintermoot V (Photo by Nathan Shafer)

define two words from the Iñupiaq language: nuna and siḷa. (The Iñupiat are an Inuit people who live in the north of Alaska.) Nuna is the Iñupiaq word for Earth, or the land, and also the name of the protagonist in the 2014 videogame *Kisima Inŋitchuŋa* (Never Alone) (Fig. 13.4) from Upper One Games. *Kisima Inŋitchuŋa* was written by Tlingit/Iñupiaq raconteur and poet Ishmael Anguluuk Hope, based on a story told by Robert Nasruk Cleveland, which was originally about a young man who must find the cause of a mighty blizzard and right was is wrong with the nuna. Cleveland's story was entitled *Kunuuksaayuka* and was included in his short story collection from 1980, *Unipchaanich imagluktugmiut* (*Stories of the Black River People*). Cleveland's story is itself a retelling of a story that has been with the Iñupiat for thousands of years. Hope's retelling of this story turns the protagonist into a young girl named Nuna along her companion, an Arctic fox. Siḷa is a much more complex term than nuna and means many different things: weather, atmosphere, climate, space, outer space; and it has a soul, it is a presence. As Fannie Kuutuuq, one of the Iñupiaq elders consulted for *Kisima Inŋitchuŋa*, "it's anything from the land, into the moon, the sun, the stars. That's siḷa." The notion of siḷa is important here as it will inform how we use technology to represent cultures who make their home in or near the cryosphere, and it is reflected in more recent philosophies which look to better understand the way humans inhabit the worlds above the land, from the noosphere, to telespheres and eventually space colonization.

In the game itself, players can either play as Nuna or the arctic fox. This animal/human team stays together throughout the entire game. One is vitally connected to the other, and there are moments were switching between the two is necessary.

Fig. 13.4 *Kisima Inŋitchuŋa* (Never Alone), (Upper One Games, 2014), videogame

In *Staying with the Trouble: Making Kin in the Cthulucene* (2016), Donna Haraway, discusses the issue of a multi-species world, where humans decentralize themselves as the most important species on the planet and learn to interconnect in a multiple species world. One of the chapters looks at sympoiesis (collective creation), world games and specifically *Kisima Inŋitchuŋa.* Videogames are often designed sympoietically, and *Kisima Inŋitchuŋa* was one of the first games to be collectively organized and developed between Alaska Native groups and videogame developers. Haraway states that "even though the models of sympoiesis are expandable, it is critical not to once again raid situated indigenous stories as resources for the woes of colonizing projects and peoples, entities that seem permanently undead" (Haraway 2016). To state it another way, it is important that as new sympooetic projects are developed, that cultures are represented appropriately.

13.3 Frostbite Bailey

An early home console videogame, *Frostbite* (Fig. 13.5), for Atari 2600, designed by Steve Cartwright for Activision in 1983, was one of the first to be set entirely in the Arctic—every level was an ice level. It combined puzzle-like gameplay elements from previous arcade games like *Q*bert* and *Frogger*. The main character, Frostbite Bailey, jumps between ice floes, avoiding treacherous creatures like snow geese, as players try to build an igloo every level by jumping on the moving ice. The igloo must be built in 45 s, which is also the temperature the game starts at. Every second, the temperature goes down by one degree, and when the clock/temperature counts 0, the level is over. This is an old model of action games, where the same basic actions are performed every level with an increase in either speed of play, or intensity.

Action games like *Frostbite*, *Q*bert*, *Pac-Man* or *Frogger*, are all significant in that there is no end to them, they could theoretically go on forever. The game ends

Fig. 13.5 Frostbite (Activision, 1983) videogame for the Atari 2600

when one dies. It is an intense imitation of life, covered in an insatiable anxiety: do the same thing over and over, with increasing intensity until you die. There is no real reward, nor winning, just doing more than others by comparison. This ubiquitous anxiety embedded in the gameplay itself perfectly illustrates Slavoj Žižek's notion that "the only emotion that does not deceive is anxiety. All other emotions are fake" (Fig. 13.6). This same anxiety is exhibited in the social acceptance of global warming, as ice levels replace our cryosphere and we are left with the real world consequences.

In the early arcades, the high scores posted on the games' start screens functioned in a competitive manner similar to children winning a spelling bee or aunties taking the blue ribbon at the State Fair. One gets to win the title and hold the mantle for only a short while. It is an anxiety of everyday life, what Michel de Certeau calls 'tactical' behaviors in his book, *The Practice of Everyday Life*. De Certeau's counter-concept to 'tactical' behavior is 'operational' behavior, where humans produce the operational structure of a system, rather than work within its confines. This can be seen as the difference between designing a game (operational) and playing a game (tactical). This is not a new binary when looking at videogames, but it will inform how I am framing the usage of ice levels when designing videogames in the age of global warming.

With early videogames, the computing power of the game engine was the main hindrance to game play going on ad infinitum. At an operational level, these games were all coded in binary, meaning that all aspects of game play, from colors, sounds, graphics and especially the level counters were base-2, and could not reset after going through all 256 bits of a byte (2^8), hence the infamous level 256 of *Pac-Man* (Fig. 13.7) where the entire game glitches out, freezing, ending game play. Restarting

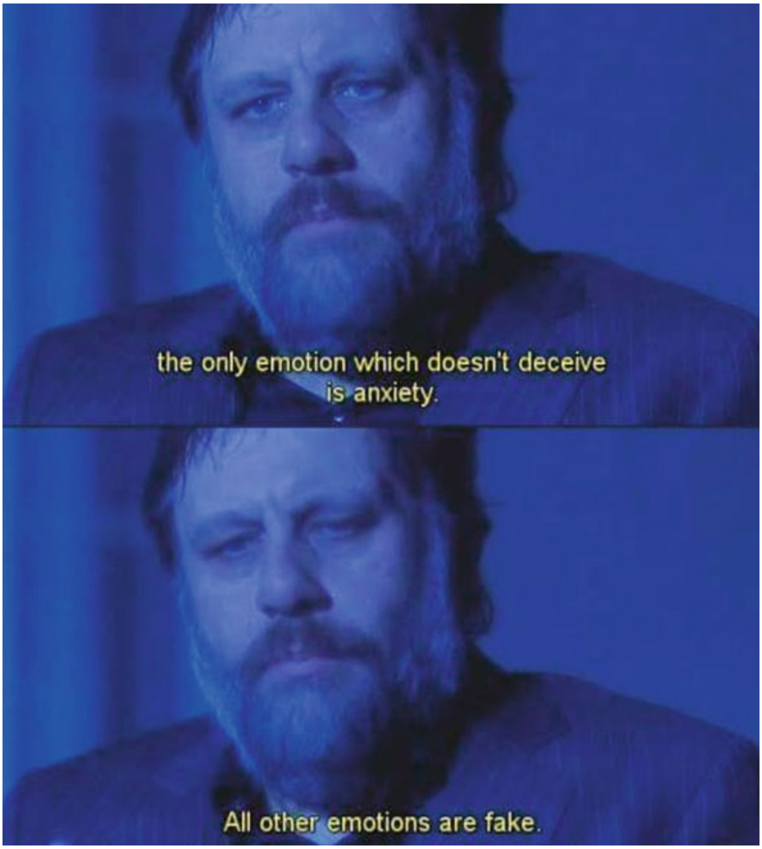


Fig. 13.6 Žižek 'Anxiety' Meme by (2017), stills taken from Pervert's Guide to Cinema (Žižek 2006)

is really the only option. Once the computing power of game engines were able to accommodate infinite play, games began to reintroduce perpetual action, and more recent mobile games such as *Temple Run* use this same game structure, creating a rather addictive set of game play, with little pay-off in the end. This apocalyptic level of anxiety permeates the digital snowflakes of the ice levels in the Anthropocene.

