Mariano Alcañiz · Stefan Göbel
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Preface

The Third International Joint Conference on Serious Games (JCSG 2017) was held in Valencia, Spain, and hosted by Universidad Politécnica de Valencia. JCSG 2017 brought together the 8th Serious Games Development and Applications (SGDA 2017) and 7th Serious Games (GameDays 2017) conferences, previously held in the UK, Norway, Germany, Portugal, and Australia.

JCSG 2017 joined experts from over 12 countries presenting and discussing recent developments to further improve the application of serious games in multiple fields like education and learning, simulation, training, health and well-being, management, and cultural heritage among others. The topics covered by the conference offered participants a valuable platform to discuss and learn about the latest developments, technologies, and possibilities in the development and use of serious games with a special focus on how different fields can be combined to achieve the best possible results.

We received 44 submissions from which 23 were selected as full papers, two as short papers, and four as posters. All the manuscripts submitted to the JCSG2017 were peer-reviewed by at least three independent reviewers, who were provided with a detailed review proforma. The comments from the reviewers were communicated to the authors, who incorporated the suggestions in their revised manuscripts. The recommendations from three reviewers were taken into consideration while selecting a manuscript for inclusion in the proceedings. The exhaustiveness of the review process is evident, given the large number of articles addressing a wide range of research areas. The stringent review process ensured that each published manuscript met rigorous academic and scientific standards.

Keynote presentations were given by: Val Shute, Mack and Effie Campbell Tyner endowed professor of education at Florida State University; Baltasar Fernández-Manjón, Full Professor in the Department of Software Engineering and Artificial Intelligence (DISIA) at the Complutense University of Madrid (UCM); and digital media entrepreneur and researcher Kam Star.

The conference and the publication of the JCSG 2017 proceedings by Springer were the remarkable outcome of the untiring efforts of the entire organizing team. The success of an event undoubtedly involves the painstaking efforts of several contributors at different stages, dictated by their devotion and sincerity. Fortunately, since the beginning of its journey, JCSG 2017 has received support and contributions from every corner. I thank all who have wished the best for JCSG 2017 and contributed by any means toward its success. The edited proceedings volumes published by Springer would not have been possible without the perseverance of all the committee members. I especially thank the Organizing Committee members, Stefan Göbel, Minhua Ma, Tim Marsh, Manuel Fradinho Oliveira, and Jannicke Baalsrud Hauge, for helping me shape JCSG 2017. The organizers of JCSG 2017 owe thanks to all the contributing authors for their interest and exceptional articles. I also thank the authors of the papers for adhering to the time schedule and for incorporating the review comments in the final version of their work. I wish to extend my heartfelt gratitude to the authors, reviewers, committee members, and production staff whose diligent work put shape to the JCSG 2017 proceedings. I especially thank our dedicated team of reviewers who volunteered for the arduous and tedious task of quality checking and critique of the submitted manuscripts. I also wish to thank my research colleagues at the Immersive Neurotechnologies Laboratory (LENI), and my PhD research scholars for extending their enormous assistance during the reviewing and editing process of the conference proceedings, with a special thanks to Alejandra Del Valle and Irene Alice Chicchi . The time spent by all of them and the midnight oil burnt is greatly appreciated, for which I will ever remain indebted. I also thanks the Polytechnic City of Innovation of my university for hosting the conference. Lastly, I would like to thank Springer for accepting our proposal to publish the JCSG 2017 conference proceedings.

September 2017

Tim Marsh
Minhua Ma
Manuel Fradinho Oliveira
Jannicke Baalsrud Hauge
Stefan Göbel
Mariano Alcañiz

Organization

JCSG 2017 was organized by the Institute of Research and Innovation in Bioenginnerring (I3B) in cooperation with the Polytechnic City of Innovation (CPI) of the Universidad Politécnica de Valencia (UPV).

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Contents

Virtual Stealth Assessment: A New Methodological Approach for Assessing Psychological Needs

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Abstract. In the past decade, the use of technology is extensively increased. Technological systems as virtual reality represent nowadays novel and efficacy tools in several areas, such as in psychology and education. Realism, sense of presence, engagement, experimental control, and ecological validity represent some of the advantages than traditional methods based on paper and pencil tests. Furthermore, psychological research gathering information about a person relative to specific attributes, such as abilities, personality, and cognitive competences is usually conducted using pre-test-post-test designs. Such traditional assessments are not able to catch and examine the dynamic and composite performances and behaviours in run. Virtual stealth assessment could provide a valid and reliable method for evaluating real behaviours in real-time during the virtual experience. In this article, we proposed stealth assessment as a new methodological approach to study the Grawe's model on the basic psychological needs by using virtual immersive environments, providing the theoretical development of the model on one psychological need with the relative virtual game.

Keywords: Virtual reality · Sense of presence · Stealth assessment · Evidence-centered design · Psychological needs · Attachment

1 Introduction

In the past decade, the use of technology for the treatment of psychological disorders has extensively increased [1–3]. Virtual Reality (VR) has emerged as an effective therapeutically tool in psychological science, including clinical psychology [4–8], neuropsychology and cognitive and motor rehabilitation [9–13]. In clinical psychology

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the major use of technologies, has been developed in the field of various treatments (e.g. for anxiety disorders, phobias, etc.) and less for the assessment of psychological dimensions. Traditional assessment in psychology, based on paper and pencil tests, provided highly validity and reliability as well as highly experimental control [14, 15]. However, it shows some limitations in term of ecological validity, defined as the degree of similarity that a test has relative to the real world [16]. In this framework, VR applications are able to simulate real experiences, eliciting high levels of sense of presence and providing realistic perception of the experience and engagement, without losing experimental control [17]. Furthermore, the traditional assessment isn't able to recollect the real behaviors that the various situations relative to a psychological construct can elicit. Stealth assessment could provide a new method of assessment performance-based in real time during the virtual experience [18, 19].

In this article, we propose virtual stealth assessment (VSA) as a novel method to evaluate the basic psychological needs in adult clinical and no clinical settings. According to Grawe [20] all human beings attempt to fulfill some basic psychological needs in congruence with their motivations, memories of past experiences, and actual aims. He identified four basic psychological needs (attachment, self-esteem, orientation/control, and maximization of pleasure/distress minimization) for mental functioning [20, 21].

After reviewing the previous studies on the VR efficacy evidences in the treatment of several psychological disorders, and the traditional methods of assessing, we claim that VSA could elicit realistic experiences and behaviors and could be a valid method to indirectly and latently recollect data about various performances related to the needs. We conclude by providing the methodological development strategy related to the attachment need.

2 Efficacy of Virtual Reality in Clinical Psychology

VR is a 3D-syntethic environment generated by a computer in which real situations can be implemented and in which users are immersed and can interact each other and with the environment as if in the real one [22]. To date, in psychology, research in the VR field is moving fast, showing its effectiveness in several psychological treatments, in neuropsychology, and in cognitive and motor rehabilitation [4–13], but very few applications of VR exist in the assessment of psychological dimensions [23].

Traditionally, the psychological evaluations are caught by direct standardized measures, like self-report questionnaires or paper and pencil tests, and indirect standardized measures, such as behavioral tasks [14]. Self-report measures provide conscious attitudes towards various experiences, focusing on the views that people have about themselves, the other, and situations at a specific time, but are not able to detect the unware responses and behaviors. Furthermore, they can't elicit the specific phenomena and situations that we want to assess. For reducing the response bias, some researchers prefer to use specific tasks, able to reveal behavioral attitudes. These tasks, traditionally, measure specific aspects of the theoretical constructs, correlating them with self-report questionnaires. However, both assessment methods show some limitations in term of ecological validity that VR attempted to solve, eliciting situations similar to the real ones [16]. Immersion, realism, sense of presence, and engagement are some of the advantages provide by VR applications. Immersion can be defined as a technical feature of the system: higher display resolution, or more input and output devices, such as Head-Mounted Display (HMD), haptic and sound devices can create a realism perception of the experience in which all the sensorimotor modalities are perceived in run [17]. The perception of realism rendered by the immersion allows to subjects to feel present in the virtual environment. The sense of presence can be defined as the perception of "being there", in which the media disappears from the perception, allowing to subjects interacting as if what it is happening in the virtuality is really happening [24]. Hence, the system features, the subject-system interaction, but also the subject attributes are able to generate engagement and active participation during the virtual experience. According to O'Brien and Toms (2008) [25], engagement can be seen as a "quality of user experience" characterized by a starting point of engagement, a period of sustained engagement, disengagement, and reengagement. Each phase of this process depends on the generation and stimulation of some engagement attributes that can vary during the virtual experience, as in real life experiences.

3 Virtual Stealth Assessment

New directions in technological application development seem to permit more accurate and composite estimations of subjects' psychological dimensions, allowing administering assessments during the VR experiences, extracting ongoing, multifaceted information from a subject.

One of the most auspicious new research areas for evaluating psychological factors is virtual "stealth assessment" (VSA), originally developed for learning and education [18, 19]. It is a performance-based assessment in which the assessment is interlaced in activities or games, highly interactives and immersive. The user performance data are continuously collected during the VR experiences and stored in a dynamic model of user [19]. Stealth assessment proposes to remove or reduce traditional test anxiety and response bias without sacrificing validity and reliability [26]. In order to develop a valid and reliable VSA, the evidence-centered design (ECD) represents the theoretical framework of reference, and it can be divided in three models: the competency model refers to identify the attributes that we want to assess; the structural model concerns the identification of those behaviors that can elicit the attributes that we want to assess; finally, in the task model situation, problems are developed to activate that behaviors linked to the attributes [27]. Recollected information is maintained within the subject model and may include cognitive as well as non-cognitive information comprising an accurate and up-to-date profile of the subject.

4 Basic Psychological Needs

Psychology has a long tradition of thinking about basic psychological needs of humans, beginning with Mc Dougall (1908) [28] and Freud (1920) [29] and continuing on through Murray (1938) [30] and Maslow (1954) [31] to the present day [20, 21, 32, 33]. In general, the concept of needs is related to motivational psychology that affirmed that individuals attempt for satisfying certain personal aims in accordance with their motivational patterns, present and past experiences, and feedback from the external world [20]. According to Grawe, “the objectives of a person are formed during his life and ultimately serve the satisfaction of the various basic needs” [21, p.169].

Grawe identified four basic needs that define as “the needs that are present among all human beings and lasting violation or breach leads to alterations in mental health and well-being”. These are the need for attachment, orientation/control, self-esteem, and maximizing pleasure/distress minimization. The need for attachment refers to the human striving for close and intimate relationships and the desire to achieve a sense of security and balance with a reference person, mainly in distress experiences [34]. The need for orientation and control concerns to be able to orientate in the environment as well as the ability to influence and master the personal environment and context and to manage various challenges. More in detail, it can be defined as people’s desire to experience ownership of their behavior and choices. At psychological level it includes the sense of self-efficacy, self-competence, autonomy, and empowerment. The need for self-esteem is defined as the need to build and develop a positive self-image and through our interactions with others and with the environment shape our own image. Finally, humans follow the logic of increase pleasure and avoid negative, dangerous, or painful experiences. All human beings strive to meet these four basic needs every day. Therefore, the behavior and interactions with others and the environment will have to be satisfied with motivation schemes that are coherent and consistent with basic needs. These schemes are formed through positive and/or negative experiences, resulting in different internal models (cognitive and emotional) that are unconscious. Within these, there are two basic schemes: the approach scheme that is the result of the effort employed by a person to meet their basic needs; and avoidance scheme that refers to the effort of a person to protect their basic needs [20, 21].

5 The Development of Virtual Stealth Assessment for Attachment Need

5.1 Attachment Paradigm and Competency Model

Attachment is a composite psychosocial paradigm, showing how people react to stressful events seeking security, proximity and support by the relationship with others. The quality of first relationships, in terms of attention and responsiveness between children and the attachment figure, affects self-perception, others’ perception, future interpersonal relationships, emotional regulation and behavioral patterns [34, 35]. More in detail, an attentive and responsiveness attachment figure to child requests is able to generate secure and positive models of the self and the others, while inattentive or unresponsiveness attachment figure causes insecure and negatives models of the self and others. The generation of these models is unconscious and involves cognitive (such as attention, flexibility, and planning) emotional (e.g. regulation and expression in social relationships), and behavioral (quality of relationship, proximity or distance from others) responses, determining the adult expectations from the self and others in relationship [36, 37]. Various studies have shown the significant relation among cognitive factors and attachment, as well as between the emotional responses and attachment mainly using self-report questionnaires and/or problem-solving tasks [38]. Individuals with a secure attachment show that they can easily shift attention between stressful cues in situation and environment, seeking others' support and accomplishing a goal or facing the stressful situation; insecure attachment individuals focus mainly their attention in the stressful situation or seeking support without flexibility of attention control. Moreover, insecure individuals can react to stressful events seeking extremely proximity with others or distancing extremely from others. Other studies have showed that secure individuals present positive models of the self and others and that insecure individuals show negative models of the self, in terms of self-esteem and self-concept, and positive models of others. In this literature framework, we propose a likely development of virtual stealth assessment for collecting multi-evident attachment behaviors relative to latent cognitive and emotional aspects (Fig. 1). More in detail, the main aim will be collected the various psychological attachment aspects in real-time during the virtual experiences, comparing the traditional assessment based on paper-pencil tests to the behavioral data.

5.2 Structural Model of Attachment

As mentioned before, the structural model concerns the identification of those behaviors that can elicit the attributes that we want to assess. Starting from the research findings over the years [39–42], Shaver and Mikulincer (2002) [43] develop a comprehensive model on the activation and dynamics of the attachment system based on three components (Fig. 2). The first includes the cognitive attentional monitoring and evaluation of distress events: if an event is evaluated as threatening, the attachment system activates the support and proximity seeking. The second component includes the evaluation of the availability, attentiveness and responsiveness of the attachment figure: if the figure is available and responsiveness, individuals feel a sense of security, allowing regulating emotions and engaging in activities to cope the threatening situation; if the figure is not available or responsiveness, individuals can develop two different reaction strategies in accordance with the internal models: individuals that act distancing from the attachment figures focusing on coping the situation and individual that react with more distress behaviors towards the attachment figures in order to receive attention and response [43]. To sum, the attachment paradigm can be related to cognitive and emotional components that virtual stealth assessment could measures during the stressful situations. In the following section, we present the virtual environment with the relative situations and task for eliciting attachment behaviors.

5.3 Task Modeling for Attachment

In order to create engagement of the user, we propose an immersive 3D game that will take place in a spaceship with six virtual characters and whose aim is to discover and settle a new land because the earth is no longer habitable. A narrative storytelling will be created for leading subject into the play and in which situation of loneliness, threatening and lost will be simulated for eliciting attachment responses (Figs. 3 and 4).

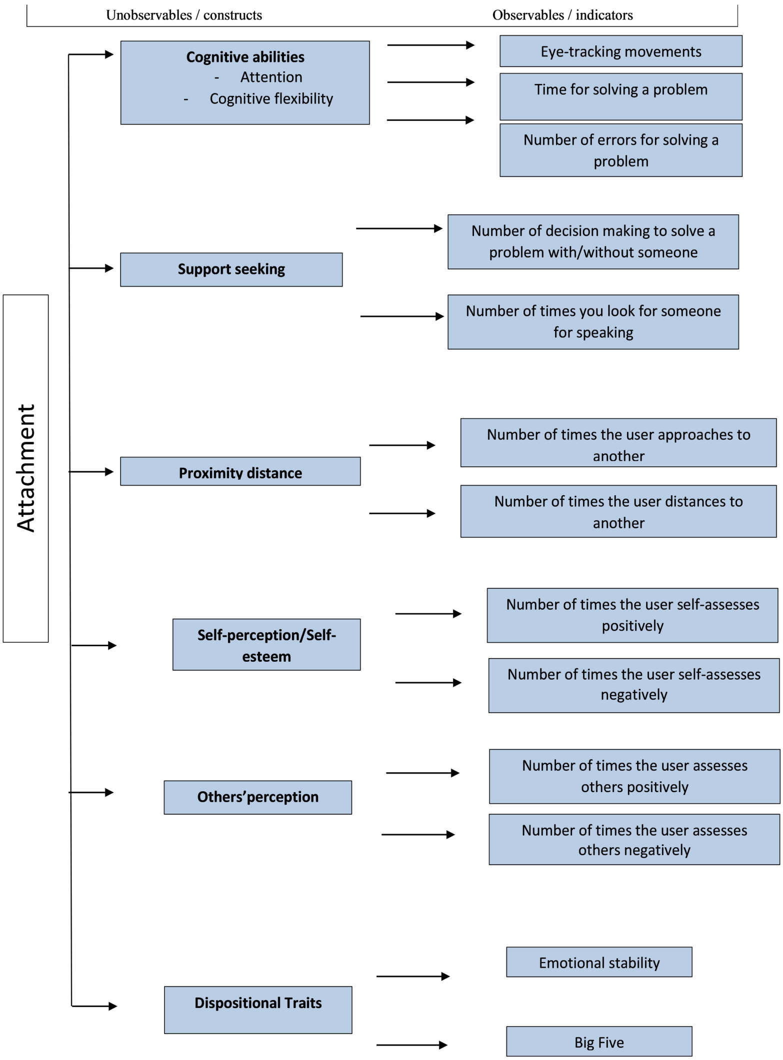

Fig. 1. Competency and structural model of attachment

More in detail, each distress situation will include two problem tasks relative to the cognitive functioning, such as attention and cognitive flexibility, by creating ad hoc and contextual cognitive sets alternation and dual-tasks, that they will previously be validated with traditional cognitive tasks. Traditionally, cognitive functions, as attention cues and cognitive flexibility are based on behavioral tasks such as the Wisconsin Card Sorting Test (WCST), in which are collected the number of errors to change strategy during the game, and the Implicit Association Test (IAT) in which time of execution represent the outcome in relation with cognitive flexibility. In the virtual stealth

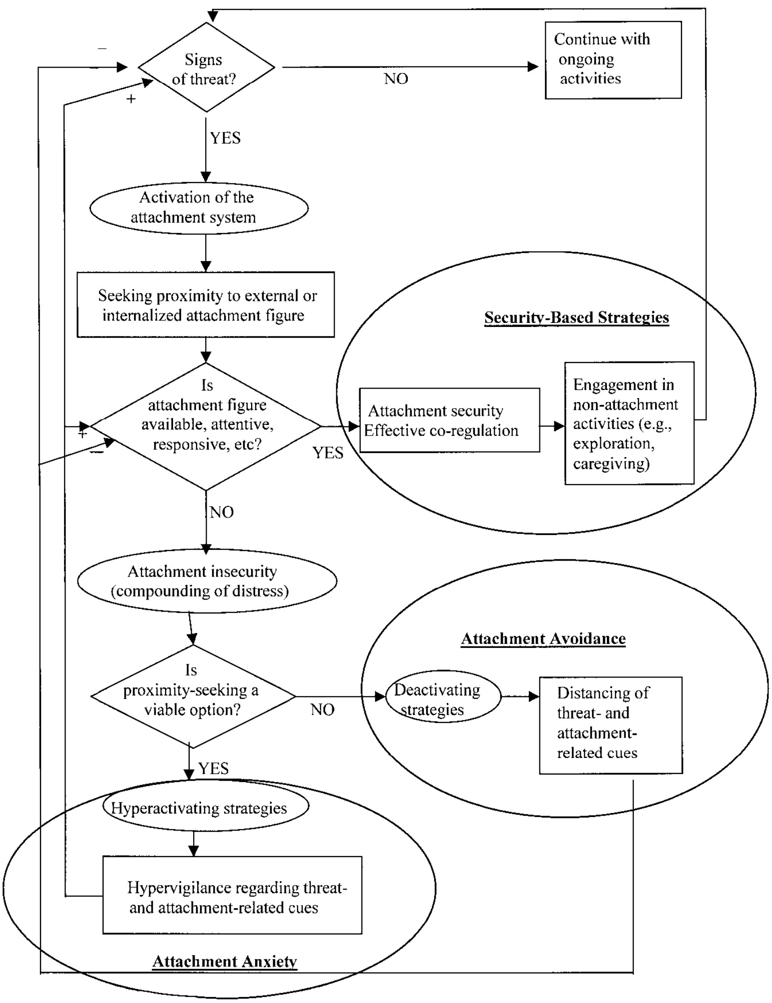

Fig. 2. Shaver and Mikulincer model on the activation and dynamics of the attachment system.

assessment, cognitive flexibility will be based on seeing how long users spend on situational tasks and how many errors commit in solving problems.

Furthermore, after the presentation of each distress situation will be asked to subject if he or she seeks support for solving the problem, as well as at the end of the situation if he or she wants to speak with someone else. At the end of each situation, subject will be asked to self- and others-evaluate for collecting the number of times that the subject evaluate positively or negatively himself and others.

To sum, each distress situation will mainly involve the data collection of the real behaviors relative to latent variables on cognitive (attention and cognitive flexibility) and emotional (support seeking, proximity distance, and quality of relationships) attributes. As well, the emotional attributes, as seeking support and physical proximity

Fig. 3. Task control room

Fig. 4. Virtual characters

will be assessed on the number of decision making to solve problems with or without someone, or number of times that user seeks support for speaking. Finally, these behavioral measures will be correlated to the traditional paper and pencil tests on attachment, self-perception, others' perception, and personality.

6 Conclusion

In conclusion, as we mentioned above, psychological traditional assessment is often too simplified, abstract, and decontextualized to provide a multi-dimensional psychological evaluation. Virtual stealth assessment can provide meaningful assessment environments by providing situations and problems able to elicit specific behavioral patterns. The performance data are then statistically linked to the specific psychological concepts. The first aim of this research project will be the yielding of the validity and reliability of stealth assessment for psychological attributes. If stealth assessment would provide accurate information about multi-dimensional psychological attributes, we could generate composite and valid subjects' profiles that then they could be taken into consideration for specific psychological treatments.

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VR Serious Game Design Based on Embodied Cognition Theory

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Abstract. Embodied Cognition (EC) theory states that systems for sensing, acting and thinking are intrinsically interdependent and that human cognition is made of modality-specific representations. This approach is based on evolutionary principles of how human beings relate to their environment and for this reason, it is very suitable to be applied to improve design of VR systems, which are clearly based on physical interactions. We can find examples of this theory in common human behaviours as counting with own fingers or walking around an empty room to think about how furniture are going to be placed.

Taking the most contrasted claims of EC, we are going to explore Virtual Reality Serious Games (VRSGs) design from an holistic point of view, trying to optimize the cognitive performance of players. Aiming this, we are going to update Arnab's et al. Learning Mechanics - Game Mechanics model adding VR specific characteristics based on Embodied Cognition theory. This LM-GM model will frame our proposal. Taking as starting point four of the most accepted EC claims, we are going to propose some interaction design guidelines with the objective of improving game mechanics in VRSGs, from a cognitive point of view.

Keywords: Virtual reality · Game design · Serious games · Embodied cognition · Cognitive science · Embodiment

1 Introduction

Over the last few years, we are witnessing a great growing of the integration between two rising disciplines: serious games and virtual reality (VR). This emerging field, VR Serious Games (VRSG) has particular characteristics that are to be analysed in order to push further their use. While using VR as a medium for teaching or training is not a new trend, it is gaining traction since technology is maturing: high resolution and affordable Head Mounted Displays (HMDs), room-scale tracking capabilities or haptic interaction devices have destroyed traditional barriers on VR massive adoption.

The potential of these technologies for training and education was clearly perceived decades ago where some companies started creating first flight simulators, mainly for military aviation [1,2], because they had lower operational costs

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and were safer. With those simulators it was also possible to replicate hazardous situations that could not be reproduced in actual practice. The interface was mainly physical, an exact replica of the controls, so they were not reusable in other trainings, what made them very expensive.

Later, the next field that firmly adopted VR as a learning tool was surgical training. Surgical simulators are complex and eminently physical environments [3], mainly based on haptic feedback. Today they are still one of the most mature examples of the use of VR in a training environment. While it began as a realistic way to simulate certain professional, physical and mechanical processes, if we analyze the reasons for using Virtual Reality in education, we find different motivations. Winn [4] pointed that immersive VR provides first-person non-symbolic experiences that help students in their learning process. These experiences usually cannot be obtained in formal education as regular teaching practice promote symbolic third-person learning experiences. Additionally, other authors as Mantovani [5], focus the benefits of VR applied to education on 'learning in difficult or impossible contexts to be experienced in real life, increased motivation, adaptability and custom educational content creation and great potential as an evaluative tool for its ease to monitoring sessions in the virtual environment'. Recently, in a wide study made by Freina and Ott [6], we see that the most used argument for including VR in the classroom is 'that it gives the opportunity to live and experiment situations that cannot be accessed physically'.

By the time the technological limitations are fading out, researchers and designers have to face new challenges. The most pressing today is to set a sound basis for experience design in VRSG. Game design involves thinking and taking decisions about narrative (what story the game tells with the players' help), aesthetics (how the game looks like) and mechanics (what the player can do inside the game). As we are living the very first moments in commercial VR game design, game companies are "translating" traditional game mechanics and interactions to new VR titles. This approach does not allow to take full advantage of VR inherent capabilities, linked to its immersive and physical characteristics.

In this paper we are going to explore VRSG design from an holistic point of view. As we are going to design games for learning we want to maximize the cognitive performance of players. Along the great number of approaches to cognition we have selected one that fits perfectly with VR nature: embodied cognition, which is based in how our body and its interactions with the environment affect our cognitive activity. For this reason, we want to set a framework to design mechanics and interactions for VRSG supported by embodied cognition theory.

The rest of this document is structured in three parts: First of all we are going to explain the principles of the Learning Mechanics - Game Mechanics model and how it helps game designers to create engaging games that lead players to their instructional goals. We want to update this model, adding VR specific characteristics based on Embodied Cognition theory. The second section is dedicated to give the reader a fast introduction to Embodied Cognition thesis.

In the third section, we are going to analyse the four more documented and studied claims about embodied cognition theory and to link to each of them a number of game design guidelines in order to optimize cognitive performance when developing VRSGs.

2 Game Mechanics for Serious Games

While there exists a clear agreement about the instructional potential of Serious Games, there is not a consensus on how Serious Games have to be designed in order to achieve their dual objective [7]:

1. Serious Games must achieve the transfer of learning to be *Serious*
2. Serious Games must remain engaging and fun to be *Games*

When we design a Serious Game, we must take specially care in the balance of this two components because if we prioritize one over the other we could obtain a boring educational game or a fun game that makes the user to learn nothing [8]. In that sense, if we focus on what makes a game engaging and fun, we should be talking about what the player actually does inside the game: the game mechanics.

The concept of game mechanic has always been accompanied by some semantic confusion, depending on the approach done to explain games. If we refer to the researchers and designers that consider games as a structure with ends and means [9], they use as synonyms the words mechanic and mechanism, defined as 'a process or technique for achieving a result'. Another group of authors, take mechanics as a set of 'rules, player choices and other designs that have been created with intent and consequence in mind' [10]. Additionally, a great number of times, this concept is mentioned but not rigorously defined [7], so we are going to set a pragmatic, working definition for this guide as: A game mechanic represents every single action that a player could chose to do in game and it has actual consequences (interaction) in the game, in the gameplay or in the narrative.

Trying to blend both worlds, instructional and game design, Arnab et al. [7] suggested that: '*high-level pedagogical intents can be translated and implemented through low-level game mechanics...* Serious Game Mechanic *(SGM) defined as the design decision that concretely realizes the transition of a learning practice/goal into a mechanical element of game-play for the sole purpose of play and fun. SGMs act as the game elements/aspects linking pedagogical practices (represented through learning mechanics) to concrete game mechanics directly related to a player's actions'*.

Even when in the work of Arnab et al. they treat dynamics (set of mechanics that, together, contribute to a higher goal or strategy inside the game [11–13]) as mechanics, witch makes their approach a little fuzzy, we are able to take their Learning Mechanic - Game Mechanic (LM-GM) model as an starting point for our proposal. We will use their association of Game Mechanics/Learning Mechanics/Thinking Skills (as they are founded in the digital taxonomy of Anderson et al. [14] to frame our VRSG design recommendations (Fig. 1).

GAME MECHANICS	THINKING SKILLS	LEARNING MECHANICS	LOTS to HOTS
○ Design/Editing ○ Infinite Game play ○ Ownership ○ Protégé Effect ○ Status ○ Strategy/Planning ○ Tiles/Grids	CREATING	○ Accountability ○ Ownership ○ Planning ○ Responsibility	
○ Action Points ○ Assessment ○ Collaboration ○ Communal Discovery ○ Resource Management ○ Game Turns ○ Pareto Optimal ○ Rewards/Penalties ○ Urgent Optimism	EVALUATING	○ Assessment ○ Collaboration ○ Hypothesis ○ Incentive ○ Motivation ○ Reflect/Discuss	
○ Feedback ○ Meta-game ○ Realism	ANALYSING	○ Analyse ○ Experimentation ○ Feedback ○ Identify ○ Observation ○ Shadowing	
○ Capture/Elimination ○ Competition ○ Cooperation ○ Movement ○ Progression ○ Selecting/Collecting ○ Simulate/Response ○ Time Pressure	APPLYING	○ Action/Task ○ Competition ○ Cooperation ○ Demonstration ○ Imitation ○ Simulation	
○ Appointment ○ Cascading Information ○ Questions And Answers ○ Role-play ○ Tutorial	UNDERSTANDING	○ Objectify ○ Participation ○ Question And Answers ○ Tutorial	
○ Cut scenes/Story ○ Tokens ○ Virality ○ Behavioural Momentum ○ Pavlovian Interactions ○ Goods/Information	RETENTION	○ Discover ○ Explore ○ Generalisation ○ Guidance ○ Instruction ○ Repetition	

Fig. 1. Classifications based on Bloom's ORDERED thinking skills, from Arnab's et al. work [7].

3 Embodied Cognition

Different approaches to cognitive science have traditionally treated human mind as an 'abstract information processor, whose connections to the outside world were of little theoretical importance' [15]. In the last two decades, a new movement in cognitive science has raised to 'give the body a central role in shaping the mind' [15]. As we read in Clark [16], *'Biological brains are first and foremost the control systems for biological bodies. Biological bodies move and act in rich real-world surroundings'.*

Traditional approaches to cognitive science, as summarizes Foglia [17], agree about, at least, three fundamental principles that are opposed to the embodiment thesis:

1. 'Information conveyed by a mental representation has no modality-specific features.' That implies that representations are independent from the sensorimotor system and its own characteristics. Embodied cognition defenders think that 'significant differences in embodiment often translate into differences in cognitive processing'.
2. 'Knowledge is represented propositionally, and meaning emerges from the relations among the constituent symbols'. Under embodiment thesis, 'algorithms that constitute cognition sometimes reflect the peculiarities of the physical body'.
3. 'Internal representations instruct the motor system, which is essentially separate and independent of cognition, and so cognitive processing is not significantly limited, constrained or shaped by bodily actions'. In the other side, embodiment thesis is committed with the idea that 'failure to include

information about the body in the description of the mind leads to accounts that are fundamentally misleading and misguided.'

As a global statement of what embodied cognition is, we can say that systems for sensing, acting and thinking are intrinsically interdependent and that human cognition is made of modality-specific representations [17].

We can find examples of this theory in common human behaviours as counting with own fingers or walking around an empty room to think about how furniture are going to be placed.

4 VRSG Design Based on Embodied Cognition Theory

In this section, we are going to analyse the four more documented and studied claims about embodied cognition theory and to link to each of them a number of game design guidelines in order to maximize cognitive performance when developing VRSGs.

4.1 Cognition Is Situated

One of the most relevant and at the same time most controverted statements about embodied cognition is that cognition is situated [15,16]. This represents, in plain English, that cognition occurs in determined place and a moment, in context with some inputs and outputs that affect the cognitive task. Even this argument has dark points because of there are evidently not situated cognitive tasks as imagining or planning, it has an strong evolutionary basis. Before we got civilized, our cognitive abilities mainly serve to our surviving capability and it was clearly related to the environment (obtaining food or avoiding predators).

VRSG Design Guidelines. If we try to exploit this affirmation, we must focus on delivering training in the most similar physical conditions to those where the user is going to apply what he learns. That does not mean that we must invest our efforts on searching photo-realism but we have to reproduce the environment where taught skills are going to be used at a level of detail appropriate to the task we are training to. For example, if we have to design a VRSG for training technicians to repair a high tension generator we not only have to replicate the place, the colours of the buttons or the banners/labels present in the scene but also we have to make the user to pick up a certain tool from a shelf over his head instead of selecting it from a menu.

This introduces new interaction issues such as what happens if the shelf where is stored that tool is two meters tall and user's height is only 1.5 m. It will be impossible that the user would success to pick it up because is out of his viewing range. These situations could represent a bottleneck and alternative approaches have to be designed. Firstly, physical conditions of users and environments affect to interaction in VR so, as designers, we have to pay attention to it.

This guideline could be mainly applied to Understanding, Applying and Analysing levels of the LM-GM model because are more practically related to do some actions in the actual environment.

4.2 Cognition Is Time-Pressured

Embodied cognition theory sets that cognition has to be understood "in terms of how it functions under the pressure of real-time interaction with the environment" [16]. For this reason, we 'should expect some aspects of cognition to be highly reactive and environmentally driven' [18]. This idea of real time processing [19, 20] shows us how relevant is embodiment in tasks such walking or swinging, where an incredible amount of inputs are processed in "runtime" to generate appropriated motor outputs.

VRSG Design Guidelines. Time pressure is a traditional game mechanic [7] used to stimulate engagement and motivation. If, additionally, we take in consideration how our cognition works under this circumstances, we must include applying (following Blooms' taxonomy) mechanics with time constraints. In order to make it more effective, we should add some visual, auditive or haptic cues that inform the user about the time remaining. It could be conditioned to different levels of difficulty. For example, in easier levels you have a lot of cues that gradually disappear just to, in final levels, have no cues about timing. Of course, in order to give the necessary relevance to time pressure, it has to have consequences as loosing points, restarting the level, loosing lives or similar.

4.3 We Off-Load Cognitive Work onto the Environment

Our cognitive capacity is limited. Cognitive theory of multimedia learning was stablished by Mayer [21] and exposes that multimedia supports the way that the human brain learns. He, and other cognitive researchers defend that people learn more deeply from words and pictures than from words alone, which is referred to as the multimedia principle. The theory was summarized by Sorden [22] as having the following components: (a) a dual-channel structure of visual and auditory channels, (b) limited processing capacity in memory, (c) three memory stores (sensory, working, long-term), (d) five cognitive processes of selecting, organizing, and integrating (selecting words, selecting images, organizing work, organizing images, and integrating new knowledge with prior knowledge), and theory-grounded and evidence-based multimedia instructional methods. We can simplify this approach focusing on (b), limited processing capacity in memory, and say that if human beings have a certain amount of processing capacity, if we use too much of this capacity trying to interact with the environment, learning the rules, understanding the missions we are supposed to do, reading menus and other activities that often are used in learning environments in VR, we will only have a very small amount of free processing capacity to storage new knowledge.

Embodied cognition theory sets that we off-load some cognitive tasks to reduce our cognitive load. A good example for this is counting with the fingers or how users rotate Tetris block shapes while falling in order to preview where they are going to fit better instead of representing it only in our mind [23].

VRSG Design Guidelines. While cognitive load in VR environments is high due to the novelty of how we perceive the world and how we interact with it, we have to give users the chance to use the environment to simplify cognitive tasks. Using physical tokens to represent some spatial relationships or writing on a wall some intermediate results in a logic problem are examples of how environment and physical interaction could reduce cognitive load in order to obtain a more effective learning. This could be translated into different LM-GM, mainly in the HOTs (Higher Order Thinking) of the Arnab's et al. model as evaluating or creating where learning mechanics as planning or accountability could by matched with game mechanics as design/editing or strategy/planning. In those cases, diagetic previews of what the user is going to build/arrange/set or the possibility to move some items to create physical representations of a problem/task/situation could be a great help. Those items could be from actual blocks to lights or giving the user the capability of drawing on a certain surface.

4.4 The Environment Is Part of the Cognitive System

As we can find in Wilson's summary [15], "the information flow between mind and world is so dense and continuous that for scientists studying the nature of cognitive activity, the mind alone is not a meaningful unit of analysis." This claim could be explained through the extense work of Merleau-Ponty [18,24] about how blinds walking with a cane, they feel the environment not with the hand holding the cane but with the cane. This represents the cane as a port of the body and 'the locus of sensation is extended to the tip of the cane'. Here, the cane is not a tool to obtain data that has to be processed to obtain information about the environment but an artifact that acquire signals and these are immediately interpreted as if they were actually *felt*.

VRSG Design Guidelines. This example of the cane is totally translatable to what users feel when receiving haptic feedback through most popular VR controllers from HTC Vive or Oculus Rift Head Mounted Displays (Fig. 2).

As a great sample of this technique, we can refer to the game "LongBow" included in the "The Lab" experience from Valve. You play the role of an archer situated on a tower of a castle that you have to defend against hordes of enemies. Each time you pull back the bowstring, you can feel an increasing vibration as haptic feedback from the controller you are "holding the arrow". That gives you actual information about how are you performing: if the arrow is properly attached to the string, how strong are you pulling and, in consequence, how far is going to be the arrow thrown... All that information is not processed, is sensed, what permits the player to optimize their cognitive activity.

So, if it is possible, we should add haptic feedback trough controllers vibrations to let the player "sense" different textures, estructures, shapes, strengths, etc. This interaction will apply directly to the Analysing level of the LM-GM model, improving game mechanics as feedback or realism and, consequently, helping learning mechanics as experimentation, feedback, imitation and simulation.

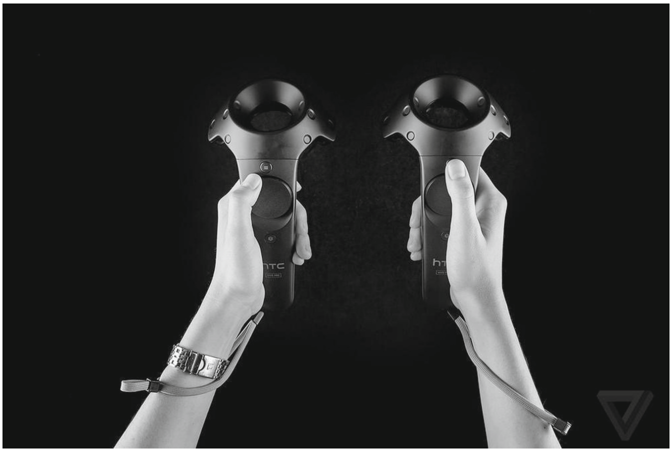

Fig. 2. HTC Vive controllers with haptic feedback

5 Conclusions and Further Work

Embodied cognition is a theory for understanding how our brain works and could give us useful clues about how to better design VR environments for learning. VR and embodiment are intrinsically related and this work wants to reinforce the idea of building VRSG with high levels of interaction because it will improve the senses of presence, immersion and as we exposed before, the cognitive performance of users.

Instructional designers and serious games designers have to rethink how interactions are designed because now, with new VR systems and controllers we have a new range of actions to add to virtual experiences that are "VR native" and not translated from desktop traditional interactions.

Additionally, after analysing how LM-GM model for Serious Games could be updated with some specific design guidelines for Virtual Reality we are totally aware that intense empirical work has to be done to prove that this design framework actually improves the learning experience of users of VRSG. Another area to be developed is the related to how we are going to measure the hypothetical cognitive gain of following Embodied Cognition thesis. As it was highlighted in previous studies [25], there is a sound basis of non-intrusive, physiological metrics as eye tracking to evaluate cognitive load in real time. Now that some new VR Head Mounted Displays incorporate eye tracking capabilities, it's possible to obtain data about cognitive activity of users based on how they look the VR environment.

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VROARRR, Audio Based VR Weapon Design

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Abstract. To "roar like a monster" may be a dream of the average 8 year old; now you can: in a video game. VROARRR builds on audio capturing game mechanics within the play space of VR. The devised mechanics attempt to solve weapon design challenges such as fire rate, balancing, environmental damage and more. The devised system makes use of the Unreal 4 games engine and blueprint to teleport the user into a Monster Simulator.

Keywords: VR · UE4 · Audio · Weapons · Games design · Parameters

1 Introduction

Vocal Audio input features in many games, ranging from indie offerings such as Yasuhati [1], Panopticon [2], Gnilley [3] To triple A titles like Brain Age [4] and Singstar [5]. These games capture player vocals using a microphone in order to affect the game mechanics. In Yasuhati [1], for example, the audio data is used to traverse platforms; whilst Gnilley [3] uses captured audio as a means of attack.

This paper presents an approach to solving vocal weapon design challenges for a VR monster title. The Title referred to in the paper is VROARRR, a VR Vanguard competition entry. VROARRR lets the player play as a Giant Monster; its unique mechanic being a "roar" weapon (Fig. 1).