13.4 Nana and Popo

The Anthropocene is a philosophical model for the geologic age of humans, where in it is postulated that humans are the most significant factor in the current geological epoch. In the Anthropocene, with human-caused global warming changing the Arctic, ice levels have come to represent something more than just a wintery redux of a

Fig. 13.7 Level 256 of the original Pac-Man videogame (Namco, 1980), videogame, arcade game

game's standard operating procedure. That is, they are not just a winter version of a level. They are becoming a fantasy of real-life biomes the way we imagine they should be in real life, or a whitewashed version of the way they used to be.

Nana and Popo, the two main characters from the 1985 NES game *Ice Climber* (Fig. 13.8) spend the game destroying ice blocks with large wooden mallets to try and save their store of vegetables from a rogue kleptomaniac condor. An updated version of the game may instead be Nana and Popo fighting like hell to keep the ice frozen to preserve their way of life. It is of note here that when Frostbite Bailey lands on an ice floe the ice turns glacier blue, though that aesthetic decision was probably not a metaphor for humans undoing climate change. At least with *Frostbite*, there is a modicum of care put into the character sprites being part of the natural environment they are representing. *Ice Climber* has instead taken a more cartoonish approach in its design with seemingly random elements in the game play that do not reflect

Fig. 13.8 Ice Climber (Nintendo Entertainment System, 1985), videogame

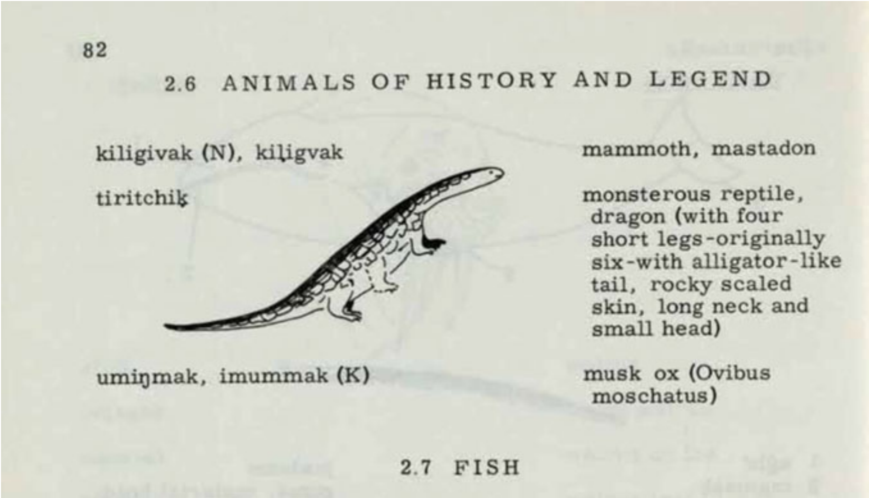
the mental spaces of the cultures being represented (Nana and Popo are generically Inuit).

In games like *Ice Climber*, there is a tendency to insert global cultural norms into the structure of the game that miss major opportunities to represent local cultures. There is a wealth from the Inuit fantasy realm, or natural world, which could have been used in place of condors and vegetables. For instance, there is a storied tradition of Iñuqułłigaurat (Fig. 13.9), or Little People, in Inuit lore, possessing supernatural strength and living underground. These characters appeared in *Kisima Inŋitchuŋa* and were beautifuly illustrated by George Smart for the Iñupiatun publication *Iñuqułłigaurat, Ahvakana*, written by Avaqqanum Quliaqtuaqtaŋik Floyd in 1970. There are legends of dragon-like creatures called Tiritchik (Fig. 13.10) which used to have six legs, but now have four, and can be seen as painted decorations on the Iñupiaq umiak, or sea boat. A good illustration of them can be found in the *Iñupiat-Eskimo Dictionary* from 1970, illustrated by Thelma Webster. There is also the Qupquġiaq (Fig. 13.11), a ten-legged polar bear. Another fairly common trope in Inuit stories is the evil being Manslayer (Fig. 13.12), who is the cause root for many wrongs in the world, and can be found in *Kisima Inŋitchuŋa*. Any one of these alternative elements could have been used in place of the condors, and may have actually been more exciting in the game play. There is also no real reason why the vegetables needed to be eggplants and tomatoes, there are many plants harvested by First People in the Arctic, which would have worked just as well: berries, tundra herbs or even small mollusks which are commonly referred to as ‘sea vegetables’ and are eaten frozen.

Looking at *Kisima Inŋitchuŋa* as an example of successfully inserting Inuit thinking and stories into its gameplay, we see examples how it can increase the enjoyment

Fig. 13.9 Iñuqułłigaurat, Ahvakana (Floyd, Avaqqanum Quliaqtuaqtaŋik, 1970) Alaska Native Language Center

of the game by earnestly incorporating elements from the real world in an authentic and culturally appropriate manner. In the first level, the game's protagonist, Nuna, must go retrieve Owl Man's drum that was stolen by Iñuqułłigaurat, by descending into their underground world. We will return to *Kisima Inŋitchuŋa* again, but as an example, *Kisima Inŋitchuŋa* stands by itself in being able to incorporate local knowledge and magical thinking without any hindrance to the enjoyment of the game's play, in fact it is one of the games many strengths. In the first drafts of *Kisima Inŋitchuŋa*, the developers had a platform game that mirrored other previous platform games from the past. Hope suggested that since the game was about a young Inuit girl who was living several thousand years before contact with Europeans, that her worldview would not have a western feel. The usage of space the characters inhabit in the game needed to reflect an actual Iñupiaq worldview. The developers of the game agreed and retooled the game to reflect the Iñupiaq concept of siḷa, among many other things. In



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2.6 ANIMALS OF HISTORY AND LEGEND

kiligivak (N), kiḷigvak — mammoth, mastadon

tiritchiḳ — monsterous reptile, dragon (with four short legs-originally six-with alligator-like tail, rocky scaled skin, long neck and small head)

umiŋmak, imummak (K) — musk ox (Ovibus moschatus)

2.7 FISH

Fig. 13.10 Tiritchik entry (Webster, Eskimo English Dictionary, 1970) (Illustrations by Thelma Webster)

the game, helpful spirits from the siḷa can enter into reality when the game is being played correctly, to assist Nuna in her tasks. In some cases she must learn how to harness the siḷa when it is doing things like creating overpowering winds, instead of getting blown over, Nuna must ride the wind to high ground. In the context of the magical thinking needed to create the worlds inside of videogames, siḷa is a perfect fit, providing a completely new vehicle through which videogames can be played. As we look at a few other videogames that host ice levels in them, it is important to see an example of how Indigenous knowledge can be put into games, increasing the role videogames play in the larger media ecology in a positive and sustainable way. Most other videogames do not do this, at an operational level, so it becomes a tactical format that artists/developers must use to connect previously produced videogames into this larger discussion of cultural representation and global warming.