Weapon designs in games have several cliché design patterns, dubbed by David Perry [7] as;

- Target and Shoot
- Target Reticule
- Just Shoot
- Auto Target
- Lean and Fire

In VROARRR, the most appropriate cliché is "Just Shoot", Perry [6] explains this as "you just shoot in the direction you are facing. If there is an enemy in the line of fire, it's likely you'll hit it." The Audio Weapon in VROARRR fires from the centre of the Head Mounted Display (HMD). When activated, it fires projectiles in the direction the player is oriented.

In order to help communicate common trends and weapon classification, Giusti, Hullett and Whitehead [7] created the following set of design patterns for weapons in shooter games:

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https://doi.org/10.1007/978-3-319-70111-0_3

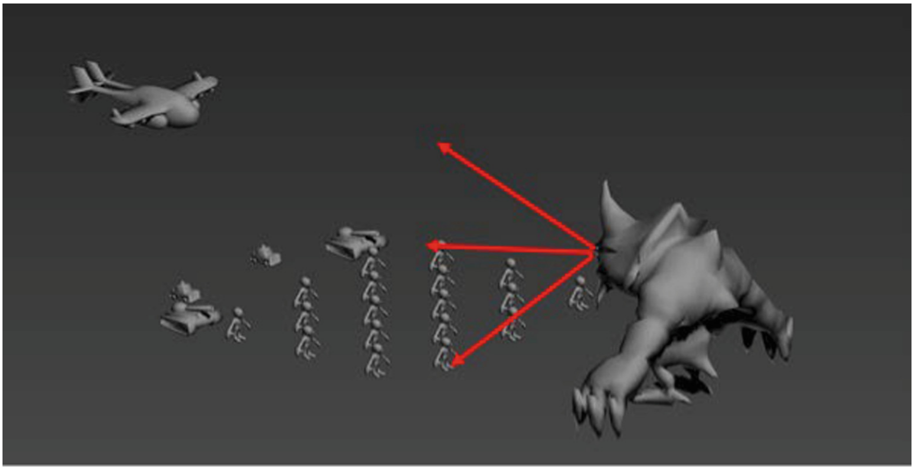

Fig. 1. VROARRR monster roar demonstration

- Sniping Weapons,
- Close Blast,
- Assault Weapon,
- Projectile,
- Power Weapon,
- Melee Weapon, and
- Placed weapon.

VROARRRs roar design pattern matches the "Assault Weapon" definition, as it fires quickly and accurately, based on the player's HMD orientation.

The VR and Audio Capture basis means that the roar Mechanic in VROARRR has significant differences to existing weapon design patterns. The player's vocal ability determines the weapon's fire rate, instead of a control pad trigger or a mouse button. It follows that the handling and control of the weapon is quite different, for example, to an Assault Weapon in Halo/Call of Duty Universes.

Therefore, the design decisions in VROARRR require modification when compared with traditional weapons design, these modifications which will now be explored.

2 Using the Microphone Input

Access to the audio stream in VROARRR was achieved by using Jackson's [8] VR Breath Test project for the Unreal Engine. Jackson's framework allowed easy access to the overall amplitude of an incoming stream, as shown in Fig. 2. Unreal allows for game play scripting and manipulation of the incoming audio stream data via the Blueprint Editor Epic Games [9].

Fig. 2. Jackson (2015) VR Breath test blueprint

3 Balancing Sensitivity Inputs

Jackson's [8] VR Breath test calculates amplitude via the collection of new audio samples every Tick. Ticks are an arbitrary unit of time and can be measured differently on hardware/OS, but on Windows a Tick represents one hundred nanoseconds (Microsoft [10]). The amplitude data passes through to Unreal which ticks every frame, therefore, without modification, the weapon would fire every frame.

In order to stop the roar from continuously firing, the amplitude data was limited by a mechanic shown in Fig. 3. The mechanic clamps the amplitude/Roar Level and compares it against a designated threshold. The clamps and multipliers at this stage were discovered via trial and error, during play testing the HMD. It is expected that the sensitivity will need to be controlled on a per user basis due to vocal differences and equipment sensitivities.

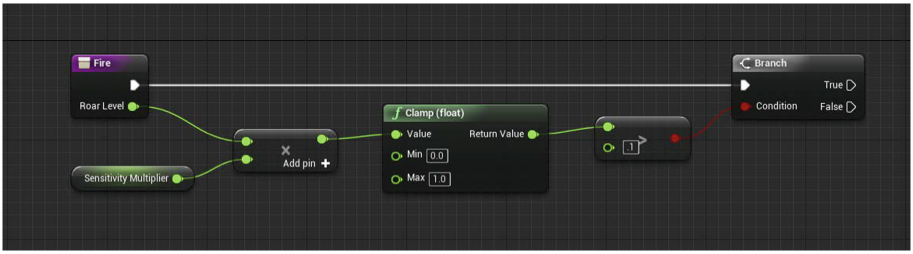

Fig. 3. Sensitivity mechanic

4 Balancing Fire Delays

With the sensitivity correctly balanced, there remained a high fire rate: the fire mechanic was being called approximately every 0.002 s, causing far too many projectiles to be spawned and enemies suffering instant death. A slower rate was required to aid game performance and balancing.

To deal with the amplitude data, a timer system was created as shown in Figs. 4 and 5. This cool down timer was triggered upon firing and a float was used to reset it to allow further firing. This system is not unique, the cool down timer is a ubiquitous mechanic in games, such as 343 Industries Halo 5 s [11] Plasma Rifles Overheat mechanic.

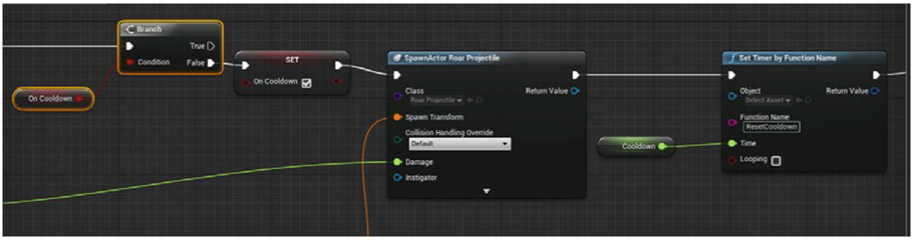

Fig. 4. Set cool down timer

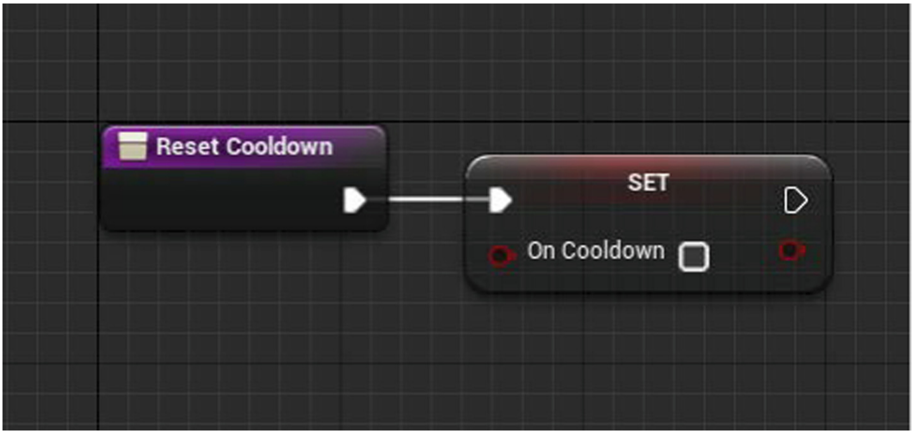

Fig. 5. Reset cool down timer

5 Managing Attack Particles

The projectiles in the VROARRR weapon spawn (Fig. 6) when a Roar had been triggered and the system is not on cooldown. The projectiles were chosen as a visual representation of:

1. the Roar power, and,
2. how the Roar interacts with the game environment.

Thus objects such as the Town Folk and Planes are all fully destroyable through collision with the roar projectiles.

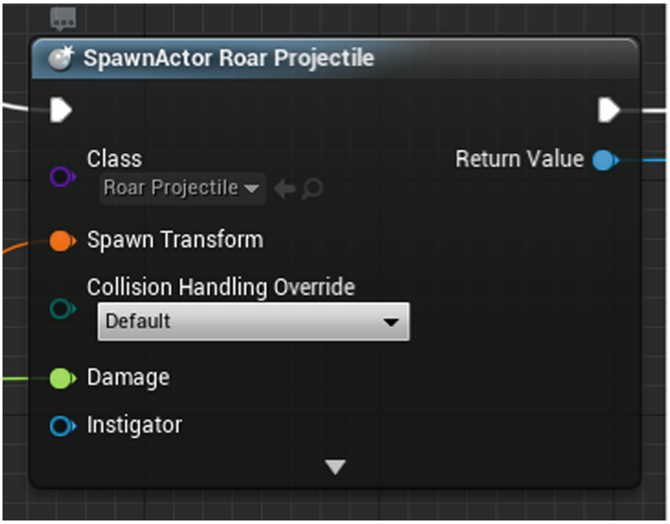

Fig. 6. Projectile spawn example

The projectiles presented a number of tricky design challenges, namely:

1. Scale
2. Damage
3. Amount
4. Speed
5. Appearance

Challenges 1 and 3 are problematic because particles that are too large or too numerous cause the HMD to become very visually "busy" for the player. A key principle of VR Design is comfort (Asforth [12]) so, where possible, particles needed to be controlled to ensure the HMD remained a comfortable visual experience.

To achieve this, a Cool Down strategy was employed once again, in conjunction with a scaling effect. Scaling in this instance produces particles that start off small and grow larger as they travel further from their spawn point. See Fig. 7 for the blueprint used to control this scaling action.

The damage of the projectiles was controlled by taking the initial roar level into account and clamping it between to values. This attempted to balance the damage based on the roar of the player, if this was not considered then frequent low amplitude roars would do the same damage as frequent high amplitude roars.

Figure 7 shows the overall appearance of the projectile, the art for this effect was mostly transparent. Several pulses emit from a sphere to give the player an idea of the directionality of the roar and the direction in which they are aiming. The visibility of the projects was designed with Asforth's [12] comfortable principle in mind (Fig. 8).

The final projectile challenge was speed, it was decided that the speed would remain constant regardless of amplitude as stated by NASA [13] it remains roughly

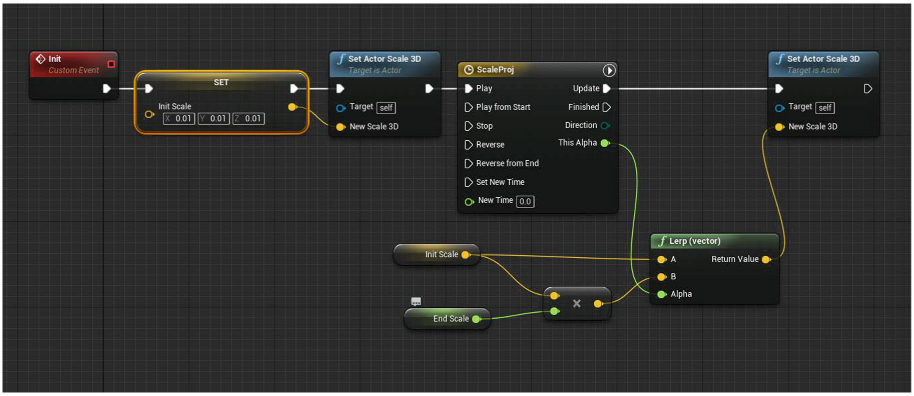

Fig. 7. Scaling particles over time

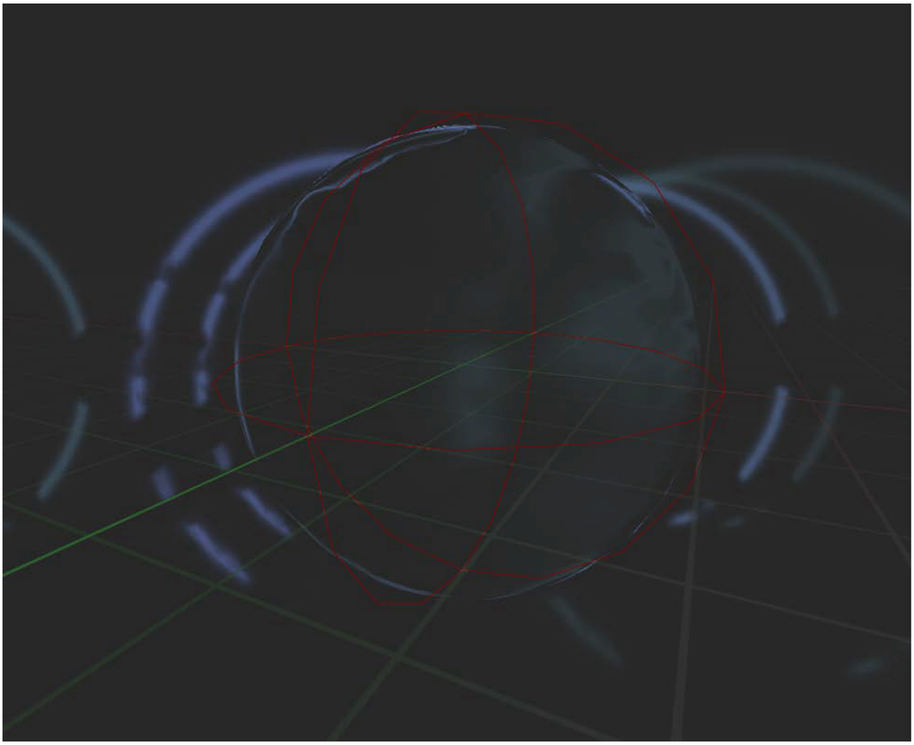

Fig. 8. Projectile appearance

constant within a medium. To get this to feel correct to the player many test plays were conducted until an appropriate speed was selected.

6 Damaging Enemies

The world in VROARRR is filled full of NPCs and vehicles such as aeroplanes. These entities can be damaged by the roar projectiles, as the roar weapon fires quickly a mechanic was devised to allow for a gradual application of damage (example shown in Fig. 9). The mechanic realised was a head enlargement to showcase the idea of the roar being really loud, this generated a progress bar effect of how damage an enemy (examples shown in Figs. 9 and 10).

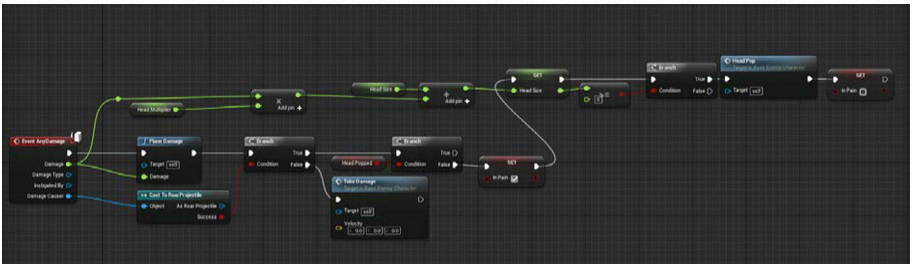

Fig. 9. Head enlargement

Fig. 10. Default grandma model

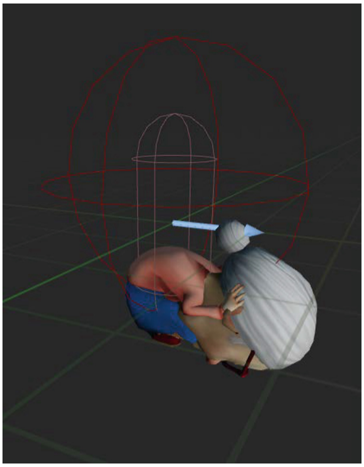

Fig. 11. Head expansion grandma

7 Environment Feedback

One of goals of VROARRRs roar was to try and create a feel of presence within the world. Ashforth [12] says with VR we are trying to help the player believe they are really in the game environment, teleported into the games universe. Up until this point the roar mechanic focused on everything but the environment. To help work with surrounding buildings a system was created whereby all the materials in game could be distorted by a wind effect. The result was such that the buildings would distort and animate with a large roar. A static example of this can be seen in Figs. 12 and 13.

Fig. 12. Static environment

Fig. 13. Material distorted environment

8 Deflection Mechanics

One of the final properties added to the roar mechanic was that of deflection. Satellite dishes were created that would deflect any incoming roar projectiles based on the facing direction of the satellite dish. This whilst interesting did not physically/accurately recreate the diffuse of sound waves but instead created focal points for the player to aim at.

9 Conclusion and Recommendations

Many of VROARRR's roar challenges lay within traditional weapon design;

- Fire rate
- Damage balancing
- Environmental effects
- Aiming.

Most of these challenges have been somewhat solved, but could certainly be taken further.

9.1 Fire Rate

The system does require calibration and can easily be cheated. A Loud hum or whistle will generate a similar weapon out as a large roar. Through testing it was noted that some players just did not want to be a roaring monster. Perhaps in this world there can be a whistling monster.

9.2 Damage

The current system is modelled completely on amplitude of the incoming audio data. This could be expanded to account for other audio properties such as pitch. The addition of pitch could create more variety in application of damage, for example a high pitch could shatter glass whereas a low pitch could move large buildings. This idea of variable damages may in fact solve the previous issue of fire rate as it will encourage the player to use their vocal range to solve problems.

9.3 Environmental Effects

The current environment effects are limited to vigorous distortion/shaking. The presence of the player in the environment is somewhat let down by the lack of building and environment damage. Additional systems here could help create a greater sense of presence.

9.4 Aiming

The positioning of the player and their scale in relation to the world does mean that player must be quite mobile to roar at lower targets. Whilst this is fun for a large spectrum of people it's not always comfortable which causes issues highlighted by Ashforth [12]. The test head set used during the production of VROARRR was a HTC Vive, the cable that connects to the computer would often cause players to get tangled/react cautiously. Future advances in wireless technology will certainly help the ability to aim smoothly.

Video of VROARRR https://www.youtube.com/watch?v=OEF-XpOeO0k

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Go with the Dual Flow: Evaluating the Psychophysiological Adaptive Fitness Game Environment "Plunder Planet"

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Abstract. Exergaming is approved by health and sport science for its improvement of physical activity and therefore is an attractive way to counteract childhood obesity. The body-centered game genre provides a motivating, multi-modal and -sensory workout experience for the player.

But the attractiveness and effectiveness of exergames can be improved even further. Game research points out the need for adaptive exergame environments, which balance player skills and in-game challenges as well as player fitness and workout intensity. This individually adjusted training positively affects the player's engagement, enjoyment, motivation, and physical performance. Numerous studies delivered further insights into the impact of body movements, motion-based controllers and in-game mechanics on the player's gameplay experience, and made suggestions for specific game balancing mechanisms. However, there is limited knowledge on how to design holistic psychophysiological adaptive exergame environments. We aim to fill this gap with the design of the psychophysiological adaptive fitness game environment "Plunder Planet" for children and young adolescents.

We conducted a study which compares the impact of a non-adaptive and an adaptive version of our exergame on the attractiveness and the effectiveness experienced by the player. We were able to show that the adaptive version holds significant benefits compared to the non-adaptive version. Furthermore, the study compared the player's experiences when playing "Plunder Planet" with two different controller types: our specifically developed full-body-motion controller and the commercially available Kinect2®. Results confirm our controller design decisions, including the positive impact of haptic feedback and physical guidance on the player's GameFlow experience and enjoyment.

Keywords: Exergame fitness training · Dual flow · Plunder Planet · Children

1 Introduction

According to the World Health Organization childhood obesity is one of todays most serious public health challenges, even though overweight and obesity as well as related diseases (e.g. diabetes and cardiovascular diseases) could easily be prevented [1]. Childhood obesity can be counteracted by regular exercise routines [e.g. 2], which calls for new incentives to motivate younger generations to be more physically active.

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https://doi.org/10.1007/978-3-319-70111-0_4

One attractive and effective way to solve this problem is through so-called exergames. Exergames (exertion/exercising + gaming) are body-centered games, which require physical motion in order to play [3].

1.1 Related Work

Effectiveness. Although exergaming was initially conceived as a form of entertainment, researchers and health professionals are interested in adopting these technologies to support healthcare treatments and to promote physical activity and wellbeing for many reasons [4]. Numerous sport-scientific and health-related studies on both commercially available exergames and specifically designed exergames confirmed the benefits of the "edutainment technology" trend in sport [5]. Studies suggest that exergames, by having the potential to increase energy expenditure [6] and improve exercise effectiveness and program compliance [e.g. 7], can be effective in fighting obesity, inactivity, and health problems associated with sedentary lifestyles. Additionally, these studies indicate that children enjoy playing exergames, which increases their motivation to keep playing. Furthermore, there is evidence that exergaming positively affects, among others things, the learning of sensorimotor skills [8], coordinative abilities [9] as well as strength and endurance [10].