For example, inserting global warming or Inuit lore into the game play of *Ice Climber* is a thought experiment in mixed reality—adding something from the real world into the virtual environment of a videogame tactically. As part of the *Dirigibles of Denali* project (Fig. 13.13), Nathan Shafer and Patrick Lichty have used a sprite editor to remix the sprites of *Ice Climber* into an augmented reality videogame, replacing the characters of Nana and Popo with Aqpik and Mars Apple (a mother daughter superhero team), set in the unrealized Alaskan metropolis of Denali City, in an AR videogame entitled *Cloudberry Tapestry: Denali City* (Fig. 13.14). Denali City, proposed by Senator Mike Gravel, in 1972, was to be a semi-domed city placing large Teflon tents above a winter-themed city. That Denali City is in fact a real city that was never built is another iteration of mixed reality thinking, a kind of aesthetic method that is developing inside of the larger mixed reality scene. *Kisima Iŋŋitchuŋa*

Fig. 13.11 Qupqugiaq, Ahvakana by Floyd, Avaqqanum Quliaqtuaqtaŋik, Alaska Native Language Center

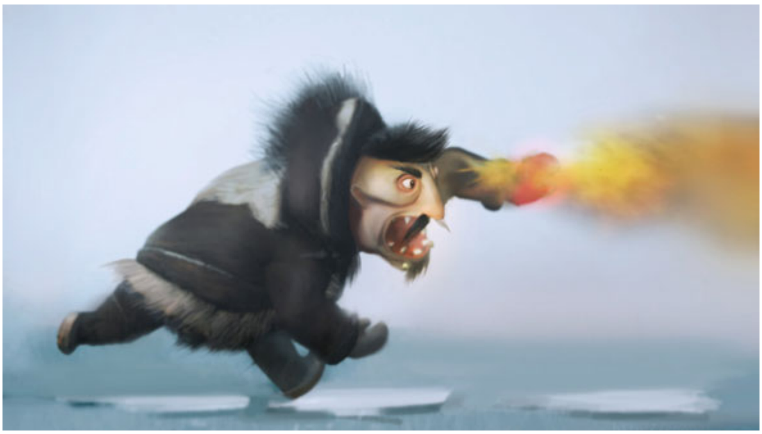


Fig. 13.12 Manslayer from *Kisima Inŋitchuŋa* (Upper One Games, 2014), videogame

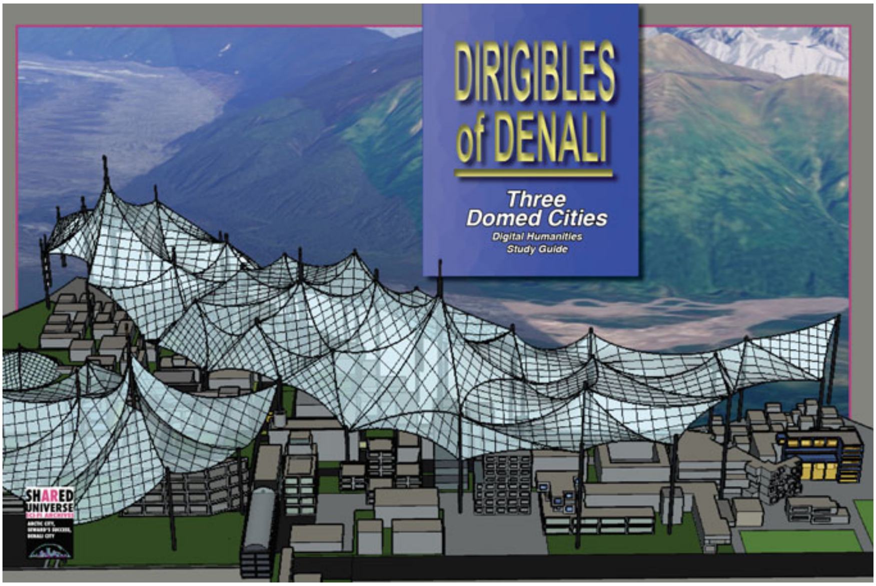


Fig. 13.13 Dirigibles of Denali (Nathan Shafer and Patrick Lichty, 2018), geolocation and target based augmented reality, interactive text, videogames, alternate history, speculative fiction

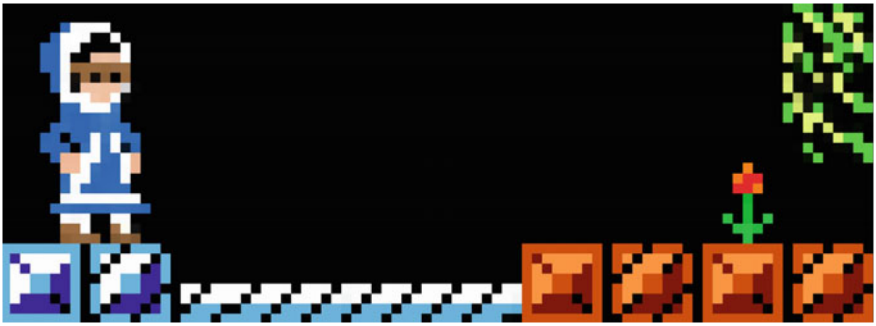


Fig. 13.14 Cloudberry Tapestry: Denali City by (Nathan Shafer, 2018), augmented reality videogame

is in the same camp here as mixed reality (the Real Environment, Real People telling stories) are placed into a virtual environment. In fact, the videos from the real world featuring a cast of Iñupiaq people are what players earn when they finish levels.

13.5 Somethings Everywhere

The standard model being used for the definition of mixed reality was developed by Paul Milgram and Fumio Kishino in 1994, and defines four main areas constituting a continuum of mixed reality: Real Environment, Augmented Reality, Augmented Virtuality and Virtual Environment (Fig. 13.15). This linear continuum is specific to a "Reality—Virtuality Continuum" with computers being necessary for all areas except for the Real Environment. Other interpretations of this continuum model place non-digital information into the continuum: site-specific myths, theme parks, tools used to better perceive the real world and various other extrasomatics.

Inside the anxiety of what a consensus definition of mixed reality is—there are conceptual variations for when something becomes gamified. Gamification is a deceptively simple way to increase a user's attention, turning the anxieties of existence into a participatory interface by leveraging our innate need for social interaction in social spaces. But it is the 'something' that is the key. 'Something' is gamified. It unlocks something else. All other aspects of a mixed reality, whether they are digital or not, leverage aspects of human anxiety into passive entertainments, or extensions of perception.

Creation stories are human fantasies augmented over place or time. Cinema and virtual reality are a rearrangement of the world into new fantasies. It is all a speculative endeavor, accumulating over the natural world. New 'somethings' everywhere, with more being added every moment, as others languish under the heap of new fantasies. Scientific instruments used to measure the universe are of the same order, increasing human understanding of the Real Environment by unlocking something, to get to something else. In Žižek's terms, this is our 'subject', "a partial something, a face, something we see. Behind it, there is a void, a nothingness. And of course, we spontaneously tend to fill in that nothingness with our fantasies about the wealth of human personality, and so on" (Žižek 2006).

There is an anxiety at the root of every human interaction with the infinite number of 'somethings' out there. There is a sense that we are continually unlocking new somethings, moving into an ultimate final level. Gamification implies that we can

Fig. 13.15 Mixed Reality Continuum reproduction made for the Dirigibles of Denali: Three Domed Cities (2018), (original source: A Taxonomy of Mixed Reality Visual Displays, (Milgram P, Kishino F 1994)

finish, that we can beat it, that it will end with us victorious. The gamification of the natural world would imply that we can, and will, win existence. It is just another level. Perhaps action games like *Frostbite* are appreciative of the human condition here, by imitating the endless actions of our existence.

Augmented videogames are an example of 'somethings everywhere', as they can be both in augmented reality and augmented virtuality, without much consideration on the viewer's end of what they are actually participating in. Digital gamification, specifically videogamification, in the broadest sense can be seen as a process in the realm of digital storytelling, that is the work's interactivity is contingent on the user's choices in a predetermined set of cultural norms woven together to tell a story, through the use of a computer. These digital stories are more connected to an oral tradition, or social games than they are to literature or cinema, but they incorporate those same elements in a manner similar to how performance art or earth art incorporates photography or videography, without being artistic photographs or videos. They are documentation of something else. Videogames use the methods of literature and cinema to tell their stories, but are not those things in and of themselves, they are a different bird all together and much is lost when we spend time analyzing them as such, much as we lose the aesthetics of earth art when we overanalyze photos of earthworks as stand-alone photographs.

Videogames built into augmented environments are most widely known in their global iterations, in games such as *Pokémon GO* and *Ingress*, but interactive POIs have always been a part of augmented reality. From Warren Armstrong's *Quantum Frogger* (Fig. 13.16) to Sander Veenhof's *Global PONG* (Fig. 13.17). The way these works gamify global culture, are through a generalist evolutionary model, how cockroaches or squirrels become ubiquitous because they generalize rather than specialize. This is an important distinction because generalized global augmented videogames are pervasive at the expense of specialized or localized augments. Site-specific videogames, or augments for that matter, are contingent on local users for survival in the media ecology.

13.6 Global Warming and Monoculture

The effects of global warming can be seen and felt around the globe, but are of specific significance to the poles and the tropics. While things like sea level rise, or increasingly extreme weather events are terrorizing the tropics, we are mostly focused on the Arctic here. Global warming is transforming the biomes of the Arctic in a way that is detrimental to cultures in the Arctic that are not generalist in their evolutionary model. To say it another way, in tandem with global warming, a global monoculture is over-riding local and Indigenous cultures as their biomes are changing. While it may be true that some of the many cultures of the circumpolar north are at risk of becoming extinct, population models of the communities suggest that they are not going anywhere, although their languages and cultures are trending towards cultural absorption into a global monoculture. That is, they are trending that way unless

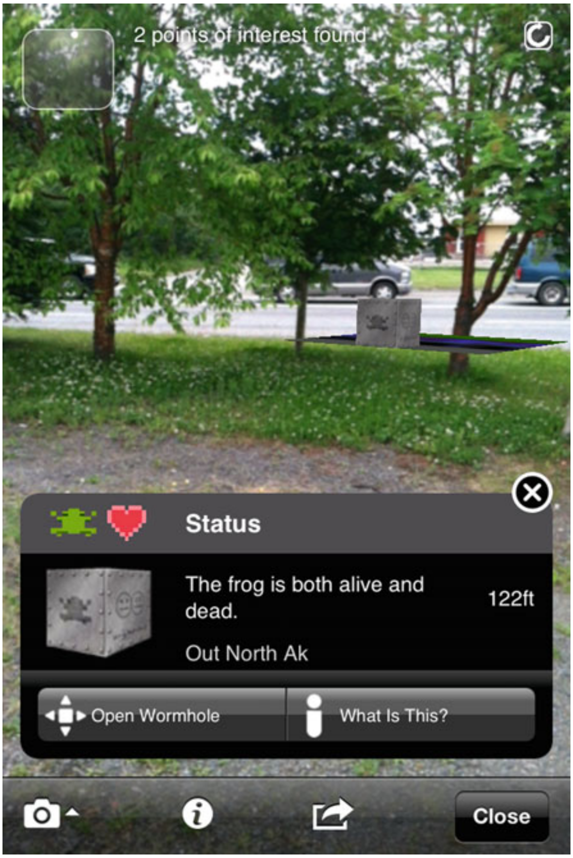


Fig. 13.16 Quantum Frogger (Warren Armstrong, 2012), augmented reality videogame

Fig. 13.17 Global PONG (Sander Veenhof, 2012), augmented reality videogame

serious care is put into practicing them, and in some cases restoring and preserving them. With an overabundance of non-Natives in places like Alaska, it becomes crucial here that the people of the monoculture (read 'white Alaskans') take care to learn and participate in the Indigenous cultures where they live. In Alaska, there is an over-whelming tendency to see all Alaskans as simply Americans, at the expense of the identities of the people who have lived there for thousands of years and are the rightful caretakers of that place.

13.7 Infomes, Virtual Anthromes

In the parlance of the Anthropocene, there is a new biome: the anthrome, or the anthropogenic biome. It is a human biome that has changed the original biomes of a place into one tailor-made for human usage. These can be anything from farmlands, landfills and cities to massive mining operations such as is found in the North Slope of Alaska. When humans finally venture into the solar system and beyond to colonize new places to live, we will be creating new anthromes to live in that will regulate and maintain environments that will keep us alive in a foreign environment.

The *Dirigibles of Denali* project incorporates the notion of how humans create artificial environments in Arctic biomes. *Dirigibles of Denali* is a recreation of the three actual domed city proposals in Alaska from the 1970s: Arctic City by Frei Otto (Fig. 13.18), Seward's Success by Tandy Industries (Fig. 13.19) and Denali City by Senator Mike Gravel (Fig. 13.20). Each of these cities was created in augmented reality using the original city planning specifications found in Alaskan archives. The virtual cities were then placed in situ on their proposed locations. Along with the augmented reality versions of these cities, speculative fiction was commissioned of Alaskan authors to imagine what life might be like in them. In the work, the domed cities were treated as retrofuturistic attempts at creating space colonies.