Attractiveness. Game research from interdisciplinary perspectives provides further insights into the theories behind exergames and the impact of the genre on the player's gameplay experience, body and mind. Csikszentmihalyi's flow theory [11] can be compared with the feeling of complete and energized focus on a particular activity, combined with a high level of enjoyment and fulfillment. An important precursor to the flow experience is the match between a person's skills and the challenges associated with a task, such as playing a game. Weibel and Wissmath define flow as a result of immersion or involvement in an activity (e.g. playing a game) [12]. Sweetser and Wyeth present the "GameFlow" model which determines the key elements of player enjoyment [13]. According to their approach, the state of game flow is modeled by a mix of elements:

- Concentration: Games should require concentration, and the player should be able to concentrate on the game.
- Challenge: Games should be sufficiently challenging and match the player's level of skill.
- Player skills: Games must support player skill development and mastery.
- Control: Players should feel a sense of control over their actions in the game.
- Clear goals: Games should provide the player with clear goals at appropriate times.
- Feedback: Players must receive appropriate feedback at appropriate times.
- Immersion: Players should experience deep but effortless involvement in the game.
- Social interaction: Games should create opportunities for social interaction.

Body. Apart from the mental and cognitive challenge, an additional physical challenge arises while playing an exergame. The bodily exertion greatly influences the player's game experiences. Bianchi-Berthouze investigated how body movement can be exploited to modulate the quality of gameplay experience [14], and they were able to identify five classes of movement: task-control movements, task-facilitating movements, role-related movements, affective expression and expression of social behavior. In general, the inclusion of holistic physical activity into gameplay is found to be a positive predictor for the feeling of immersion and engagement [15].

Controller. Additionally, the type of controller has a big influence on the player's game experience. Nijhar et al. found that players become more immersed if the movement recognition precision increases [16]. Similarly, Skalski et al. discovered that the perceived "naturalness" of game controller interactions shapes the sense of spatial presence, which is related to the feeling of immersion [17]. Stach and Graham showed that haptics matching on-screen actions improved immersion and enjoyment [18]. Kim et al. found that an embodied interface improves energy expenditure, player experience and the intention to repeat this experience inside the exergame [19].

Dual Flow. The attractiveness and effectiveness of an exergame can be improved even more, e.g. by a well-balanced adjustment of the physical and psychological aspects of its design. Sinclair et al. [20] applied the flow theory to the task of playing a physically and mentally challenging exergame, calling it "dual flow". Accordingly, an optimal exergame training has to balance player skills and in-game challenges as well as player fitness and workout intensity to create a maximum positive player experience. The player is then neither physically overstrained nor under-challenged ("effectiveness"), and feels well-balanced between psychological stress and boredom ("attractiveness"). The player experiences the feeling of "being in the zone".
Based on this theoretical framework, there are various approaches investigating and making suggestions for the implementation of a balanced challenge-skill level and the dual flow concept in exergames. For example, "dynamic game balancing" mechanisms (DGB) or "dynamic difficulty adjustments" (DDA) [21] can be implemented on various levels of an exergame environment (in-game-, body- and controller-level).

There are several suggestions on how to balance differently skilled players within a multiplayer exergame to simultaneously provide a fun and flow experience for more and less skilled players while playing together or against each other. Gerling et al. [22] experimented with game adjustments, such as score multipliers, the precision of input movements or the amount of movements each player had to perform, which were implemented in a dancing game. Altimira et al. [23] studied the multiplayer balancing effects of playing digitally augmented table tennis, which encouraged the more skilled player to either play defensively or aggressively.

Another approach, which focuses on the individual gameplay and flow experience of a single player, is the psychophysiological, dynamically adaptive method. Cardano et al. developed the exergame "Exerpong" [24] and investigated how physiological response can be modulated through in-game parameters. Mueller et al. [25] implemented real time heart rate balancing in a remote jogging application, because it allows players to focus on their own fitness levels while still engaging with another person.

Although current literature shows that there are already numerous insights into DGB- and DDA-strategies available, the especially promising approach of dual flow-based exergame design has not yet been fully exploited. Our work aims at bridging this gap with a comprehensive approach in both research and development, in order to make an innovative and sustainable contribution to the improvement of physical activity experience and to encourage children and young adolescents to become further engaged in healthy physical activity.

2 Research-Based Development of Plunder Planet

Based on our player-centered design model for psychophysiological adaptive exergames [26] and related research and development work, we developed “Plunder Planet”, applying a user-centered design process [27]. “Plunder Planet” is a psychophysiologically adaptive fitness game environment for children and young adolescents.

Currently, two different single-player input devices are used to physically control the exergame: In one game setup, the player uses the specifically developed full-body-motion controller (FBMC), which provides six large buttons, positioned around the player’s moving area. The player navigates by jumping up and down and hitting buttons. The FBMC offers haptic feedback, and demands coordinative and cognitive skills (Fig. 1). In the other setup, and as a contrast to the FBMC, we implemented the commercially available, gesture-based Kinect2® sensor (KIN), which allows for higher freedom of movement (Fig. 2). The player navigates by predetermined and free movements (e.g. pushing the arms forward, jump and squat). In both game setup versions, the player’s objective is to steer a flying pirate ship.

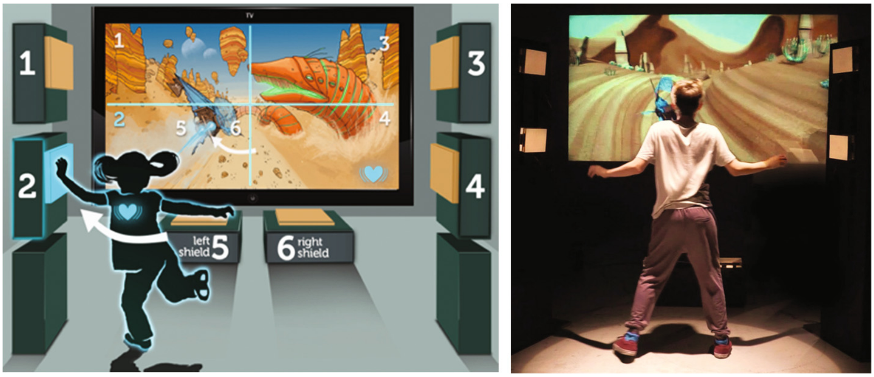

Fig. 1 “Plunder Planet” FBMC-setting. (Source: ZHdK)

We also implemented three adaptive game mechanics: one targeting the more physiological dimension of the game, and two others focusing on the more psychological aspects.

- During a “Plunder Planet” session, the player wears a Polar H7 sensor which measures the player’s heart rate (HR). The Trainer-GUI offers the possibility to gradually adjust the frequency of obstacles in real time in order to reach the optimal physical level of challenge for each player. The optimal training level for each

Fig. 2 "Plunder Planet" KIN-setting. (Source: ZHdK)

player/sports type (health zone, fat burning zone, aerobic and anaerobic zone) can be ascertained by calculating the individual maximum HR [28]:

$$HR_{max} = 220 - \text{age} \tag{1}$$

- The in-game performance is assessed by the amount of collisions, successfully overcome obstacles and opponent attacks defended. As a result, the track varies between easier or harder layouts. Also, overcoming obstacles can become easier or harder. Again, the cognitive level of challenge can be gradually adjusted via Trainer-GUI.

For all variables, the quality of adjustment features three independent levels of difficulty (low, medium and high, and each with three to four sub-levels: 0.0–0.3, 0.4–0.6, 0.7–1). Thus, the game difficulty and complexity can be adapted to the current physical, cognitive and emotional state of the player in real time.

In our previous feasibility study [27] we focused on the evaluation of "Plunder Planet" in a manually adaptive condition. We investigated the impact of two different controller devices (FBMC and KIN) on the gameplay experience as well as the spatial presence experience of children and young adolescents. Participants reported positive gameplay/spatial presence experiences and felt very motivated by the game. All participants enjoyed the audiovisual appearance and the story of the game, as well as the implementation of different controller devices.

Additionally, we drew inferences on the effectiveness of the exergame workout based on the analysis of various in-game events, which were tracked during each session. We found that the average HR lay between 125–145 beats per minute (bpm) for the FBMC and 130–160 bpm for the KIN-setup after a play session of 40 min. Thus, children worked-out within the "fat burning zone" (60–70% of HR_{max}) and the "aerobic zone" (70–80% of HR_{max}) [28], while in both setups none of them realized the effective duration of the training session.

3 Evaluation

In an advanced study, we deepened the approach of our previous feasibility study. We wanted to prove whether the adaptive "Plunder Planet" version provides benefits compared to the non-adaptive version (independent variable) regarding the "Game-Flow", the dual flow, motivation, enjoyment and spatial presence as well as the physiological response (HR) of children and young adolescents (dependent variables). Additionally, we investigated the impact on the player's experiences caused by playing both versions with two different controller devices (independent variable).

3.1 Method

Participants and Procedure. We recruited 54 children and young adolescents (30 males and 24 females) with and without experience of playing video games (28 GX and 26 nGX), and who did or did not frequently enjoy athletic activities (28 A and 26 nA). The age of the participants ranged from 10 to 14 years (M = 12.26 years, SD = 1.28). For the intervention, participants with GX and nGX as well as with A and nA were divided into two groups: 27 children and young adolescents were assigned to the KIN-group and 27 were assigned to the FBMC-group. The groups did not switch between the two controller versions. All participants remained with the controller version they were assigned to. Both groups can further be divided into four sub-groups (7 GX/A, 7 GX/nA, 7 nGX/A, 6 nGX/nA).

Each exergame setup was played twice, once in the adaptive and once in the non-adaptive condition. To balance sequence effects, half of each group started the session in the adaptive condition, while the other half started in the non-adaptive condition. Every session took four minutes. Before we began data collection, all participants were briefly introduced to the schedule and the idea of "Plunder Planet". Every participant then played one "Plunder Planet" session in order to become familiar with the game and with the respective controller. Participants were treated in accordance with the Declaration of Helsinki [29].

Pre-classification Guideline. During the familiarization session we pre-classified the individual dual flow-range for each participant, following an explorative guideline: The pre-classification started in the "low level" (0.1–0.3; warm-up level). If the player performed correctly (without in-game collisions) for about 10–20 s, the difficulty and complexity of the gameplay were increased by 0.1–0.2 sub-levels. This procedure was repeated until the player performed almost correctly (up to max. five collisions) for about one minute. Then the upper flow-threshold was reached. To verify the lower flow-threshold, the difficulty and complexity level needed to be carefully reduced for 0.1–0.2 sub-levels every 20–30 s. Again, this procedure was repeated until the player performed collision-free. The range between the lower and upper flow-threshold could then be defined as an individual dual flow-range.

Adaptive Condition. The adaptive condition started at the "low level" (0.1–0.3; warm-up level). Within two minutes the level of the adaptive condition was gradually increased until the pre-defined individual dual flow-range was reached. The principal investigator could then operate dynamically within this range via Trainer-GUI for the remaining two minutes. Both the psychological and the physiological game mechanics can be adjusted independently within the predetermined range. For example, it was possible to continue challenging the fitness-related physical skills of the player while the cognitive load was reduced during a short interruption of the player's attention span (e.g. higher frequency of obstacles, but less stressful layout variations of the track). Conversely, the more cognitive and emotional challenge could remain on a high level while the physical difficulty needed to be reduced if the HR of the player was too high (e.g. less obstacles, but a more challenging layout of the track). The division into more psychological and more physiological game mechanics allows for the accurate setting of the individual perfect training mode.

Non-Adaptive Condition. By contrast, the non-adaptive condition followed the approach of commercially available exergames, which mostly provide predetermined difficulty levels ("beginner", "advanced" and "expert" level). After a short warm-up phase, the challenge is gradually increased until the level reaches its climax. The level structure is not specifically matched with the player's physical capacity and gaming skills. For this study, we therefore provided a fixed average level of challenge (corresponding to the "advanced" level) without precise adjustment opportunities. Accordingly, and to keep the adaptive and the non-adaptive conditions comparable, the non-adaptive condition started at the "low level" (0.1–0.3; warm-up level). Within two minutes, the difficulty level in the non-adaptive condition continuously increased until it reached its climax. The fixed level of challenge then lasted for the remaining two minutes of the session. Based on the findings of our feasibility study, the fixed maximum difficulty and complexity level for the non-adaptive KIN version was set at 0.6 and 0.7 for the non-adaptive FBMC version.

Data Collection. After each of two completed runs, participants were asked to answer questions which were derived from Sweetser and Wyeth's "GameFlow" model" [13, 30], applying a 6-point scale (from 1 = "I do not agree at all" to 6 = "I fully agree"). Additionally, participants were asked to answer questions about their dual flow experience, enjoyment, motivation and spatial presence, again applying the 6-point scale. Furthermore, every three seconds, HR, in-game performance (in-game events and related in-game actions) and difficulty level of all players and play sessions were recorded.

Statistical Analysis. For statistical analysis IBM SPSS 24 was used. We created a scale by calculating the mean of all "GameFlow" items, "challenge", "concentration", "skills", "control", "clear goals", "feedback" and "immersion". As the reliability of this scale could be improved by removing "challenge", we created a reduced scale and analysed both, the reduced "GameFlow"-scale and "challenge" as a dependent variable. Furthermore, we conducted analyses on "motivation", "overload", "underload", "optimal challenge", "enjoyment", "spatial presence" and the average "HR". The differences between the FBMC- and KIN-controller versions, the four sub-groups (GX/A, GX/nA, nGX/A, nGX/nA) and the two play conditions (adaptive and non-adaptive) are evaluated in the framework of a repeated measurement ANOVA, with two between factors with two and four levels, and one within factors with two levels. In addition to the p-values, we report effect size η^2. In order to correct for multiple testing, we perform a Bonferroni α-correction and compare the nominal p-values with α divided by the number of comparisons. Instead of $\alpha = 0.05$, we use $\alpha_{corrected} = 0.05/27 = 0.002$.

3.2 Results

Table 1. Overall “GameFlow” (without “Challenge”)

Influence factor		*M*	Std. error	p-value	Partial η^2
Controller	FBMC	5.26	0.049	<0.0005	0.416
	KIN	4.87	0.049		
Condition	adaptive	5.38	0.033	<0.0005	0.972
	non-adaptive	4.74	0.038		
Sub-groups				0.176	0.101

For all “GameFlow” items (“concentration”, “skills”, “control”, “clear goals”, “feedback” and “immersion”; Table 1), there is a highly significant difference between the KIN- and the FBMC-version with a higher mean in the FBMC-version ($p < .0005$). “GameFlow” is rated significantly higher in the adaptive condition ($p < .0005$). There is no significant difference between the four sub-groups ($p = .176$).

Table 2. “Challenge”

Influence factor		*M*	Std. error	p-value	Partial η^2
Controller	FBMC	5.26	0.088	0.583	0.007
	KIN	5.19	0.088		
Condition	adaptive	5.11	0.067	0.007	0.150
	non-adaptive	5.34	0.081		
Sub-groups				0.001	0.296

For “challenge” (“To me the challenge of the game was…”; Table 2) there are no significant differences between the KIN- and the FBMC-version. The mean of “challenge” is higher in the non-adaptive condition ($p = .007$). Additionally, we found a significant difference between four groups ($p = .001$) with the highest valuation of challenge in nGX/nA ($M = 5.54$, $SEM = .131$) and the lowest in GX/A ($M = 4.79$, $SEM = .121$).

Table 3. “DualFlow_Optimal Challenge”

Influence factor		*M*	Std. error	p-value	Partial η^2
Controller	FBMC	4.518	0.092	0.053	0.079
	KIN	4.259	0.092		
Condition	adaptive	5.333	0.076	<0.0005	0.963
	non-adaptive	3.443	0.065		
Sub-groups				0.360	0.067

For “optimal challenge” (“Did you feel optimally challenged by the game?”, Table 3) the difference between both controllers is not significant ($p = .053$). The mean “optimal challenge” is significantly higher in the adaptive condition ($p < 0.0005$). There is no significant difference between the four sub-groups ($p = .36$).

Table 4. "DualFlow_Overload"

Influence factor		*M*	Std. error	p-value	Partial η^2
Controller	FBMC	2.247	0.108	1	0
	KIN	2.247	0.108		
Condition	adaptive	1.286	0.087	<0.0005	0.797
	non-adaptive	3.208	0.120		
Sub-groups				0.194	0.097

For "overload" ("Did you feel overchallenged at some point while playing the game?", Table 4) there are no significant differences between both controller versions ($p = 1.0$). The mean for "overload" is significantly higher in the non-adaptive condition ($p < .0005$). There is no significant difference between the four groups ($p = .194$).

Table 5. "DualFlow_Underload"

Influence factor		*M*	Std. error	p-value	Partial η^2
Controller	FBMC	2.438	0.089	0.001	0.214
	KIN	1.991	0.089		
Condition	adaptive	1.199	0.053	<0.0005	0.852
	non-adaptive	3.229			
Sub-groups				0.057	0.149

For "underload" ("Did you feel underchallenged at some point while playing the game?", Table 5) we found a significant difference between the two controller versions ($p = .001$) with a higher mean in the FBMC-version. "Underload" was valued significantly higher in the non-adaptive condition ($p < .0005$). There is no significant difference between the valuation of "underload" for the four sub-groups ($p = .057$).

Table 6. "Motivation"

Influence factor		*M*	Std. error	p-value	Partial η^2
Controller	FBMC	5.292	0.110	0.043	0.086
	KIN	4.967	0.110		
Condition	adaptive	5.5	0.078	<0.0005	0.783
	non-adaptive	4.759	0.088		
Sub-groups				0.874	0.015

For "motivation" ("Did the game motivate you to be physically active?", Table 6) there is no significant difference between the controller versions ($p = .043$). The mean of "motivation" was significantly higher in the adaptive condition ($p < .0005$). There is no significant difference between the four sub-groups ($p = .874$).

Table 7. "Enjoyment"

Influence factor		*M*	Std. error	p-value	Partial η^2
Controller	FBMC	5.339	0.076	<0.0005	0.427
	KIN	4.708	0.076		
Condition	adaptive	5.497	0.048	<0.0005	0.949
	non-adaptive	4.551	0.064		
Sub-groups				0.123	0.117

For "enjoyment" ("Did you enjoy the game?", Table 7) we found a highly significant difference between the KIN- and the FBMC-version with a higher mean in the FBMC-version ($p < .0005$). The mean "enjoyment" was significantly higher in the adaptive condition ($p < .0005$). There is no significant difference between the four sub-groups ($p = .123$).

Table 8. "Spatial Presence"

Influence factor		*M*	Std. error	p-value	Partial η^2
Controller	FBMC	5.158	0.088	0.868	0.001
	KIN	5.137	0.088		
Condition	adaptive	5.708	0.062	<0.0005	0.847
	non-adaptive	4.586	0.080		
Sub-groups				0.119	0.118

For "spatial presence" ("Did you feel immersed into the game?", Table 8) the difference between the controller versions is not significant ($p = 868$). The mean of "spatial presence" is significantly higher in the adaptive condition ($p < .0005$). There is no significant difference between the four sub-groups ($p = .119$).

Table 9. "HR"

Influence factor		*M*	Std. error	p-value	Partial η^2
Controller	FBMC	134.99	1.073	<0.0005	0.488
	KIN	145.05	1.073		
Condition	adaptive	140.03	0.861	0.961	0.000
	non-adaptive	140.01	0.709		
Sub-groups				<0.0005	0.373

For average "HR" (Table 9) there is a highly significant difference between the KIN- and the FBMC-version ($p < .0005$). For KIN the mean of HR was 145 bpm while it was 135 bpm for the FBMC-version. The means of the adaptive and the non-adaptive condition are identical. There is a highly significant difference between the four sub-groups ($p < .0005$) with the highest HR in GX/nA ($M = 146.14$, $SEM = 1.49$) and the lowest challenge in nGX/A ($M = 135.96$, $SEM = 1.49$).