At the moment, we are not creating anthromes on other planets, but we are creating hyper-anthromes in the virtual spaces we already inhabit. I am going to refer to these virtual hyper-anthromes as 'infomes', as they are a way to create anthropogenic biomes in infomatic or virtual spaces. Before the digital age, these spaces were used to store knowledge of the natural world, the oral tradition and our collective unconscious. Infomes are cybernetic by nature, and are extensions of FM 2030' a notion of 'telespheres', Pierre Tielhard de Chardin's concept of the 'noosphere' and the 'ideopshere' from memetic theory, as championed by Aaron Lynch and Douglas Hofstadter in the 1980s. They are also based very judiciously on the Iñupiaq concept of siḷa, which *Kisima Inŋitchuŋa* so wonderfully brought into the larger mixed reality consciousness. One of the main differences that infomes possess related to these other concepts is their site-specificity—they are heavily connected to temporal-spatial locations, and are very much connected to a civilization's physical presence in a specific place. Infomes are owned by the denizens of a place—they concern Indigenious sovereignty and are constantly in danger of being eradicated by global monocultures, which function like invasive species inside of infomes.

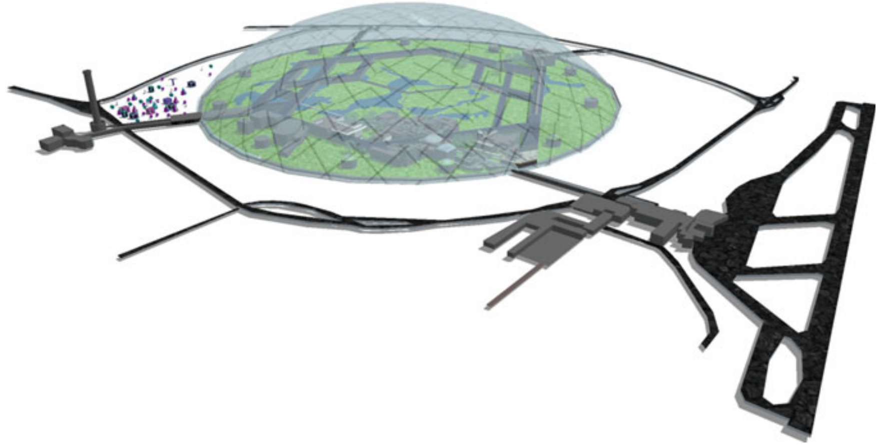


Fig. 13.18 Arctic City (Nathan Shafer, 2018), geolocation based augmented reality from Dirigibles of Denali

Fig. 13.19 Seward's Success (Nathan Shafer, 2018), geolocation based augmented reality from Dirigibles of Denali

For cultures on the fringes of the global monoculture, infomes are some of the last vestiges they have of maintaining site-specific control of the virtuality above their anthromes. One of the ways the global monoculture is consuming these cultures is through the representation of them in the global media ecology. For example, the way Inuit or Dene are portrayed in the media by people who are not part of, or at least aware of those cultures, produces works that castrate these cultures and create false narratives or representations of them. However well-intentioned these global representatives of other people's cultures are, they tend to rely on stereotypes or assumptions of the site-specific Indigenous groups and become the de facto experts on their existence. A lingering example of this is that the cartoon penguin Chilly Willy (Fig. 13.21) is still the most famous fictional character residing in Alaska. What may

Fig. 13.20 Denali City (Nathan Shafer, 2018), geolocation based augmented reality from Dirigibles of Denali

seem innocuous is in fact a deep colonial overreach of the global monoculture into the regional infomes of Alaska. For instance, in the 2011 movie *The Big Year*, about two men in competition to have a 'Big Year' (a bird watching competition to identify the most birds in a single calendar year) adds penguins suspiciously nesting in the Aleutian Chain into a montage of birds being identified by the main characters. Several Alaskan tourist websites even add penguin pages onto their sites to meet the demand by enthusiasts. In reality, penguins do not naturally live in Alaska and function only as a signifier to the notion that it is cold in Alaska, and penguins are visual representations of the cryosphere in a global monocultural context. We see penguins, we think cold. Reality television has only compounded this overreach. Its effects are devastating infomes in Alaska, as that old 'North to the Future' mentality has created a cottage industry of toxic fantasies about life in the north, with its seemingly infinite accumulation of Alaskan-based reality shows.

An intriguing science fiction story, entitled *Nuniva* was written in the early 90s by a Siberian Yupik seventeen-year old named Merle Apassingok and was included in *Tales From the Great Turtle*, a collection of Indigenous fiction from North America in 1994. It is the story of a young man named Nuniva who ends up killing one of his friends one winter in a dispute while playing cards. During his sentence in a low-orbit prison, Nuniva is offered participation in an experimental program where inmates are placed into therapeutically designed virtual biomes for the duration of their prison sentences. Nuniva asks to be placed in an Arctic biome, but is eventually limited to a few hours a day and ends with him enjoying the few moments of an environment his body and mind yearn for.

Fig. 13.21 Chilly Willy (Paul Smith for the Walter Lantz Studio, 1953), animated television show

Nuniva is a striking example of how people participate in the ownership of their own infomes, and a rather fascinating take on the concept of siḷa. It is also a perfectly mannered embodiment of the way people use virtual reality as a projection of what is missing from their own realities. Nuniva's anxiety to return to life in an Arctic biome is his only emotion that does not lie to him, to return to Žižek for a moment.

13.8 Gamification of Megafauna in the Anthropocene

A more recent videogame published by Activision, the same company who brought us *Frostbite*, is the first-person shooter game, *Cabela's Alaskan Adventure* (2006) (Fig. 13.22), designed by Christian Gabriel Radu and Deodar Popa for PC, Xbox and PlayStation, is a literal extension of the colonial monoculture into the infomes of Alaska. Even with the due diligence put into a factual rendition of the megafauna in Alaska, it is clouded by the game's purpose: trophy hunting. It is telling that one of the first videogames to accurately portray Alaska's biomes does so only to gamify megafauna for a virtual hunting experience. Couple this with the notion that global warming is destroying the habitable land of these creatures, the anxiety inside of this game is evident in the collecting of the increasingly rare big game in Alaska, due to the loss of their natural habitats. In fact, one of the trophy hunts is for the glacier bear, or blue bear, a sub-species of black bear that lives near glaciers.