4 Discussion, Conclusion and Outlook

Generally, "Plunder Planet" received very good valuations for "GameFlow", "dual flow", "motivation", "enjoyment" as well as "spatial presence" by all study participants. The adaptive game version achieved significantly higher rankings by the test persons than the non-adaptive version. Thus, the general hypothesis, that individually balanced exergames hold benefits compared to non-adaptive exergames, can be confirmed for "Plunder Planet". Regarding the effectiveness of "Plunder Planet", we found similar HR-values for the adaptive and the non-adaptive condition. Average HR values in both cases result from three "Plunder Planet" sessions (twelve minutes) and fall within the "fat burning zone" (60–70% of HR_{max}). Considering the short time frame this can be seen as a very good result. We found a tendency towards better ratings in the FBMC-version for all "GameFlow" items and "enjoyment". This result confirms our controller design decisions.

To conclude, the presented study suggests that "Plunder Planet" is a scientifically approved tool which provides attractive and effective training. Thus, it can help children and young adolescents to prevent childhood obesity and excess weight in a playful way.

Our future work will focus on the implementation of further adaptive game mechanics (e.g. audiovisual style, story, etc.). We also aim to derive an algorithm for individual game balancing and automate the adaption process during the "Plunder

Planet" session. Simultaneously, we want to continue experimenting with different controller types (e.g. haptic, gesture-based, mixed reality, etc.), which can also be integrated into the dynamic game adjustment approach (e.g. changing the position of a button dependent of the player's performance). Regarding the in-game and controller-based balancing mechanisms, we want to experiment with body-movement variations.

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Smart Mobility, the Role of Mobile Games

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Abstract. Cities are increasingly making accommodations for increasing bicycle use as one of the smart city strategies on mobility planning. Our study addresses the use of mobile applications (apps) to incentivize the increased use of cycling for commuting to work/study, we conducted a survey to identify trends and gaps in smart mobility research, especially on urban cycling promotion through mobile devices and games supported by geospatial analysis. The analysis of 140 publications, provided insights from the smart mobility concept like the constant support of mobile devices and location-based services on this research field as well as a strong bias towards experiments and a few theoretical reviews, the frequent use of intrinsic motivation when designing games, and customised platforms for experimenting instead of commercial applications. Finally, the lack of integration between game narratives and the capabilities of geospatial analysis is considered the biggest research challenge for game designers and smart city advocates.

Keywords: Serious games · Gamification · Urban cycling · Geospatial

1 Introduction

Before the automobile revolution, bicycle commuting was normal practice in European cities. However, due to industrial and cultural changes, just a few cities are considered cycling commuting leaders with about 30% of bicycle commuting share [29]. Optimizing public spaces for cycling, walking and public transportation usually means adding restrictions for private cars [16]. Better cycling spaces or bike-friendly spaces, help on reducing the frictions preventing people from commuting by bicycle.

Cities are still deciding if they will support bicycle commuting or adopt some sort of behavioural change campaign for engaging alternative commuters [29]. Such decisions can change the mind of certain citizens that perceived cycling as a dangerous and uncomfortable activity, cycling infrastructure as deficient, or simply prefer to have a car and use it for any kind of trip. Environmental conditions also prevent people from cycling due to the effort needed in hills, the risks of staying outdoors in polluted areas, or simply the uncertain traffic or weather conditions that could produce delays [43]. To create bike friendly spaces and promote its use improve urban mobility and pedestrian safety, such results are better perceived when citizens take part on participatory decision-making processes [36].

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Enhancing citizen participation and improving living conditions help on define the "smart city" concept, defined as the union of information technologies with sustainable development and citizen empowerment and participation [33]. Alternative commuting, especially cycling, is considered an environmentally-friendly solution for building sustainable cities, and could improve the traditional top-down approach of policy-making if cyclists are allowed to provide "on the road" feedback on their experiences. Enthusiastic cycling advocates aim to overhaul transport systems to include urban cycling as a normal component of multi-modal systems, and they use information technologies for supporting their analysis as well as for increasing participation.

Geospatial technologies are the kind of technologies that help monitoring and analysing spatial relationships within cities. Urban transport systems usually deal with relationships between paths, origins, destinations, roads, vehicles, goods and persons; therefore the use of geospatial technologies for transport systems goes beyond the basic analysis of x, y, z points with time stamps, to fully adopt the concept of trajectories [26]. Although some of those technologies are becoming popular within cyclists (i.e. search for places to visit, estimate the shortest path, record bike trips) and virtual rewards are commonly used by mobile applications, existing computing capabilities are capable to process a higher volume of data using parallel computing and data stream processing [11] in the background, providing better and more complete feedback to a mobile client device.

Described elements drive the concept of smart mobility, that applied to urban cycling, involve elements like geospatial technologies for analysing urban cycling, gamified tools for increasing enjoyment as well as citizen participation for helping on urban planning, that together could be formulated as in (1):

$$\{UrbanCycling \cup GeospatialTechnologies \cup Gamification\} \subset Smartmobility \quad (1)$$

This review critically analyses scientific outcomes regarding smart mobility and existing initiatives for promoting urban cycling; focusing on cyclists' motivation and engagement as well as the role of geospatial technologies and mobile devices on these tasks. The review also gives insights into selected scientific publications that consider urban cycling, gamification, geospatial technologies and mobile devices; presents tendencies and gaps of smart mobility promotion; and concludes with research directions and recommendations.

2 Methodology

The review started with a concept-based search on four scientific repositories, a set of documents were briefly described according to applied methodology, relationship with urban transport, and use of gamification; the analysis was made after selecting those reporting the use of game elements on promotion of cycling, research trends and gaps were identified as well as conclusions and a short description of future tasks.

2.1 Concept-Based Search

The search was performed over four scientific repositories SpringerLink, ScienceDirect, IEEEXplore, and Scopus, aiming to focus on information technologies repositories. It was driven by the concept of smart mobility; therefore, it considered the following keywords "Cycling", "Urban Cycling" and "bikeability"; complemented with "GPS", considering location based services and mobile devices, and "Gamification", considering game tools on non-gaming contexts. To link those keywords logical connectors were used, first "OR" operators linked cycling related keywords, then "AND" operators linked the two last keywords to just consider publication reporting location-based services and gamification. The final expression used for searching is shown in (2) while the relationships between keywords are shown in Fig. 1. A temporal window from 2014 to 2017 was defined so that the search is considering only recent and comparable publications.

$$\{\{Cycling \vee UrbanCycling \vee Bikeability\} \wedge GPS \wedge Gamification\} \quad (2)$$

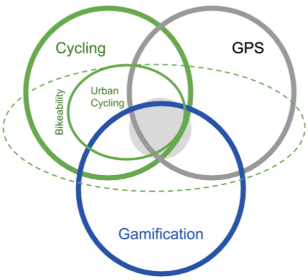

Fig. 1. Conceptual relationships considered on the review

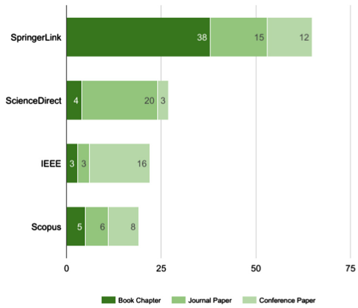

Fig. 2. Book chapters, journal and conference papers reviewed

2.2 Document Description

The search produced one hundred and forty scientific documents (140). From these documents, simplified meta-data was generated with features like access URL; year of publication; years of the most recent and oldest reference; and the number of citations [31]. Each document was described considering four topics and a set of features listed in Table 1.

2.3 Selection of Cycling Related Publications

The subset of cycling related publications was defined by the fields of the second topic (Relationship with urban transport and cycling) and complemented with features like the type of mobile device, use of location services, applications or platforms, city and country of the experiment, and finally the use of quantitative or qualitative methods.

Table 1. Structure of the description table

Topics	Field description
Reported methodology	- Literature review, when reporting text compilation and analysis
	- Experiment or test, when reporting experiments or tests of hardware, software, applications or algorithms
	- Design, when reporting new methodologies, platforms, information systems or frameworks
	- Survey, when reporting data gathering from participants, interviews, workshops or derived analysis
	- Reported participants, when reporting the number of participants in a survey or experiment
Relationship with urban transport and cycling	- Urban traffic, when reporting analysis of traffic conditions
	- Health, when reporting measurement of health benefits
	- Sports performance, when reporting performance measurements
	- Environmentally friendly actions (green living), when reporting behavioural change towards green living
	- Related to cycling, when reporting use of bicycles in urban areas
Relationship with location based services - LBS	- Location services, when reporting usage of GPS or any other location technology
	- Mobile devices, when reporting usage of mobile devices
	- Wearables, when reporting usage of wearable devices, mobile accessories, virtual reality headsets or similar devices
	- Social networks, when reporting interaction through social networks
	- Web pages, when reporting interaction through websites
	- Virtual survey systems, when reporting non-personal surveys
	- LBS Related, an aggregated description using “No Device”, “Device Enabled” or “Mobile and Location enabled” categories
Relationship with urban transport and cycling	- Intrinsic motivation, when reporting intrinsic motivation
	- Extrinsic motivation, when reporting extrinsic motivation
	- Negative impacts of gamification, when reporting evaluation of gamified tools
	- Gamification relationship, an aggregated description using “gamified” or “non-gamified” categories

2.4 Analysis and Comparison

The analysis was supported on set of graphics that provided insights of each of the described features, multiple comparisons between topics allowed to identify such patterns, tendencies, and gaps; and related work used for defining smart mobility was considered during analysis. Contrasting cycling and non-cycling related publications helped to identify trends and gaps. A selection of relevant graphics were compiled and annexed to this paper [31].

2.5 Discussion and Conclusion

The discussion was driven by the identified trends and gaps, they allowed to identify future works and conclusions about urban cycling promotion as well as the way that such works would help emerging open smart cities.

3 Results

The relevance on the web of the words used for search allowed to understand the interest on those terms through time. Table 2 shows a constant and usually low interest for general concepts like “Cycling”, “Biking” or “Urban Cycling” on the one hand, and a sequence of stationary variations during the northern hemisphere summer on the other. The “GPS” concept showed a decreasing interest tendency, probably associated with its ubiquity and massive integration with more complex devices and tracking systems (i.e. fitness trackers, onboard computers, driving assistants, etc.), while the relevance of “Gamification” significantly grown from 2011 when emerged as a novel and trendy concept.

The review was made up of over one hundred and forty (140) scientific publications, of which, sixty-six (66) from SpringerLink, thirty (30) from ScienceDirect, twenty-four (24) from IEEE Xplore and twenty (20) from Scopus. Figure 2

Table 2. Concept interest on the web from Google trends

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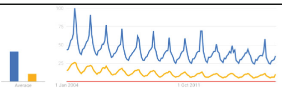
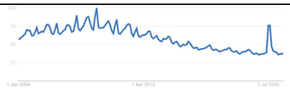
<tr><td>
Cycling, Urban Cycling, Biking</td><td>
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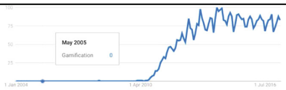
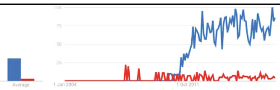
<tr><td>
Gamification</td><td>
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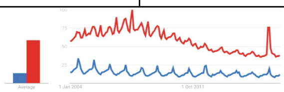
<tr><td colspan="2">
Cycling Vs. GPS</td></tr>
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shows not only the high contribution of publications but also the strong proportion of book chapters from SpringerLink; the large number of journal papers from SpringerLink and ScienceDirect as well as several conference papers from IEEEXplore and a balanced distribution of publications from Scopus. Not shown in the figure were seven (7) publications reporting either abstract compilation, workshop synthesis or lecture notes.

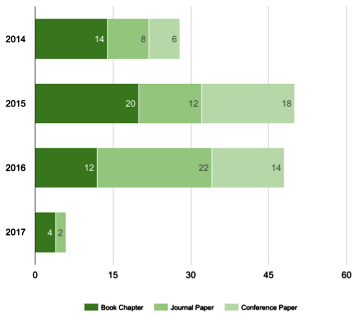

Fig. 3. Distribution of publications through selected years

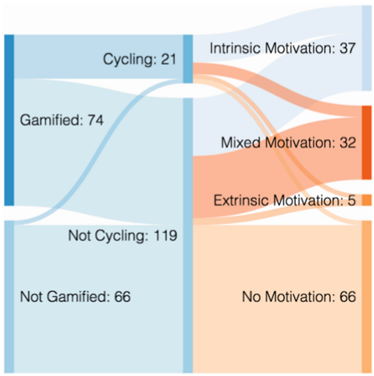

Fig. 4. Number of publications related to urban issues

The number of publications from 2014 to early 2016 has increased as can be seen in Fig. 3. But, although journal and conference papers show a constant growth, the number of book chapters decreases in 2016. Some journal papers and book chapters could under publication processes and therefore unaccessible yet. Reported methodologies were mainly literature reviews with sixty-two (62) publications (close to 45%) or experiments and tests with fifty (50) publications (close to 35%), the remainder reported either design issues (20), or surveys (7), for close to 20%.

Just thirty (30) publications (close to 20%) explicitly reported human subject participants. Most of them were experiments, tests or surveys, but also design. In these, participants played roles beyond traditional form-filling or instruction-following tasks to get involved during the design and operational phases. Participants were reported as contributing to an existing citizen science platform [21], sensor calibration [7], and platform functionality tests [13].

While surveys usually included more than two hundred and fifty (250) participants, there were three publications found with 275 [40], 394 [39] and 405 [38] participants. Far fewer participants were reported for experiments and tests. Only one operative platform reported one thousand (1.000) participants [21] while eighteen (18) publications reported from ten (10) to fifty (50). Among those numbers, it is interesting to see the job of [8], with more than three hundred and five (305) participants using a mobile social learning platform in a primary school for testing the convenience of virtual badges to reward learning achievements; as well as by [42], with two hundred and thirty-nine (239) employees taking part in a campaign that mixed gamification, motivation and social dynamics to promote bicycle commuting. These two last publications had the highest number of participants from this review, and they provide a reference for future gamification experiments about the number of participants to be recruited.

Even though "gamification" was considered as the concept that would provide publications reporting the use of serious game elements (see Fig. 1), just half of the obtained publications (74 of 140) effectively were reporting this use, whereas the remaining publications solely contain the keyword in sections like conclusions, recommendations and related or future works. Gamification usually considers two types of motivation: intrinsic, when it comes directly from users' preferences, or extrinsic, when it comes from external valuable elements [17]. Selected publications mostly relied on intrinsic motivation and avoid the negative implications of extrinsic motivation on long-term engagement [23]. Few documents reported extrinsic motivation as the main strategy (5 of 74, close to 7%) while some others reported it mixed with intrinsic motivation (32 of 74, close to 43%).

Regarding the use of technology and research production, the review provides additional insights. A few publications (less than 10%) did not report the use of any mobile device or web tool while the huge majority used tools like these two as well as wearable accessories, augmented reality headsets or biometric sensors; this evidences the strong support of information and communication technologies to this research field. Moreover, Thirty-three (33) publications had at least one citation (23%) with a ratio of 1.24 citations per publication being obtained from dividing total citations by all reviewed publications (174/140); although the low estimated ratio, the relationship between cycling and urban transport is an important research driver [16] that would need some additional time to improve not only the number of publications but also indicators like citation indexes.

3.1 Results from Urban Cycling Publications

When focusing on the use of gamification and mobile devices for promoting urban cycling, a subset of twenty-one (21) (15% approximately) cycling related publications were selected. Although modest in number, the subset provided new insights in terms of fewer documents reporting "Literature Review", from 45% to just 10%, and more documents reporting "Experiments and Tests", from 35% to 70%. These changes show a different state of research, with a higher focus on testing gamified tools that promote urban cycling than theoretical development or literature reviews.

Publications related to urban transport, urban traffic, environmental impacts of transportation, sport performance or health had also changed when contrasted against those cycling related; from a uniform participation of each topic (close to 10%) to a bias towards topics like sport performance (rising to 60%) and urban transport (rising to 50%) within the cycling related subset. Almost half of cycling related publications reported the use of location-based services and mobile devices, while three quarters-reported only the use of mobile devices (up to 70%).

Just three (3) cycling related publications reported use of publicly available applications, SmartMo [19], Moves [32] and SocialCyclist [37]; however, only Moves had a considerable number of users, up to one million downloads from the Google play store, while the others had less than one thousand downloads on the same store in February 2017. The use of mobile applications on cycling related publications are mainly based on prototypes that are not published on commercial platforms.

The previously identified bias towards gamification was expected on cycling related publications. Figure 4 shows that ninety percent (90%) of them reported gamification; of which those reporting intrinsic motivation were eighty percent (80%), mostly as the only kind of motivation but sometimes combined with extrinsic motivation. A small number of publications reported only the use of extrinsic motivation, a fact probably linked to the negative consequences of extrinsic motivation for behavioural change [23].

Although quantitative methods are mainly used for mobile and geospatial related research and nineteen (19) cycling related publications reported this approach (close to 90%), a remarkable number of them reported either a mixed method (5 of 19, close to 23% of the total) or a qualitative one (close to 10%). There is a lack of quantitative research about gamification and behavioural change that not only report insights from the technological perspective but also from the human and social.

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3.2 Existing Trends of Cycling Related Research

After reviewing twenty-one (21) cycling related publications, four research trends were identified: gamified platform design, experiments with gamified tools, behavioral change strategies, and data collection; they were grouped and described below.

Gamified platform design. This section groups publications reporting tests for gamified tools like the SocialCycle mobile application [27] that are designed to encourage people to either start or increase bicycle riding. It considered requirements from a cycling experience survey as well as those from a users' evaluation of existing mobile applications. It groups the user interfaces into four categories: encouraging, enabling, engaging and exemplifying cycling.

The physical activity monitoring device for aging people - PAMAP uses the concept of "ambient assisted living systems" for motivating balanced training ([7] and provides personalized feedback from sensors and GPS location. Testers have found it useful for balancing aerobic and strength workouts. The Individual Persuasive Eco-Travel Technology - IPET added a set of gamified tools based on pervasive technologies and support behavioural change. Volunteers were willing to adopt sustainable transport alternatives for large scale travels [25].

A mixed platform used virtual reality headsets for engaging users with physical activity, Occulus headsets, and Microsoft Kinect devices and provided virtual rides that increased enjoyment, connectedness and motivation of participants [18]. A virtual immersion of cyclists into bike trips successfully motivated them to work out; the bike-attached sensors controlled navigation within the virtual environment, while the exergame rewarded them based on their displacements [15]. Based on the term "Fitnessifying" in which popular video games are modified to include physical exercise setting, the static bicycle has been changed into an augmented gamepad and it provided more enjoyment to participants than the original game [20].

The immersive virtual reality (IVR) platform Rift-a-bike was successfully tested for supporting physical exercise and providing a cycling immersive game environment, as it provided multiple insights on the effectiveness for increasing physical activity using bicycles [41]. Finally, the use of two wearables: a smartwatch, and a wrist-worn accelerometer, as input devices enabled a gamified mobile application to potentially promote fitness and exercising based on the huge satisfaction and enjoyment expressed by participants [44].

Experiments with gamified tools. This section groups experiments that evaluated gamified tools with users, starting with the serious game ecosystem called "Serious Games Community Building" that promoted greener transportation using a virtual coin system, interaction through social networks as well as a rewarding system for expert-evaluated challenges. This has received positive feedback for being a reliable business model and sustainable operation [4].

A new methodology for designing user interfaces, considering not only complexity in the interaction, but also exercise intensity [14], was specially tailored after analysis of existing exergames and it allowed users to effectively choose tools that fit into their exercise times. The Pittwater Council supported a set of experiments performed by students from Macquarie University's, which used gamification and mobile devices to identify environmentally friendly routes for protected areas in North of Sydney, as well as serious games for evaluating new business ideas from students while involving experienced businessmen at a Business and Economics Faculty [24].

Behavioural change strategies. This section groups either positive or negative outcomes of gamified strategies. It starts with the evaluation of extrinsic and intrinsic motivation for shifting modal strategies towards environmentally friendly modes of transportation [10]. By using a tailored mobile application, participants increased walking or cycling after two weeks; however, results had no statistical significance. Applying financial rewards for drivers willing to avoid traffic jams and instead use alternative transport modes during peak-hours produced negative effects such as the very low wiliness to change behaviour after the financial reward ends [9].

Qualitative analysis about negative influences of gamification found not only negative effects when competition is promoted, it can drive enthusiastic users by obsession rather than enjoyment. Moreover, clubs of cyclists expressed their concerns about the increasing use of mobile and GPS enabled technologies, mentioning associated effects on family and personal relationships of competitive cyclists. Finally, they identified common interaction patterns in commercial tracking applications that could be re-used to improve usability [2].