Fig. 13.22 Cabela's Alaskan Adventures (Christian Gabriel Radu and Deodar Popa, 2006), videogame

Similar to the accurately represented gamification in *Cabela's Alaskan Adventure* is *Eskimo Games* from 1991, for Commodore 64. Or at least it looks to be; the game was designed by Magic Bytes in 1989, and has several different methods of gameplay, which are pretty typical for sports videogames featuring unique sporting events. The selection of game modes in *Eskimo Games* however is quite elucidating: one level has players shooting snowballs at anthropomorphized polar bears (Fig. 13.23) and townies on snow machines, another is on the side of a sea cliff, where the player must collect sea bird eggs, without colliding with the sea birds (Fig. 13.24). The collecting of sea bird eggs is a very unique aspect of almost every Indigenous culture in the Arctic, and its inclusion on this game is intriguing. The specifics of collecting sea bird eggs in *Eskimo Games* however reflects some of the same issues that other games do: specifically, unforced errors versus creative license. To illustrate, in the game, when birds are sitting in their nests to lay eggs, they read a newspaper. This is obviously not an accurate portrayal of the natural world, but it is a creative abstraction of the natural and social spheres that is completely fine. As a symbol for the passage of time, it does better than a penguin signifying cold. Counter to this: some of the sea birds in *Eskimo Games* are pelicans, which of course, are not indigenous to Alaska,

Fig. 13.23 Snowball Shoot from Eskimo Games (Magic Bytes, 1991), videogame

Fig. 13.24 Seabird Egg Collecting from Eskimo Games (Magic Bytes, 1991)

or the circumpolar north. This is just an unforced error, a Chilly Willying of the Inuit worldview.

The last two game modes in *Eskimo Games* get a tad bit more cartoonish and bizarre. One of them has the hero aggressively serving ice cream sundaes to town's folk and the random biker polar bear, in a manner similar to the breakneck pace of games like *Pac-Man* as the game goes on. Another level has the hero building an igloo while jumping over seals that keep popping up out of ice holes.

Another Commodore 64 videogame was 1984s *Chilly Willy* written by Ken Pletzer and Chris Hart, to return to the penguin. *Chilly Willy* is a simple puzzle game, where players build igloos, and of little significance, as are videogames such as *Spy vs. Spy: Arctic Antics* (1989) and *Thin Ice* (1986) (another game with penguin protagonist).

13.9 Cheechako Wizard Suicide Runners

Building on the anxiety of the Arctic as a dangerous place, which needs to be conquered is the 1982 coin-operated arcade videogame *Freeze* (Fig. 13.25). Its production predates *Frostbite* by a year, but does little in the way of representing anything but ice in the Arctic. A man is trapped in the ice and must use a flamethrower and his jetpack to escape. The Arctic as a setting here could literally be anywhere else where there is ice: Antarctica, Saturn's moon Titan even. *Freeze* is probably the first actual videogame set in the Arctic, but its concept is too generic to garner much mention by way of the notion of ice levels. What is of note here however is that the ice is seen as a net negative that must be overcome, much in the way that the domed cities of Arctic City or Seward's Success in the *Dirigibles of Denali* project were created as anthromes to conquer the natural world of the Arctic. This is not the same deep notion of the natural world that the siḷa represents, one that gets to be good, bad and everything in between, and has a soul.

Another videgame that was turned into a tactical augmented reality videogame in *Dirigibles of Denali* is 1991s *Arctic Adventure* (Fig. 13.26) for DOS, designed by the great videogame designer George Broussard. *Arctic Adventure* is a platform game that is the sequel to Broussard's *Pharoah's Tomb* and a prequel to his *Monuments of Mars*. The protagonist is Nevada Smith, an adventurer based very loosely on Indiana Jones who is traveling the Arctic in search of buried Viking treasure. Gameplay for *Arctic Adventure* borrows heavily from the *Super Mario Bros.* games in that it reuses the tropes of collecting keys and coins, begins with an over-world map and travel to different levels happens via magical pipes in the virtual environment. Like Nuna in *Kisima Inŋitchuŋa*, Nevada Smith has infinite lives, the levels can be played over and over again until they are completed. Both of these games, *Kisima Inŋitchuŋa* and *Arctic Adventure* address the anxiety of existence in this way, by making the finality of death irrelevant.

In *Dirigibles of Denali: Cheechako Wizard Suicide Runners* (Fig. 13.27), by Nathan Shafer and Joelle Howald (2015) the sprites from *Arctic Adventure* were transformed, in the same manner as the *Ice Climber* sprites were. The videogame premiered at Practice Gallery in Philadelphia, PA (Fig. 13.28a–c). The augmented reality videogame produced using the sprites from *Arctic Adventure* ended up being a site-based racing/combat fishing game called *Cheechako Wizard Suicide Runners*. A suicide run is a cultural term in the Anchorage Bowl which refers to something that happens in the summer when the salmon are spawning. In the month of July, a person works a full day at their job, then drives four hours to the Kenai River to

Fig. 13.25 Freeze (Cinematronics, 1982), Arcade Game

dipnet red salmon all through the night, then drive 4 h back into Anchorage and work another full day at their job. That is a suicide run, and it is a real thing.

In *Cheechako Wizard Suicide Runners*, the runners begin at the air tram from Seward's Success into Anchorage. This air tram was never actually built, just like the city of Seward's Success, and is the first of the infamous 'bridges to nowhere' in Alaska that gained prominence in popular culture during the 2008 presidential race as a conservative talking point. The air tram was also supposed to circumambulate the entire city of Anchorage, terminating at the Kink River going into Seward's Success. The sprites in *Cheechako Wizard Suicide Runners*, are all remixes of the original sprites from *Arctic Adventure.* The main characters are based on Nevada Smith's character, with the addition of a point at the top of his hat, which could either be read as a high-fantasy style wizard hat, or a traditional Tlingit cedar hat from Alaska. The characters names are based on the extrapolation of the name Nevada Smith from Indiana Jones, using that algorithm as the nomenclator: first name is one of the fifity states, and last name is one of the fifty most common surnames in the United States,

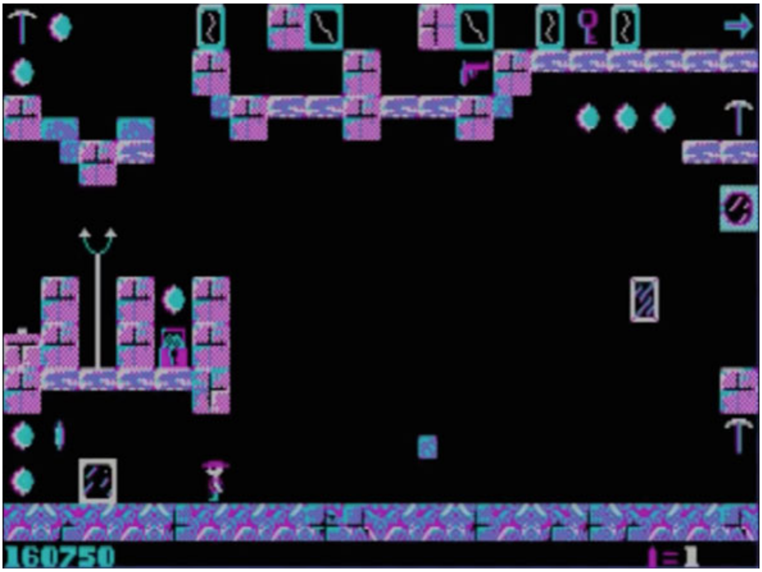


Fig. 13.26 Arctic Adventure (George Broussard for Apogee Software, 1991), videogame for DOS

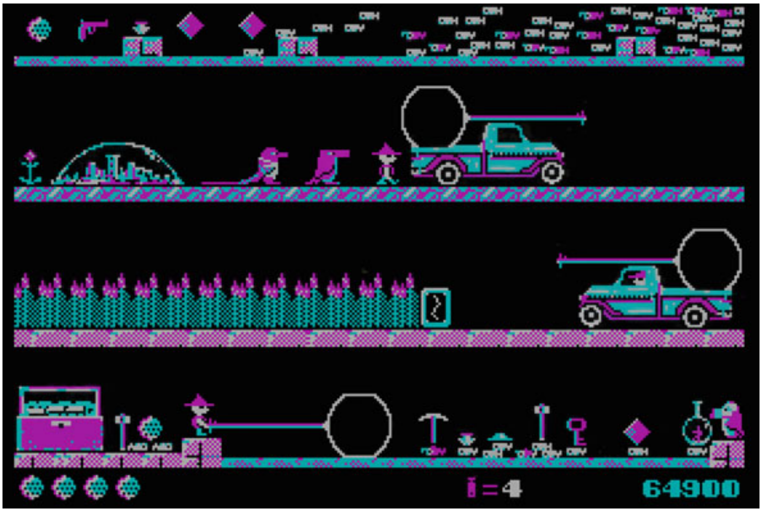
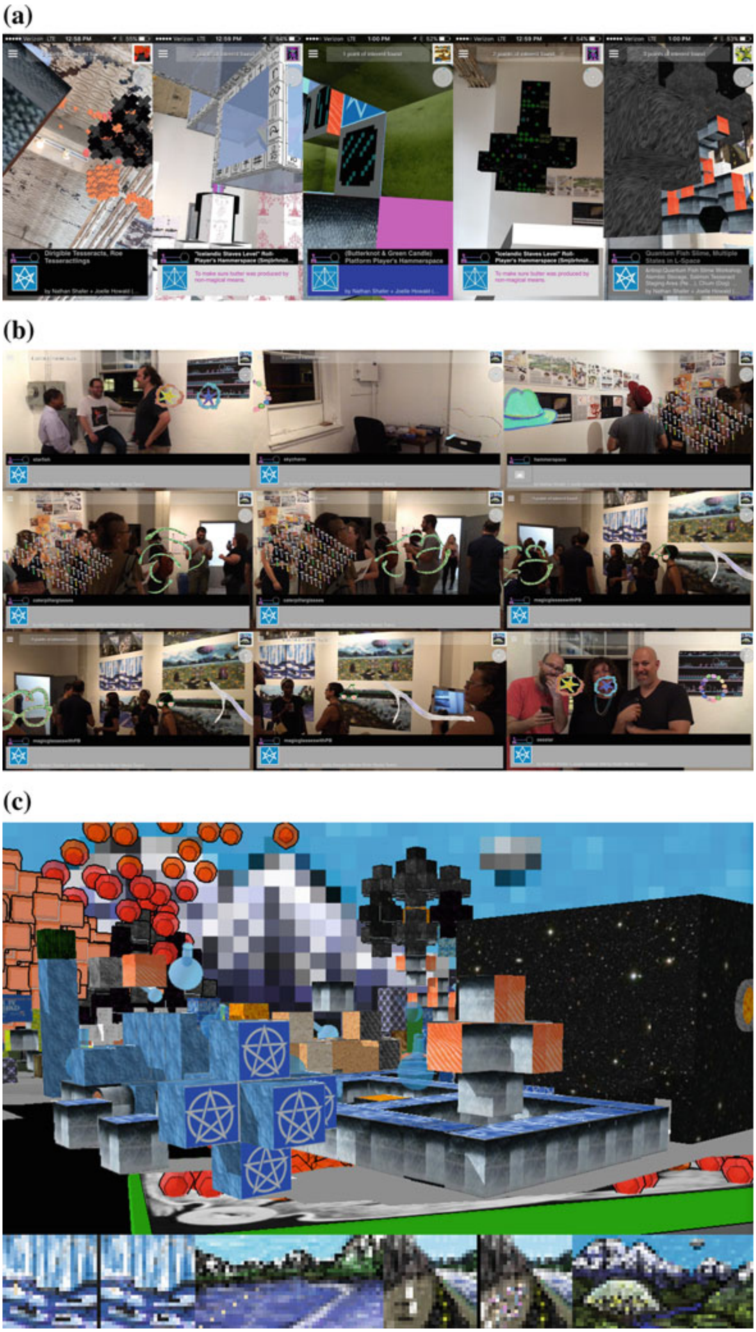


Fig. 13.27 Cheechako Wizard Suicide Runners (Nathan Shafer, 2016), augmented reality videogame



◂**Fig. 13.28** **a** Cheechako Wizard Suicide Runners (Levels: Quantum Fish Slime, Dirigible Salmon Roe, Butterknot, Icelandic Staves), (Joelle Howald and Nathan Shafer at Practice Gallery, Philadelphia, PA, 2016), augmented reality videogame. **b** Magic Items from the Cheechako Wizard Suicide Runners (Joelle Howald at Practice Gallery, Philadelphia, PA, 2016), augmented reality videogame. **c** Cheechako Wizard Suicide Runners, AR targets and Quantum Fish Slime Level (Joelle Howald and Nathan Shafer at Practice Gallery, Philadelphia, PA, 2016), augmented reality videogame

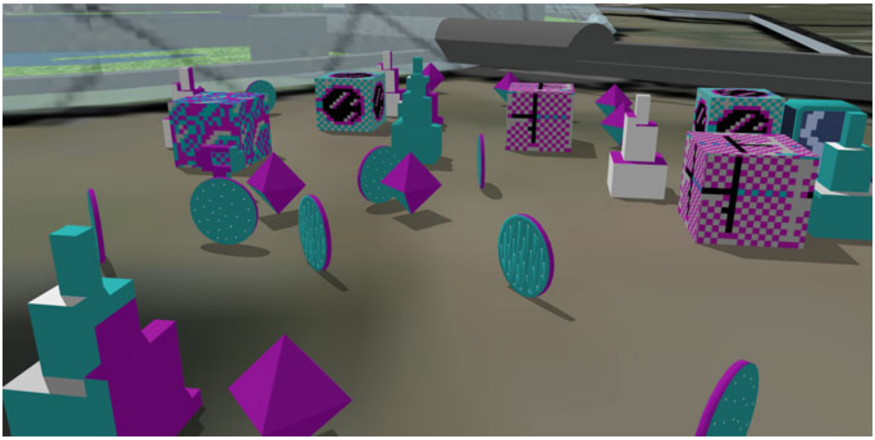


Fig. 13.29 Arctic adventure sculpture garden at Arctic City (Nathan Shafer, 2018), augmented reality

producing names like Wyoming Garcia, Florida Johnson and Deleware Davis. These are the Cheechako Wizards, the business men who work in Seward's Success and are doing the suicide runs to the Kenai River. This AR videogame is built on location in real life as well, with POIs along the Seward Highway, from north Anchorage, to the Kalifornsky Beach in Kasilof, where subsistence salmon netting on the Kenai River occurs. There was also a public sculpture which were three-dimensional renderings of the sprites from *Arctic Adventure* designed to go on the outskirts of the augmented reality version of Arctic City, when it was placed on location at Lockhard Point near Kotzebue, Alaska (Fig. 13.29).