The Biking Tourney strategy that promoted alternative commuting within a group of workers from 14 companies during six weeks [42], created a successful experience with 15% of overall participants starting to use the bicycle for commuting as well as the 30% more occasional bike commuters. The analysis of individual and collaborative challenges to promote personal mobility changes appeared to be relevant to behavioural change support systems [34]. Although challenges themselves are game elements, challenging individual behaviour was better perceived by the subset of users willing to also use information technologies or electronic participation to tackle a challenge. An important role of gamification in policy making and smart city planning was found; although its use is not commonly considered by policy makers, positive effects of including gamified tools in citizen engagement, co-design and participatory decision-making processes were reported [30].

Data collection. This section groups initiatives for collecting data using game elements. They consider the lack of urban cycling datasets, as well as the need of updated and highly-detailed travel behaviour data, in order to increase better research development and decision making. Tools for collecting short, long or multimodal trip paths, as well as those made by alternative modes (i.e. Intermodal walking/cycling, car- and ridesharing, electric cars, etc.) could integrate gamified tools [5]. The SmartMo application could provide information about demand size, citizen needs, attitudes and perceptions towards alternative transport, including measurements of pro-environmental travel behaviour [6]. Finally, analysis of sampling processes for transport related surveys lists other relevant challenges of GPS-based surveys as well as privacy issues linked to them [1].

4 Discussion

Although the review provides a relevant group of publications using the serious games approach for promoting cycling, there are various gaps in this research field. This section discusses how the reviewed publications are helping on either identifying or overcoming the frictions that prevent citizens from bike commuting [29], the tools that better support such strategies, and the existing opportunities for creating not only novel serious games, but also providing better feedback for both urban cyclists and cities.

4.1 The Serious Game Approach

With just six out of twenty-one (6 of 21) cycling related publications reporting successful behavioural changes towards urban cycling, the use of information and communication tools on serious games is still under development. Although the use of indicators such as distance, speed, saved time, burn calories and non-emitted CO_2 are commonly used incentives in reviewed publications; they are usually considered abstract and not always relevant to urban commuters, consequently, new designs should provide more relevant measurements of comfort, safety, effort, and environmental conditions that are more relevant for urban bike commuters [16].

On the one hand, existing sport tracking applications rely on motivation coming from competition between users, usually trying to make them to bike more or faster [2,14]. Game designers must be aware of negative effects of gamification, such as excessive competition or obsession, described by [2]. Moreover, they should include virtual and personal interaction between cyclists and other urban actors to produce long term engagement with sustainable commuting [22].

On the other hand, reviewed publications explore a wider range of purposes, from promoting healthier habits to the optimization of data collection processes. Game narratives can be improved by using pertinent stories for each of the identified purposes, therefore game designers could create new stories that motivate players beyond the marketing strategies that tend to be used by commercial sport tracking applications; they could now gather citizens' participation or help to connect cyclists and expanding their social communities, this novel approaches will demand lots of innovation from designers [4,24].

The incentive behind urban cycling is not always individual, it can also come from the sense of belonging to a community, group achievements or shared benefits [9,42]. Some communities like workers, students, artists, etc. can be motivated with new gamified tools that rely on positive feelings of playfulness, fun, freedom, flexibility, well-being, social and human interaction associated to cycling [9]. This novel approach would provide benefits for citizen participation, civic engagement, social interaction and sense of place, all of them linked to the research agenda of open smart cities [12].

4.2 Technology and Analysis

Surveys are the preferred data collection tool for transport analysis based on trip origin and destination; however, smart mobility is more complex and demands higher detail. Although adding location to a survey with a GPS reference is considered a huge improvement [5], location based services can provide very high detail about cyclist behaviour like the final destination or integration with different modes of transportation [36]. Virtual maps and shortest path estimations are widely provided by mobile phones but they are far from describing cycling dynamics; geospatial analysis could be used for better describing smart mobility by identifying preferred streets for cycling (i.e. Strava Density map) [3], and cities are asking for those products that better support policy making [35]. Cycling infrastructure is currently integrating public bike sharing platforms, checkpoints, dedicated spaces as well as physical barriers that not only influence cycling dynamics but also provide new datasets [11].

The combination of location technologies like GPS, internet connected cycling infrastructure, sport tracking platforms as well as high capacity computing platform for geospatial analysis offers an attractive environment for research [28], not only for geographic information scientists looking to understand cycling patterns [11], but also for game designers willing to motivate and engage citizens with smart mobility, provide relevant feedback and promote greener ways of commute. This could make up for a combined research field that is not clearly envisioned by reviewed publications.

The global trend of designing open smart cities focuses on citizen participation trough information technology [12] and smart mobility that demands active participation of citizens and games enabling social interaction [9]. The way cities involve citizens on improving urban transport systems will demand civic engagement, then the use of game elements looks appropriated to produce such engagement since they can be personalized to fit into the different levels of complexity demanded [3].

Future research on game design and gamification should consider new strategies that take advantage of geospatial technologies. New narratives should then involve outputs of the multiple sensors deployed by the city, the interaction between players in real-time as well as the use of wearable and virtual reality devices. These products could be part of city planning processes that better engage citizens with public participation and smart mobility.

5 Conclusions

The review investigated the relevant research topic of smart mobility and the role of mobile games and geospatial technologies on promoting urban cycling promotion. The one hundred and forty reviewed publications showed the diversity of authors, topics, approaches, methods, and outcomes. Although there is a balance between the experiments and literature reviews of the selected documents, the review identified biases towards experiments using mobile devices and location-based services on cycling related publications, unfortunately, most the experiment tailored tools are not publicly available except from three publications.

Cycling related research focused on using intrinsic motivation for gamification, moreover, extrinsic motivation should not be considered for promoting urban cycling since its results strongly depends on the external reward. Gamification seems to be useful for encouraging behavioural change towards urban cycling; however, in urban contexts cyclists are less willing to compete but to participate or interact. Game designers should create narratives that link the sense of belonging to a community, the participation on policy making or the desire of having better cities, and motivation should be linked to the feelings of playfulness, fun, comfort, well-being, freedom, social and human interaction associated with cycling.

Just one commercial platform was reported by a cycling related publication. Since the lack of public research outcomes from commercial applications does not prevent cities from establishing partnerships or joint research efforts (i.e. Waze helping cities with traffic management), it could potentially support urban planning and decision making while improving traditional techniques of data collection based on crowdsourcing and location-based services that would increase not only quality but also the precision of urban datasets.

Finally, the review identified tendencies of urban cycling promotion as well as the lack of conceptual reviews about game design and gamification techniques applied to this promotion. Based on the strong relationship between cycling and mobile devices a higher level of scientific publication was expected.

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An Extensible System and Its Design Constraints for Location-Based Serious Games with Augmented Reality

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Abstract. In the project SPIRIT, we developed a playable prototype of location-based Augmented Reality storytelling for museums. In order to develop a full experience, several aspects have been tackled by an interdisciplinary team, which are described here: the SPIRIT app catering to special location-based experiences, the formalized content structure STARML supporting authoring, a plot engine managing content based on STARML, integrated concepts for interaction as well as interactive storytelling. The result is an extensible system that constrains the design for a specialized experience. The paper describes each of the aspects and discusses potential extensions of the system for further application.

Keywords: Serious games · Cultural heritage · Augmented Reality · Location-based storytelling · Interaction design

1 Introduction

1.1 Overview

Since the advent of Mixed and Augmented Reality systems, their use in conveying digital information for museums and historical sites has been one major application area [6, 23], next to maintenance support systems [17]. With varying hardware and varying principal software components, several museum applications were conceived in research projects over time [4, 9]. The connection of the technology with location-based games [3] and storytelling [11, 12] has been recognized as an opportunity for learning and entertainment before the term 'serious games' was even coined. The existing examples range from research prototypes never used outside labs up to evaluated systems. Their differences often lie in the degree to which a concept is readily applicable. Moving from the labs towards usable systems, requirements change. Technology must be invisible and functional; story and interactive system must be fully integrated. AR systems – even those that are supposed to help people – are often faced with complex and unfamiliar user interaction styles that have to be learned by novice users in the first place. A meta-study of user experience research with AR systems has pointed out that a majority of evaluations have been conducted with technophilic male test subjects [2].

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However, within the last three to five years, personal handheld devices with a reasonable screen size and a variety of sensors have been getting ubiquitous as a platform for gaming and entertainment, including mainstream concepts for museums or tourism.

In this paper, we report on the project SPIRIT, in which a system and a case study have been developed as a running prototype that has also been finally evaluated with consumers as visitors of an outdoor museum. Within the project, in order to develop a full experience, several aspects have been tackled by an interdisciplinary team:

- The SPIRIT player app: An Augmented Reality system, running on off-the-shelf mobile phone and tablet hardware (Android), sensing the environment with GPS, camera, and gyroscope/accelerometer as well as Bluetooth signals from beacons, and using image processing for recognising locations in the unprepared environment
- STARML: A formalized content structure as XML dialect to be authored by storytellers or game designers, extending the existing location-based standard ARML [15] with elements for plot- and GUI management, thus enabling interactive storytelling and game design for creators
- A plot engine reading the content structure, managing the presentation in time and in relation to contexts and variables
- Concepts for user interaction, resulting in several ideas for interaction patterns making use of the big variety of available sensors, providing guidance and learnability for users, tested in formative evaluation cycles
- A case study with an example fictional scenario story ("Spirit: Aurelia, Saalburg AD 233") that fulfils requirements of being adequate to visited locations and connected to historical facts, running with one interaction pattern fully elaborated with a tested GUI.

Fig. 1. User holding up a tablet, having tracked down spirits of Roman soldiers (of the year AD 233) at the "Principia" building (of now), who discuss the recent attacks of the Germanic tribes (Videos including artist credits are available at https://www.youtube.com/user/hsrmstory).

In summary, the result benefits from several technical developments as well as utility solutions by solving design challenges. The achievements consist of a playable case study prototype with location-dependent content that can be experienced at a specific historical outdoor site (the Saalburg Roman Fort [20], see Fig. 1), and of a functional extension concept allowing authors and future developers to create similar experiences. In the following, the paper is organized along the line of addressed aspects that are finally integrated in the holistic user experience. We summarize each of the individual solutions by also explaining their rationale and their relation to the state of the art. In each section, we also discuss the system's constraints for scenario designs, and we show possibilities for extending the system in the context of serious games and interactive storytelling.

2 Design Constraints Set by the Augmented Reality System

2.1 Overview

At first, we describe our developed AR system in order to later discuss its influence on content design. Grounded in the original idea for the applied research project, the whole experience and technology is designed around the metaphor of 'meeting spirits of the past' at a location where the referenced historic characters lived their life. Hence, the system as well as the premise for creating content is first and foremost location-based, with the claim to present matching media triggered by users' orientation in the environment.

This was the motivation to base the structure on principles defined by the Augmented Reality Markup Language ARML of the Open Geospatial Consortium [15], which is also used by other outdoor spatial AR applications, such as Wikitude [24]. The technical concepts of the AR player application have been described in previous papers [5], so only a brief summary is given here. ARML describes visual assets that overlay features as representations of the real world. The Spirit player extends the ARML-defined asset media types by the use of video. Particularly semi-transparent video with cutout effect (see Fig. 1) is obtained through rendering the video stream as a SurfaceTexture using the MediaPlayer Android API and modifying it using Fragment Shaders. The videos need to be pre-produced using green/blue-screen technique with chroma-keying and some post production, to create the ghost-like illusion of 'floating in thin air'. Further, ARML specifies an anchor for triggering augmentation of a real world feature, distinguishing between a location anchor and a trackable anchor. GPS data and (for indoor environments) beacon signals are interpreted to recognize users' locations.

Further, a video-based tracker has been implemented using OpenCV and the ORB algorithm [19] for matching camera input with stored reference images. The reference images can be a series of photographs of a real location, taken under different lighting conditions. Gyroscope, tilt/inclination sensors can also be used to trigger media. Consequently, mobile devices to be used for the application (phone or tablet) need to be equipped with a rear/main camera, GPS, gyroscope, tilt/inclination sensors, and the graphical capability of displaying AR video. Bluetooth/BLE is also useful for indoor navigation. For our prototype, we use Android with Java for direct hardware access to above components, further OpenGL and the OpenCV library for image detection.

In relation to the state of the art in Augmented Reality systems, our system does not address 6DOF tracking and registration of 3D objects, which in an emerging technology, but still a challenge in unprepared environments [1, 10]. However, compared with the 2D concepts of for example Wikitude, the Spirit player includes reasonable advancements, integrating sensors such as the gyro for more complex spatial interactions, and providing the interface to the STARML markup language and the plot device described in the next chapter.

2.2 Discussion

The system has proven to recognize locations, images and orientations quickly and effectively in the outdoor environment, even under differing lighting conditions. On the other hand, there is a certain level of imprecision in the exact superimposition of media assets. Fortunately, for displaying 'spirits' floating in thin air, this can be negligible. Thus, the base technology constrains creators to think mainly of communication scenarios with virtual characters, being displayed from one side without a 3D impression.

At this point the system is imperfect, yet "satisficing"[1]. Asking for the added value that AR could contribute to the user experience in a (partly) educational setting, we found that it is exactly a connection to reality, which marks the difference towards more conventional media. Two main benefits especially for museums could be associated with these properties: (a) AR displays explanations and illustrations directly on physical objects, to let users see correct relationships between explanation and object parts; and (b) AR facilitates the potential experience of an 'aura' of 'the real', to encourage people to visit historical places [12].

The SPIRIT system clearly caters for this latter level of amazement in order to be rewarding, entertaining and motivating, while precise superimposition of visual features is less important. However, designers of games and location-based storytelling would need to work and 'write' around this constraint. This means that exact positions in the outdoor environment are hard to be referenced within a game or story, as the system is best suited for communicating dialogic scenes with 'spirits' integrated visually in a camera background.

3 Formalized Content Structure and Plot Engine

3.1 Overview

Based on this technology including the ARML standard, we developed an extended formalized content structure as well as a plot engine that manages the different sensorial contexts (i.e., interpreted user behavior) and provides situation-dependent adequate pre-authored storytelling content.

[1] "Satisfice" is a term coined by H. Simon, a portmanteau word of suffice and satisfy.

We extended the OGC standard ARML and developed it further into so-called STARML (Storytelling Augmented Reality Markup Language), which we described in a preliminary version in [7]. Basically, this includes author-friendly terminology to support the description of a more complex stage for action. For example, the declaration of GPS coordinates is integrated in tags to define “active areas” (see Fig. 2). Within an active area, file paths to reference images, such as photos of the environment, can be declared to define certain so-called “backdrops”, in front of which pre-recorded video storytelling can be staged (compare Fig. 2). In order to organize scenes with storytelling and/or game progress, several “chunks” of video pieces can be declared that can be concatenated by the plot engine into a linear presentation, yet interruptible between single video files. Given that authors then can include more preconditions into certain “chunk” elements, authoring of nonlinear content presentations is possible. For example, as illustrated in Fig. 2, authors can distribute several groups of spirits around one user location. These could also have a fictional conversation with each other in one scene, provided that the user turns around – stepwise – to visualize them. This is foreseen to be managed by interrupting and resuming chunks of videos. Layered parallel to videos, sound files can be declared (for example to support continuous ambient sound independent of the user’s triggering).

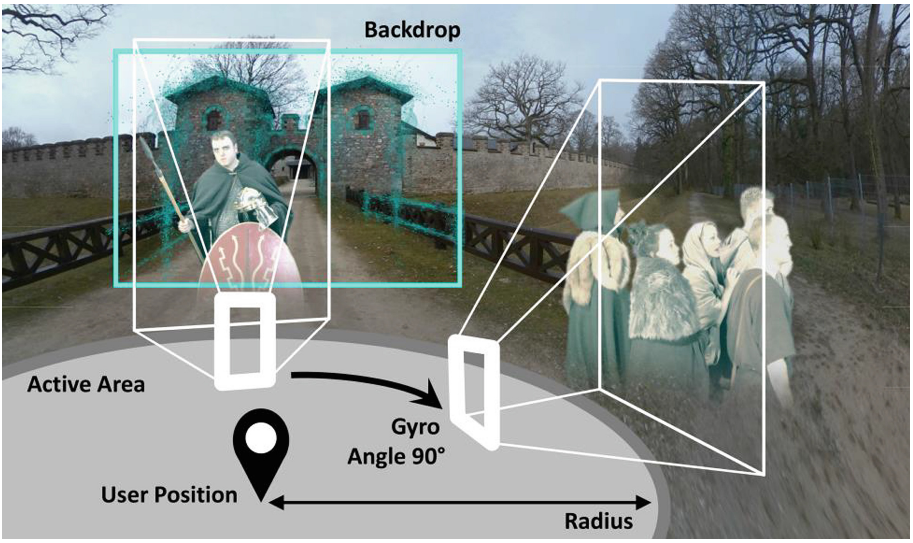

Fig. 2. Location-dependent content structure of an “active area” including a declared GPS coordinate (user/tablet position), a prepared “backdrop” image to start a scene (here in front of the eastern gate), as well as a gyroscope condition triggering further video files when a 90° turn to the right is recognized by the tablet. Note that spirits are not staged ‘at’ the GPS coordinate, rather ‘roughly’ in front of a backdrop or in a viewing direction.

STARML has been extended to also include descriptions of more interactions. For example, authors can declare content working only on the condition that the gyroscope signals a turn to one side by the user. Another interaction possibility that can be declared is a timer that supports the design of a "timed-gaze" input selection or similarly, timed proximity (e.g. proximity to a beacon placed in the environment).

Lastly, STARML can also be used to declare dynamic graphical user interface (GUI) elements, such as buttons, dialog boxes, graphics, and subtitles. 'Dynamic' here refers to the feature that GUI elements can optionally be handled as plot-dependent content elements, similar to videos, except that they have screen coordinates (while videos move according to the device movement, staying adjusted to the camera image). Other dynamic elements are plot-dependent text notes that can be read as one goes or in between, such as for including fact information. This could also be feedback for users on their achievements, such as an inventory of spirits met, and a tour history.

The plot engine interprets all STARML elements, checks preconditions after each event and determines the next possible action or event to be played. Implemented like a state machine, it processes propositional strings as pre- and post-conditions to advance the plot. These concepts have been inspired by narrative structures used in previous projects of the interactive storytelling community [13, 16, 22], and adapted to be specific for location-based Mixed Reality using implicit sensors next to deliberate choices of players.

3.2 Discussion

STARML as a content structure enables the separation of player app and content, thus, to extend the system by authoring alternative content. This XML dialect had to be developed closely together with the performed case studies of content ideas. It also has been changed constantly during iterations of user interaction design cycles and formative evaluations, as this influenced user requirements concerning GUI elements and their timely behavior possibilities. As a conclusion, we expect that with further ideas for redesign or content adaptations, it is likely that STARML would need extensions again, as consequences of authoring ideas are hardly foreseeable before they are tested with users. Therefore, many aspects of the case study, such as the STARML content structure, the interaction design and the concrete story with its dialogs, were developed at the same time, respectively in iterations. As a matter of course, this also meant that the plot engine was under constant change. In the interdisciplinary team, consisting of software developers, a creative writer, and interaction designers, this was partly also a source of friction, due to hen-and-egg situations. For further extensions of the system at the content structure level, these mutual dependencies have to be taken into account.

In the case study, a creative author was involved to write compelling dialogs and an interesting story about deals, corruption and the life of families during the Roman occupation on Germanic territory (around AD 230). Visitors of the Saalburg stroll about the area and encounter parts of the story, dependent on found locations. The STARML possibilities of authoring non-linear dialogs have not been fully exploited by the authoring team (yet). Besides conceptual challenges for 'making' the story, this would have also posed more difficulties on end-user interaction, which will be described next. For the sake of getting the case study up and running with non-professional users, keeping it simple (thus linear) was important in the first instance. However, in currently starting future work, this challenge will be tackled again.

4 User Interaction Patterns

4.1 Overview

One of the first visions of this project was to fully realize the metaphor of just meeting spirits of history, possibly with no profane GUI elements that remind at any operation system, but directly using the sensors and camera of the mobile device. However, without any markers in the environment, users were not able to get a clue about where to point their device at, or where to go. Increasingly over the time of design and development, GUI elements were added together with several ideas to simplify or constrain the huge variety of possibilities.