Like many of the other videogames set in the Arctic, one of *Arctic Adventure*'s recurring antagonists are penguins. There are also sasquatches. In the development of *Cheechako Wizard Suicide Runners*, kids from several locations in Alaska assisted in editing the original sprites from *Arctic Adventure* to be more culturally accurate, so instead of penguins, the sprites were edited into ravens and magpies, the sasquatches were converted into the Hairy Man (an Alaskan cryptid similar to Yeti) and Kushtaka (land-otter people from Tlingit stories) and the floating coins were turned into floating pilot bread (a kind of hard-tack cracker that is popular in Alaska). Alternate versions of the *Cheechako Wizard Suicide Runners* are also mentioned in some of the specualtive fiction that was produced as part of the *Dirigibles of Denali* project, and were reimagined as videogames parrallel to the early Nintendo Entertainment System.

The *Dirigibles of Denali* project was very heavily influenced by notions of the Anthropocene, particularly anthromes, and the way domed cities function as anthromes in the circumpolar north. Ultimately, domed cities represent an extension of human consciousness that does not pay much heed to the natural world around themselves. In the Arctic, domed cities are a way of conquering the ice, the way the *Freeze* arcade game sought to conquer the ice with flamethrowers. But these are virtual spaces, not really social spaces. One of the significant aspects of the concept of siḷa is how it is a realm of human consciousness (other examples: the noosphere, telespheres, or the memosphere) that also includes the natural world in its definition.

13.10 Conclusion. Final Bosses: Sovereignty and Justice

In producing the *Dirigibles of Denali* project, there were several conceptual drawings that accompanied the proposal for the city of Seward's Success from 1968. Some of them were very deep relics from the mid-twentieth century, for example: the public art work in one of the mall commons featured floating totem poles and artwork made from sacred Tlingit clan imagery (Fig. 13.30). This was the kind of artwork that Tandy Industries imagined would be in a 'City of the Future', back then. At that moment in time, Alaska had a lot of decorative artwork that was either completely culturally appropriated imagery or fake imitations thereof. The formline style from southeast Alaska, which is mostly associated with Tlingit, Haida and Tsimshian cultures, was (and still is) the most imitated or appropriated art form in Alaska. There are others to be sure, but fake totem poles are really one of the most striking and noticeable forms of cultural appropriation in Alaska. In turning the original conceptions of Seward's Success into an AR city, there became an issue over whether to recreate the floating totem poles and clan imagery displayed throughout the city proposals. Instead, a contemporary Tlingit artist, Benjamin Schleifman, was commissioned to create artworks to replace the inappropriate ones from the original city plans. His works were then displayed as part of the AR city of Seward's Success (Fig. 13.31).

In looking at all of the videogames set in the Arctic, *Kisima Inŋitchuŋa* is the first videogame to not only accurately represent a culture in the Arctic, in tandum with an accurate portrayal of the natural world the story occurs in, but also to be developed and written with Alaska Natives. Hopefully in a hundred years, this will be a ridiculously dated notion, that people from the culture being represented are included in the creative process in more than a ceremonial role, but in a true sympoeisis. But *Kisima Inŋitchuŋa* is the first to really do this, and it was done in the hopes of starting a sustainable and evolving process for the creation of Indigenous videogames. Since *Kisima Inŋitchuŋa* came out, that momentum has slowed and the hard work and reality of replicating the model for successfully achieving an Indigenous sympoeisis in a videogame, has become an archived ideal. This is one that I am hoping will start to turn around, and produce more videogames in the spirit of *Kisima Inŋitchuŋa*,

Fig. 13.30 Public artwork in Mall at Seward's Success (Tandy Industries, 1968), city proposal

games that are operationally site-specific, accurately portrayed and are in soverign control of their infomes.

Because the notion of inclusion of people into their own representations in the global media ecology is good, but it is also a very basic step. The real goals we should be reaching for here are more than simply representations or inclusions, they should embody the same desires that are readily afforded to any of the people inside of the global monocultures: soverignty and justice. Indigenous gamification needs to be something that allows its cultural stewards access to soverignty over themselves and their spaces, as well as justice for when their soverignty is taken. These are the final bosses of our moment in the Anthropocene: soverignty and justice. But just like how cultural absoption is working in parrallel with global warming, soverignty and justice need to work in parrallel with environmental protections and technological advancement. Though there is going to be a lot of anxiety in practicing mixed reality in this manner, it is one of the most important steps as more mixed reality videogames are produced as site-specific digital stories.

Fig. 13.31 New public artwork (Benjamin Schleifman, 2018), augmented reality

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Concluding Remarks: From Pokémon GO to Serious Augmented Reality Games

V. Geroimenko

This two-volume work introduces a broad range of state-of-the-art research into augmented reality games—from the ground-breaking Pokémon GO app to their practical use as serious games in a variety of areas. It is the first monograph on the topic of augmented reality gaming. It was not easy to make it happen, because research on augmented reality games is still in its infancy. This is why the team of authors (to whom we owe a debt) was put together from all around the world and included 70 leading researchers, practitioners and artists from 20 countries, distinguished by their specialist expertise, significant publications and on-going projects. We have succeeded in producing and publishing these two pioneering books and we hope that the reader will not judge us too harshly. We have accepted the challenge of being the first, and we have done our best to bring out the two volumes.

In Volume I, the phenomenon of the Pokémon GO game was analysed in theoretical, cultural and conceptual contexts, with emphasis on its nature and the educational use of the game in children and adolescents. Game transfer phenomena, motives for playing Pokémon GO, players' experiences and memorable moments, social interaction, long-term engagement, health implications, the lessons learned from the rise of this leading augmented reality game, and many other issues were examined and discussed.

Volume II explored the practical use of augmented reality games as a novel type of serious games, and the most important and challenging issues that have been raised by the utilization of the augmented reality approach and technology in the gamification of education, healthcare, medicine and digital art. It presented a systematic analysis of educational augmented reality games, their use for health

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promotion in old age and for improving people's well-being, the gamification of augmented reality art and immersive reading experiences, among other issues.

The world of augmented reality gaming is growing rapidly and becoming increasingly essential not only for the 'for-fun' gaming industry, but also as serious games in different domains. If you doubt it, just type the keywords "augmented reality games" into Google's Search and see the up-to-minute results. The scientific research follows the rapid development of this emerging field closely and in many cases paves the way for its future. Again, just try the same keywords in Google Scholar.

In these comprehensive volumes, the authors' team tried to provide a thorough and multi-faceted research into the evolving field of augmented reality games and considered a wide range of the major issues involved. We hope that a 2nd edition (revised and updated) will be possible quite soon and it will be able to bring in new authors, new thought-provoking chapters, new significant findings, and numerous current topics and issues.