Interaction design was done in many iterative cycles of designing and testing with users. In order to test preliminary ideas before the AR system was fully implemented, we developed a mockup tool (MockAR [8]) that allowed the design technique of wireframing with AR overlays. Further, previous prototypes approached the interactive story experience by using graphical stand-ins and voices of the authors, before the final bluescreen shooting (which involved most of the costs) could happen. As far as possible, tests were done in the office before traveling to the location. In this case, excluding the aspects of GPS and search, we mounted posters with backdrop photographs on office wall corners for experiencing alternative solutions of content and GUI design. Getting closer to the current solution, 20 subsequent test cycles with fresh users have shown that the pattern of interaction is still not easy to learn if nobody demonstrates it. However, it is easy to remember. As a solution, a tutorial has been designed that can take the role of demonstration.

The result is an interaction pattern that has to be learned at the first location, and can be repeated at all further locations. The following user actions are part of the pattern, repeating a certain order of actions.

- Searching for a next location, with the help of the map or with the help of a stencil, which represents a memory image shown by the spirit Aurelia in the Saalburg story. User tests have shown that both ways of searching were preferred by different people, and both were found to be entertaining.
- Aligning the stencil, which matches the finding of a "backdrop", leads to the trigger of the first video available in an active area (compare Figs. 2 and 3 left), thus starting a scene.
- Eventually, arrows occur on the side of the screen, as an affordance for the user to make a quarter turn in the indicated direction. This causes a next part of the dialog to be triggered. In user tests, this was the most critical part to adopt for most of the users, because the turning movement needs to have a certain dynamic to be effective for the gyro sensor. Once learned, it can be repeated easily.
- This can repeat for a while, depending upon the authored content structure at one location.
- In the particular Saalburg story, after all content elements of one active area are played out, the main spirit Aurelia turns to the user and shows a memory image of the next location ("active area").

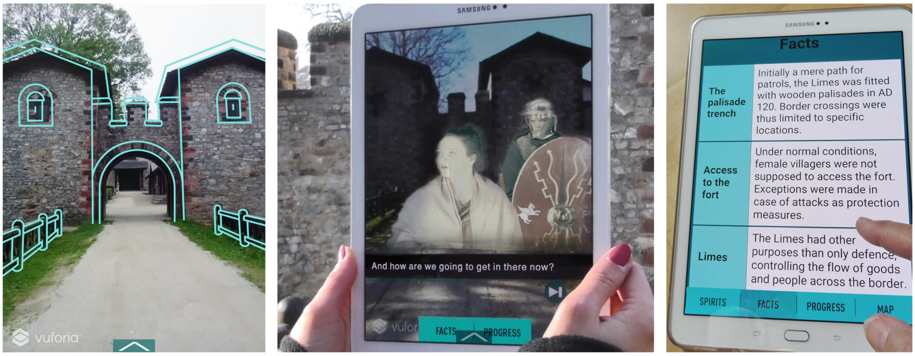

Fig. 3. Left: Search screen with memory stencil overlay fitting the eastern gate backdrop. Middle: Triggering of a scene, including a subtitle and an update notification of "new facts" (at the bottom) associated with the scene. Right: Interaction with the facts menu in reading posture.

- Then the user can walk and search for the next location and repeat, until the end of the story.
- In addition, it is possible to access the menu at the bottom of the screen anytime. It provides access to historical facts information, suited to a current fictional scene (see Fig. 3, right). Further, users can check the spirits they met so far and see their current progress about already visited locations. Finally, the menu contains a button to access the map.

The project could hardly make use of existing design principles for mobile Augmented Reality, except for generic principles like those of affordance, feedbacks and constraints [14]. For this particular application area, there is little reference material, as many applications include AR as a very brief interaction, instead of one to directly experience stories with. Concepts for games with more proportions of AR interaction have specific interactions tuned to the particular game design [18], which is a similar case for the SPIRIT project.

4.2 Discussion

Interaction design is closely related to the way of interactive storytelling, as it defines possible user participation or influence on the story. The previously described system of sensors including STARML enables a plethora of options how this could be designed. One option could be that all information, also on how to use the system, was conveyed by the dialogs with met spirits, within 'the storytelling'.[2] However, such a decision constrains the storytelling to entertaining direct dialogs with users, also diminishing the believability of a historical character, such as a spirit of a Roman soldier.

[2] Early prototype videos on https://www.youtube.com/user/hsrmstory show how this could look like.

Design decisions were made after again revisiting the question for the added value of Augmented Reality in the interactive educational and entertainment application. We expected AR to facilitate a potential experience of an 'aura' of 'the real'. We made the user turn around to make him/her look into different directions on the spot, also to find spatial relationships. For example, standing in front of the eastern gate and turning to the right lets us look to the "Limes", the historically built frontier by the Romans to the Germanics area. These aspects can be stressed in the fictional story, by letting the spirits look into this direction for the arrival of their scouts (compare Fig. 2). They can also be addressed by text in the 'Facts' menu. As a matter of fact, in this case the interaction design is especially effective, if the story content is written in direct accordance with it.

Further, we found that not only the technology, but also the design of characters including their acting could have an effect on the experience of presence of the spirits in 'reality'. This is a reason why we separated fictional play of the story of the spirits from factual information, to let the spirits stay 'in character'. Facts can be consulted at the users' convenience, or not at all, as they wish. In our formative evaluation cycles during design, test users differed in their tendency to use the "Facts" button, which for us underlined the necessity to design this feature as 'optional'.

Within the project, we have also explored other interaction patterns by prototypes, which were lending themselves to different kinds of content genres, such as adventure games. For example, we cashed beacons at two different locations to identify fictional user/player friendship with either Romans or Germanics, or we can let authors set a timer for reaching a certain goal in physical space. In principle, these kind of interactions could be fleshed out with an extension of the system, and a new framing story matching this kind of experience would then need to be written.

5 Storytelling

5.1 Overview

The SPIRIT system has been conceived as a location-based Augmented Reality system for interactive storytelling, which is the reason for the particular design of many of its components. So far, we have one playable prototype running with one location-based story connecting to the Roman occupation of northern Europe, to be experienced at a particular place, the Saalburg Roman fort.

The story has been designed in a laborious collaboration of a writer and designers with the rest of the technical team. The more the characters, dialogs and actions of the story take up knowledge of the specific location, and can indeed connect to historical facts, the better we expect to experience real presence at the place through technology. However, this location-dependency can also be a drawback, as one has to intricately travel there for the experience. Nevertheless, especially the storytelling part is easily extensible without much technical development, given that the current interaction pattern remains unchanged.

This has been achieved in small authoring evaluations with student groups in Media Management, who did not have programming experience. By just replacing GUI elements and authored video content, and adopting the exact interaction scheme of searching, watching and turning around, one group built an entertaining welcome application for the foyer of a big company, to be used in recruitment of young adults as employees. However, more student groups pursued history themes around the city of Wiesbaden, as it lends itself better to meeting 'spirits of the past' that guide us with their memories. In summary, although many stories can be told, it is recommendable to question the suitability of the medium for each story, as it is fascinating, but also complicated.

5.2 Discussion

A challenge that still needs more exploration is making use of the existing content structure for 'interactive' or non-linear interactions in storytelling. First, there is a barrier to be crossed by creative story authors to fully embrace interactivity. Second, as also in our case, we found during our tests with one prototypical nonlinear scene that end-users had many more difficulties in using it than with a strictly linear scene. Similar to the situation depicted in Fig. 2, we created a distributed dialog scene with two groups of spirits facing each other from different positions. Users could randomly look back and forth to either group of spirits and listen to them, as they wish. Their turn would trigger the spirits' dialog to start, instead of the system prompting the user where to look at. Unfortunately, this kind of frequent non-linearity is also combined with a certain difficulty in the usability of moving the device with the right momentum, so that the sensors apply. Here more exploration is needed in all aspects, including more designed feedback for the user through an interface.

Other more global non-linearity, for example based in an undefined order of active areas to visit, is not as much a technical problem with the system, as a potential practical one. At first sight, it seems similar to known adventure game styles. However, our evaluation of the case study with 107 museum visitors revealed other aspects that need be considered, concerning the museum situation. A large group of subjects complained about having to walk one segment twice, although from the story's logic it made absolute sense, for example to return to the eastern gate. A guided 'tour' with ever-new sights was rather expected. Apparently, as the app is location-based, it could be that the effort to walk overrules the ideal of having free choices. Some visitors expected rather more factual information about buildings than to experience fictional scenes. The latter, including love, personal dreams and corruption, had the goal to stimulate imagination of how one's life could have been at this place. As mentioned in Sect. 4.2, we decided to provide a separate Facts menu that would be up to the user to check it out, or leave it. Our preliminary tests (with subjects from close to our lab) did support this hypothesis that some users would not want to hear talks about Facts. This felt differently in the evaluation on the spot, where the subjects were museum visitors who decidedly came there, before they knew of the app.

6 Conclusion

With the SPIRIT project, we developed a system for a specialized form of location-based interactive storytelling or gaming with Augmented Reality. At several levels, the system is optimized for this kind of connecting a story or game to a place, while other more general features of e.g. Augmented Reality are not as much supported. The concept separates the story content from its structure that is tuned with the running app and interaction design. Next to video AR content, also interactive elements such as GUI items can be managed by a plot engine. Under the umbrella of creating specialized AR experiences with a goal to create a feeling of local presence, this system is extensible. Non-programming authors are able to create content easily, as far as existing interaction patterns are adopted. Otherwise with more effort in development, further interaction patterns could be designed.

The performed case study of content production and user evaluation points out that research is still to be done also in terms of the suitability of developed content, its structure and technology, and matching of target groups and situations. The study showed how mutually dependent all aspects – also beyond system design – are to be successful. Although the described system is extensible, there are certain limitations from within the subject matter of location-based Augmented Reality. There is the potential that struggling with unfamiliar interaction patterns distracts a bit from feeling the presence of spirits in the environment, and to even remember the content after the experience.

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Full Lifecycle Architecture for Serious Games: Integrating Game Learning Analytics and a Game Authoring Tool

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Abstract. The engaging and goal-oriented nature of serious games has been proven to increase student motivation. Games also allow learning assessment in a non-intrusive fashion. To increase adoption of serious games, their full lifecycle, including design, development, validation, deployment and iterative refinement must be made as simple and transparent as possible. Currently serious games impact analysis and validation is done on a case-by-case basis. In this paper, we describe a generic architecture that integrates a game authoring tool, uAdventure, with a standards-based Game Learning Analytics framework, providing a holistic approach to bring together development, validation, and analytics, that allows a systematic analysis and validation of serious games impact. This architecture allows game developers, teachers and students access to different analyses with minimal setup; and improves game development and evaluation by supporting an evidence-based approach to assess both games and learning. This system is currently being extended and used in two EU H2020 serious games projects.

Keywords: Learning Analytics · Serious games · E-learning · xAPI · uAdventure

1 Introduction

Games have been applied in multiple fields such as medicine [1], science [2], arts [3] or military [4]. Their benefits, such as their goal-oriented, engaging nature, makes them especially adequate for education, where students' motivation is essential.

Serious Games (SGs) are videogames where the main purpose is not pure entertainment: it may be to teach, to change an attitude or behavior or to create awareness of a certain issue [5]. There are several examples of successfully applied SGs: *Aislados* helped teenagers to prevent drug addiction and other risk behaviors [6] while *Darfur is Dying* created awareness of the ongoing war in Sudan in 2006 [7].

Most games, however, follow the black box model when it comes to collecting players' interactions: they merely report final results, which are far less informative than access to real-time learning progress. In fact, the usual method to evaluate SGs

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effectiveness is through pre-post questionnaires [8]. This evaluation method requires significant investments of time and effort, and individual solutions have to be provided ad hoc for every particular game, severely impacting the scalability of the solution.

The pre-post evaluation method also fails to detect changes in learning as they occur. Learning concepts appear at different stages of the game for different players; and this learning process should be tracked in real-time through the observation of in-game interactions for optimal feedback regarding the effectiveness of the games' learning design.

In the entertainment games industry, data analysis has been long applied to capture players' interactions and to improve their user experience as well as the game design [9] in a discipline that is usually called Game Analytics (GA).

In e-learning and different learning systems, such as learning management systems (LMS), Learning Analytics (LA) is commonly used to capture learners' actions to try to understand their learning process and prevent their failure. There are several definitions of LA; we could define it as "the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environment in which it occurs" [10, 11].

To apply these analytics models to SGs, we have to break the black box model to gain insights of players' interactions as they take place. This information could be then related to each student's learning process. Game developers could also benefit from this information to determine areas of minor or greater difficulty for players, or even game bugs such as unreachable areas. If the game design is suitable and the relevant interaction data is captured by tracing players' interactions in the SG, it should be possible to trace the evolution of their knowledge, telling apart the areas where they struggle or shine.

In Sect. 2, we describe the lifecycle of evidence-based SGs' impact. In Sect. 3, we describe the proposed abstract architecture for applying game and learning analytics for SGs and the different steps it comprises in design, development and evaluation. In Sect. 4, we describe a reference implementation as part of two EU H2020 SG-related projects. Finally, in Sect. 5 we summarize the main contributions and future work.

2 Lifecycle of Evidence-Based Serious Games' Impact

The combination of LA methods with the technologies long applied in GA allows players' interactions within SGs to be traced and analyzed, providing insight into their learning progress. We call this process Game Learning Analytics [5]. GLA allows an evidence-based approach to games' lifecycle (e.g. development, validation and evaluation).

The lifecycle of a serious game (see Fig. 1) goes from initial conception to development, validation (which may require several iterations if design flaws are uncovered before widespread release), and exploitation, during which periodic evaluation of student progress and outcomes will take place, once the game is released to its target players. The role of integrated analytics is critical to collecting and analyzing interactions to generate actionable feedback.

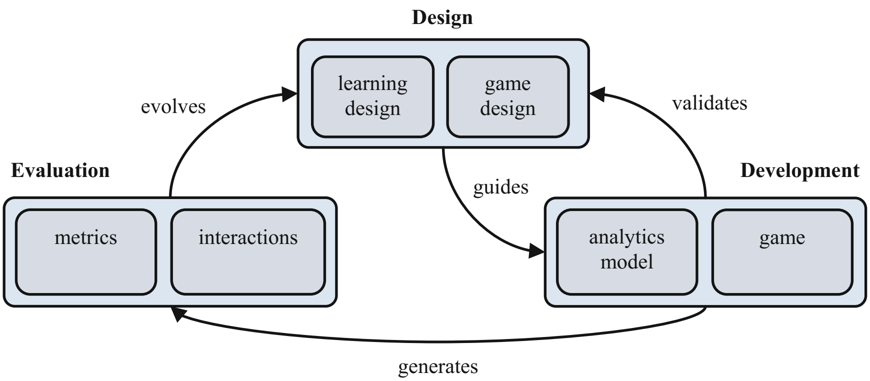

Fig. 1. Lifecycle of a serious game: from learning and game design, through development, validation and evaluation.

Both validation and evaluation require a strong integration of analytics to benefit from feedback and allow players to be evaluated meaningfully on their progress. The use of a unified analytics framework that can do GLA (that is, analyses both at the game level and the learning level) combining separate systems presents advantages for both. Integration of GLA into the development platform also presents significant benefits, comparable to those that test-driven design brings to programming: an early emphasis on choosing and measuring evidence of quality.

Both teachers and students can benefit from closer analytics integration. Analytics can provide real-time knowledge of what students are doing, but interpreting the data is difficult unless it is well presented. Dashboards that combine complementary visualizations appear to be an appropriate way of communicating data to stakeholders, who generally do not need to understand the details of the analysis performed underneath.

To achieve the most informative results, ad-hoc visualizations would be needed; however, providing meaningful default dashboards ensures that no setup is required to start enjoying advantages.

3 Proposed Abstract Architecture

We propose a complete and scalable analytics architecture, based on standards, that encompasses the whole process from game development to the analysis and visualization of results; a design guided game development where the interaction tracker sends players' interactions to the analytics platform composed of collector, analysis and dashboard; feedback will be sent back to the learning and game design (see Fig. 2).

In this architecture, SGs send traces in a standard-based format to a server that analyzes the data and transforms it into useful information. This analyzed information is then displayed in dashboards for different stakeholders: teachers or instructors in charge of players, the players themselves, game developers or designers and researchers [12].

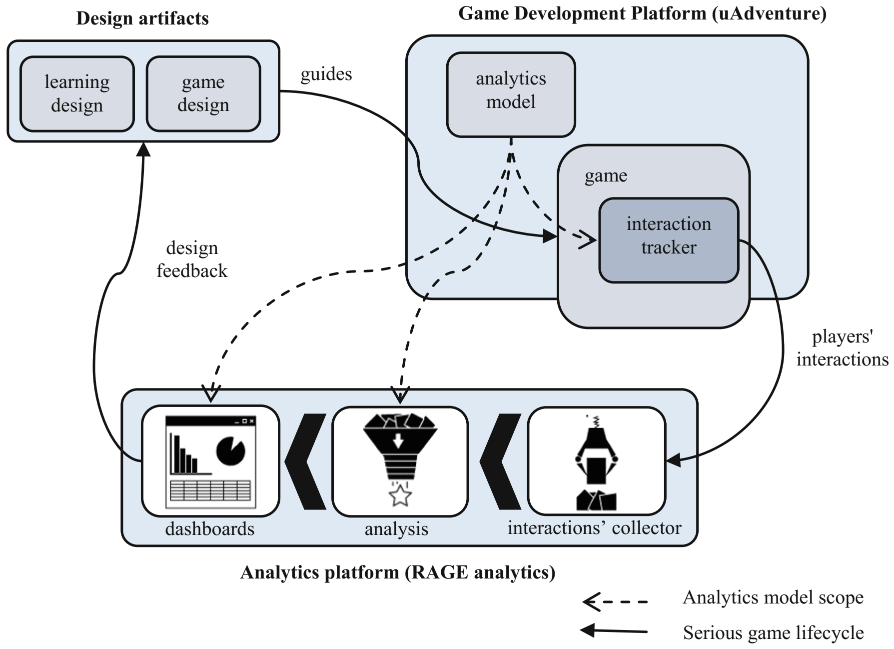

Fig. 2. Proposed architecture: design guides game development.

3.1 Analytics Models

Essential questions when performing analytics are those of what to track, how to analyze it, and how to present the results. Another way to frame these questions is to attempt to create a list of visualizations that would evidence that the goals of the game mechanics and the learning design are being met, and work backwards to define the analyses and data-collection that would be required. As illustrated in Fig. 2, analytics models inform all these decisions, and are an integral part of the game development.

The best analytics models are those that are designed together with the game itself, and are both influenced by the game's design and, where necessary, result in changes to the design that make the resulting game easier to analyze. However, there is a strong case for providing default analytics models whenever possible, to minimize the burden on game designers and developers (which could otherwise decide to forgo GLA altogether) and provide sane defaults on which more targeted analytics can be built.

3.2 Interaction Tracking

Analytics requires collection of each player's interaction with the game prior to any analysis. A standard collection format is desirable to allow interoperability and avoid data lock-in. After analyzing the current state of data standards and SGs, in addition to previous experiences applying e-learning standards to SGs [13, 14], a new interaction representation model has been defined and implemented based on the Experience API standard [15, 16]: the xAPI Serious Games vocabulary, or xAPI-SG for short.

Experience API (xAPI) is a data format developed by a community led by the Advanced Distributed Learning Initiative (ADL) [17]. The standard derives from Activity Streams, which represent a series of statements regarding learning activities with three main attributes: an actor, a verb and an object. Additional attributes may be included such as the result of the action or a timestamp. Figure 3 shows an xAPI-SG sample trace generated with [18] representing that the learner completed the SG with a score of seven.


```json
{
    "actor": {
        "mbox": "mailto:learner@example.com",
        "name": "Example Learner",
        "objectType": "Agent"
    },
    "verb": {
        "id": "http://adlnet.gov/expapi/verbs/completed",
        "display": {
            "en-US": "completed"
        }
    },
    "object": {
        "id": "http://adlnet.gov/expapi/activities/serious-game",
        "definition": {
            "name": {
                "en-US": "Serious Game"
            },
            "description": {
                "en-US": "Serious game example"
            }
        },
        "objectType": "Activity"
    },
    "result": {
        "score": {
            "raw": 7
        }
    }
}
```


Fig. 3. Sample xAPI trace. The serious game activity was completed by Example Learner with result score of 7.

The interaction model comprises several concepts such as *completables* (e.g. levels, quests or the serious game), *alternatives* (e.g. options in questions or dialogs) and general *variables* to track interactions in the specific domain of SGs. If desired, custom interactions may also be defined to extend the information for a specific SG.

In the architecture illustrated in Fig. 2, games contain an interaction tracker component that communicates players' in-game interactions via xAPI-SG to the analytics platform. The analytics model defines which interactions, events and targets are reported and how they are mapped to their corresponding xAPI-SG statement attributes, verbs and activity types.

3.3 Game Development Platform

Integrating tracking of GLA with a developed SG is typically performed ad hoc, and both the tracker and the analytics model are external to the chosen game development platform. However, a game development platform which follows the architecture illustrated in Fig. 2, must include the tracking component in each game, and configure it with an analytics model that is fully integrated with the game's authoring environment. This integration greatly reduces the investment of time and effort required from game developers to benefit from analytics, and therefore increases the likelihood that they will be able, with some additional effort, to improve the game design, the analytics model, and most importantly the game itself in each successive iteration of its lifecycle.

In our reference implementation of the architecture this component is implemented using uAdventure [19, 20], a complete rewrite of eAdventure, an authoring tool for point-and-click games written in Java and previously developed by the e-UCM Research Group [21, 22]. As many platforms and devices no longer support Java, uAdventure is built on Unity3D.

3.4 Data Analysis

Once the data is collected, the analytics server can begin to process it. Again, the analytics model must provide information on the metrics and KPIs that will be used to prove the effectiveness of the learning design. We distinguish two types of analysis:

1. Game-independent analysis that should be suitable for any SG that connects to the analytics server, as long as the game generates standards-compliant xAPI-SG traces.
2. Game-dependent analysis, which must be developed ad hoc for each game, but allow game and learning designers to create dashboards that perfectly match their game's goal and design.

The information obtained as result of the analysis should be stored for its later visualization; in the proposed architecture, analytics results are stored in a time series database (in our reference implementation of the architecture, Elasticsearch [23] is used), which can analyze and query large amounts of data in semi-real time, and is especially suited for later visualization.

3.5 Data Visualization

To facilitate the understanding of the analysis results for a range of stakeholders (including teachers, students and developers), it is important to provide each with informative dashboards to display results. The need for easy to understand and informative visualizations is especially important in the case of teachers, which can greatly benefit from real-time information to monitor a class while students are playing a game, and to provide targeted feedback to students that get stuck. Students will see their own personal progress in real-time and a general ranking within the same class competing with other students. Visualizations about the overall usage of the games such as session's length and server loading are shown to the developers, though the student specific data is only shown to the teacher because of privacy concerns.

In our reference implementation of the architecture of this component, visualization dashboards have been developed using Kibana [24], an open source visualization engine which is directly connected with Elasticsearch. Kibana provides a browser-based interface to quickly develop analysis and visualizations with different predefined graphics (e.g. line chart, bar chart, pie chart). Two sample visualizations available: the left one shows number of correct (in green) and incorrect (in red) answers in each alternative; the right one, the progress (in range 0 to 1) in each of the three completables and in the complete serious game for each player (see Fig. 4). New visualizations and dashboards may be configured in the system by selecting the required fields to be analyzed and displayed in the graphs.

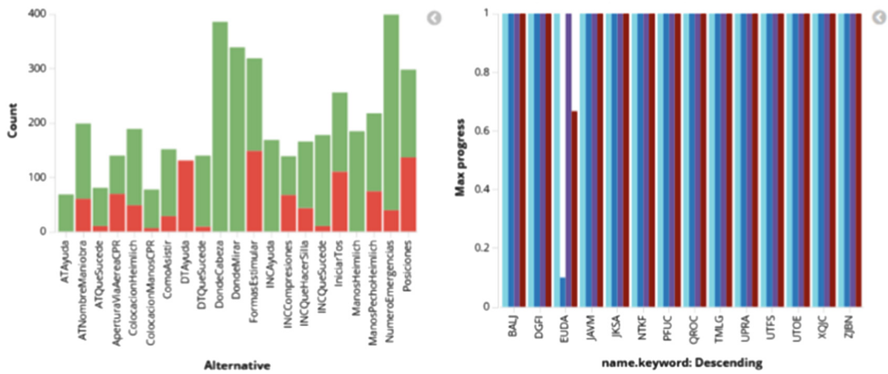

Fig. 4. Two sample visualizations containing errors made in *alternatives* and progress made in *completables*. (Color figure online)

To extend the usefulness of these visualizations, recommended actions may be included to help teachers provide timely feedback. In our implementation, alerts

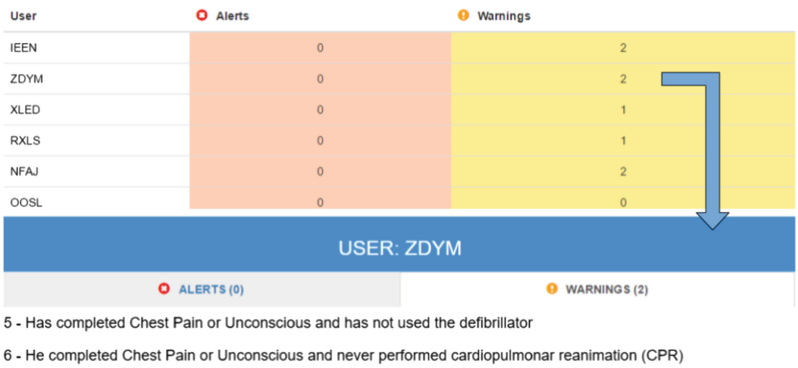

Fig. 5. General view of alerts and warnings for each anonymized user. Clicking on a specific user provides further details on the user's alerts and warnings.

(situations that require immediate action, e.g. “a student has made an important error”) and warnings (less urgent actions, e.g. “a student has been inactive for two minutes”) provide near real-time information to teachers. Figure 5 shows the general view of alerts and warnings (on top); clicking on a specific user in the general view displays details on the selected user’s alerts and warnings (bottom part).

4 GLA Architecture Reference Implementation

A complete architecture to manage GLA requires handling several interlocking parts: data tracking, data analysis and results visualization. We proposed the following standard-based architecture, a combination of modules that work together to analyze and visualize information collected from SGs [12]. Figure 6 shows a diagram of the GLA architecture: from learning and game design, the serious game is created. Its embedded tracker sends xAPI traces to the collector, which stores them in a LRS for batch analysis and sends them for real-time analysis. Visualizations developed from analytics provide feedback to come full circle improving the learning and game design and helping to assess students.

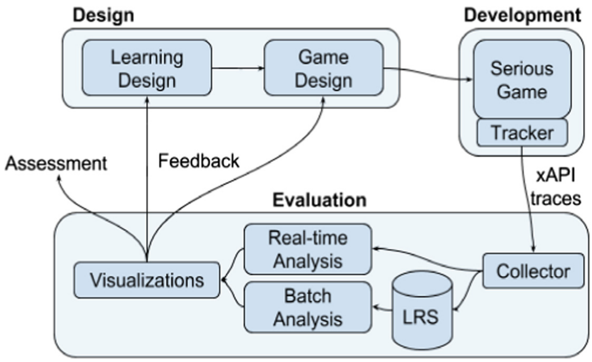

Fig. 6. GLA system: from design to development and evaluation.

- The learning and game design determine the SG implementation. This includes the game mechanics, structure, goals and in-game items or characters. Both these designs also determine the elements that will contain the relevant information for learning (usually as game variables), that is, the elements that are essential to be tracked as they will tell if the game is helping players to learn or not.
- The SG itself will use a tracker component to send traces in xAPI format (called *statements*). The tracker provides an application programming interface designed to send data to the server without having to know the underlying xAPI format specification. Current tracker implementations include Unity C#, pure C# and JavaScript to facilitate their integration with different SGs.

- xAPI-SG statements are sent to a collector endpoint on the server-side. Then they are sent to a real-time analysis component which updates the information for each player. xAPI statements are also sent to a Learning Record Store (LRS), a scalable database designed for storing xAPI learning activity data to perform a different analysis ("batch analysis").
- With the analysis results, visualizations in suitable dashboards show all metrics of interest for the stakeholders. If configured, personalized visualizations, alerts and warnings will also be displayed.
- Finally, the process is completed when the information obtained through analysis and visualizations provides feedback and improvement actions that can be reintroduced in the system for following iterations of the learning and game design. Additionally, this information may also help teachers in students' assessment.

4.1 Architecture Implementation

The GLA architecture described above has been developed as part of an EU H2020 SG-related project. All components are open source and available online[1]. When deployed, the components are launched as Docker containers [25] which eases deployment by eliminating all dependencies except for Docker itself. The main components are:

- An authorization and authentication component (A2), which enforces access controls and allows integration with existing institutional single sign-on systems, as well as hiding the complexity of all other components behind a reverse proxy.
- A frontend that allows stakeholders (teacher, developer and student) to configure and/or view dashboards for which they have appropriate credentials.
- A backend that collects incoming traces, analyzes them (either in real-time from incoming data or on-demand from LRS queries), and exhibits results for the frontend.
- A xAPI Learning Record Store (LRS) which allows third-party systems to query xAPI traces collected by the backend.

Since teachers, students and other institutional stakeholders typically already enjoy single sign-on in institutional systems, the A2 component has been extended to interact with these institutional systems via login plugins for either SAML2 (Security Assertion Markup Language v 2.0) [26] or LTI (Learning Tools Interoperability) [27]. These plugins simplify deployment in applicable institutions, since no additional credentials need to be created. Additionally, in the case of LTI, certain setup tasks, such as registering students as belonging to a particular teacher's class, can be eliminated altogether. Further information about the RAGE Analytics System can be found in the e-UCM Research Group's GitHub wiki page [28].

[1] eUCM Research Group, RAGE Analytics (2017). https://github.com/e-ucm/rage-analytics.

4.2 System Applications

The proposed system has been recently tested in an experiment with more than 200 students of a school in Madrid. With the goal of evaluating the whole GLA architecture, students played a SG to teach first aid maneuvers [29] while teachers obtained real-time dashboards about what students were doing, being able to control which students were progressing and which students were falling behind.

Students' anonymization was ensured via unique codes provided at the beginning of the experiment and required to access the game. Teachers were the only holders of the mapping between individuals and codes; all information collected in the system was only identified through this code.

During the experiments, it came to light that some visualizations were not easy to understand by teachers. As teachers are the only experts qualified in the evaluated field to know if students are learning or not, dashboards need to provide information in a clearer or more simplified manner for their easy comprehension.

5 Conclusions and Future Work

Although GLA is no longer an emerging field, it is still performed mostly through ad-hoc solutions, and therefore it could greatly benefit from a general standardized approach. Such an approach can increase adoption of SGs by promoting quality through evidence-based iterative improvement and better evaluation; while minimizing GLA deployment and development costs.

Our approach has three main pillars: first, the integration of analytics into the game authoring tool itself; second, the use of a standard xAPI-SG interaction model to standardize trace collection; and third, a default set of analysis and visualizations for the main SG stakeholders, including game developers, teachers and students.

Games created with the authoring tool uAdventure can effortlessly integrate tracking and analysis of results. Moreover, they can be deployed on a wide range of platforms, and can also support geolocalization [30].

Ad hoc analyses and visualizations can also be created by adding configuration files to the system or selecting the attributes to be visualized, respectively. Theses personalized analyses and visualizations could be useful if a particular game requires them; however, a moderate use of these is recommended as the more personalized configurations included, the less general the solution will be and the more effort it will require.

With these contributions, we have advanced towards a systematized standards-based system that helps to complete the full circle of GLA for SGs: learning and game design, SG development, tracking, analysis, visualization, and feedback, as depicted in Fig. 2.

However, there is still work to do. Some areas for improvement include:

- Improved explanations to allow novice users to interpret dashboard visualizations; especially for users that may not have been involved in the game design process.
- Simplified creation for custom visualizations. We are developing a wrapper around Kibana's built-in authoring environment to ease the process for non-programmers.

– Bidirectional communication between the tracker and the server, allowing the tracker to be notified when certain conditions are fulfilled in order to adapt the game's learning design and/or provide in-game, real-time feedback to players.

The system will be tested in more experiments with serious games currently under development. Work will continue on these and other improvements as the system is going to be improved and extended as part of the H2020 SG-related projects RAGE and BEACONING.

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InterPlayces: Results of an Intergenerational Games Study

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Abstract. Our submission describes the conceptualization and the results of an intergenerational games study composed of various games held in the Welios Science Center. We aim to identify design criteria (game mechanics, goals, etc.) for intergenerational digital games with haptic elements in a museum context that are not only fun, but also foster the communication between old and young players. In order to reach our goal, we confronted players with several different commercially available games as well as a specifically developed game prototype. To address the physical context (museum) in our methods and our game design we also carried out observations of existing installations plus interviews with museum guides. Results show that cooperative intergenerational games in a museum should include haptic elements, consist of several phases, with the possibility of reruns and should not be too complex, both technically and conceptually.

Keywords: Intergenerational play · Game design · Cooperative play

1 Introduction

According to the WHO[1] the number of elderly persons (60+) in western countries will increase considerably in the following years. These demographic developments have led to societal, political and technological challenges. Consequently, several initiatives were launched with the goal to increase the well-being of seniors through information and communication technologies (ICTs). One very relevant factor that contributes to the well-being of elderly people is a frequent face-to-face contact with the family and close friends (especially young and old). Based on these facts, the question arises: how can the social exchange and the relationship between the generations being fostered via ICTs?

[1] http://www.who.int/mediacentre/news/releases/2015/older-persons-day/en/.

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A very promising solution to this issue can be identified in the field of computer games (in this case: intergenerational games as a social medium). Intergenerational games offer the benefit of connecting different age groups while playing as these games increase positive interactions that lead to improved self-esteem and provide talking points for conversations [18]. Several studies revealed that there is a preference towards designing cooperative compared to competitive intergenerational games [14]. This cooperative aspect is especially relevant for grandparents to get in contact with their grandchildren [8].

Regarding the player behavior and preferences it was shown that older adults tend to engage cooperatively, seek more agreement and confirmation of actions from other players compared to children [10], as well as have a higher tendency to help, rather than compete against other players [2]. Another interesting aspect that was found out is the fact that younger people report that social interaction is one of the strongest motivators to play video games [12]. Furthermore, in contrast to the older generations, younger players show proactive behavior during gameplay [21]. Although the beneficial impact of intergenerational games is indicated in various publications, fairly little is known how older and younger adults play video games together and how the cooperative elements should be designed.

One of the few attempts can be found in the work of [14]. The researchers identified several design factors that should be addressed when creating intergenerational games: role differentiation and interdependence (collective versus individual roles of the players, balance of building positive interdependencies between players to contribute towards shared goals), gameplay assistance (addressing imbalance in skill levels both within and between the age groups), focal points (mutual exchange of ideas and information), physical engagement (physical attributes of the game), and instructional support (quality of game instructions). Although these factors may help designers to create intergenerational games, the authors note that the game-type used in the evaluation, and differences in gaming expertise must be acknowledged as influential factors. We want to address this issue by employing and evaluating various games (that share the recommended characteristics of intergenerational games such as cooperation and co-creation). We deem that the proposed study format is a powerful tool to design and evaluate intergenerational games as it follows a human-centered research procedure and brings together players of different ages and game researchers with expertise related to the design and evaluation of such games [9].

2 Our Contribution

In our submission we describe the results of an intergenerational games study composed of various games held in a science center (museum context). The proposed research is part of a bigger project, where it is the main aim to design and create an intergenerational game installation for the Welios Science Center[2]. Based on the current literature in the field we want to identify design criteria

[2] http://www.welios.at/.

for intergenerational games (game mechanics, goals, etc.) that not only are fun, but also foster the communication between old and young players.

In order to reach our goal, we organized and carried out a study where we confronted players with several different available commercial games as well as our own game prototype, called Mr. Robojump, that is based on existing game design guidelines and recommendations. Furthermore, we address the physical context (museum) in our methods and our game design via literature research (e.g. [3]), observations of existing installations plus interviews with the museum guides of the center. Through our approach we can identify possible design solutions and methods regarding intergenerational games for the application context (games that fit into the existing portfolio of the science center). The results of the study and the preliminary activities should aid both designers and researchers to create intergenerational games in a museum context that are fun to play and foster the communicative processes among the players. In the following information on the preliminary investigations (observations and interviews), the structure of the game study, and the employed games is given.

2.1 Preliminary Investigations

In order to set up the intergenerational games study, data about the interaction context was gathered. This was done by carrying out preliminary investigations focusing on existing exhibitions (how to integrate intergenerational playful experiences), target groups (age, gender, behavior), and interviewing relevant stakeholders (e.g. interview museum guides to find out which exhibition pieces are well received by both young and old people). On the 23rd of March 2016, an observation was carried out at the Welios Science Center to get a detailed picture of the facility and the exhibits. The Welios Science Center is Austria's first science center on a surface of 3,000 m^2, and is conceptualized as an Join-in-Museum with more than 120 interactive exhibits. It addresses aspects of natural science in a playful way by focusing on a funny transfer of scientific topics, learning by awaking all senses, and learning by doing. The goal of observations were to provide a grasp on how old and young museum visitors experience and appreciate the existing exhibits. The observation included all floors of the science center and lasted about four hours, wherein observations were limited to those exhibits people interacted with. In addition to the systematic observation of visitor behavior, we conducted a guided interview with an experienced museum visitors' guide.

Observations. The Welios Science Center has a couple of bigger exhibits on which it is required (or at least highly useful) to be a group of people when interacting with them, such as the Marble Run, the Hydroelectric Plant, or the Pellet Conveyor. The Marble Run exhibit, for instance, is one of the most cherished by visitors old and young. The task is to lay plastic pipes on a vertical magnetic wall to transport balls from one end of the installation to the other. In between a crank has to be operated to carry the balls from one pipe to another. Especially young children (aged 5 to 7) enjoy playing on this exhibit with their grandparents. The grandparent is needed to help, plan, and coordinate where pipes should go, because of the vastness of the magnetic wall. Sometimes the children are not physically strong or tall enough to move the pipes where they are needed, hence they require the support of a grandparent. In these cases, the children are mostly concerned with handling the crank, applying the balls, or providing the pipe pieces for the grown-up. If the children are equipped to handle the exhibit by themselves, grown-ups enjoy sitting on the bench opposite of it to watch the children play. In these cases, the children regularly enforce attention and appreciation of the adults in the audience. The exhibit is highly cooperative and consists of different haptic elements. People usually spend quite a long amount of time with this exhibit.

Interview: Museum Guide. According to the Welios museum guide, the visitor groups consisting of children with their grandparents particularly enjoy the above mentioned multi-person exhibits, as well as some of the other cooperative stations. After looking at the mentioned favorite exhibits, we concluded that important for an intergenerational game was to involve haptic elements (like for example pipes, bricks, gadgets, cranks, levers) and cooperation between participants. Regarding technical obstacles, the guide pointed out that grandparents usually let the children interact with technical equipment at first and take the role of observer and planner. Furthermore, it is important to have a short and understandable game description in an easy to read font and a huge enough font size on screens, because the grandparents often have to read the instructions for the children. It was specifically stressed that a vital component for grandparents is to have sitting accommodations near or in front of the exhibits.

Outcome of Preliminary Activities. In conclusion, children engage exhibits pro-actively, prefer haptic interactions with components, and enjoy being watched by an audience. Grown-ups, specifically grandparents, are more cautious and diffident toward an exhibit and let the children interact with it first before actively engaging themselves. While adults read instructions first, the children just get started with a game or installation, but usually not before the adult is at least watching. If adults do not engage with an installation directly, they almost always serve as a source of information or at least as an audience for the children. It was evident that both, young and old, have a preference for haptic elements and cooperative activities. However, cooperation could mean different things: first, grown-ups have to help if physical strength is needed, or a bit more elaborate planning, than is manageable by the children. Second, the game needs at least a second participant to engage in the game. Finally, third, the children need or demand a grown-up, especially a grandparent, to be an active audience by appreciating the child's game effort.

2.2 Intergenerational Games Study

Based on a literature research on game preferences of younger and older users and on experiences with intergenerational games (e.g., [1,5–7,17,20]), we formulated evaluation criteria for the selection of games and the design of our own game prototype for the design study. These evaluation criteria were paired with the insights from the preliminary investigations. Following a human-centered research procedure [19] we involved users at an early stage in the development and design process and conducted a study to test six gaming concepts based on our evaluation criteria. We developed questionnaires suitable for older and younger users and supplemented these with systematic observations by game station supervisors. The study provided valuable information on gaming preferences and technological challenges of our target user groups. The study took place at the Welios Science Center on the 15^{th} of July, 2016. The overall goal was to evaluate gaming concepts applicability for intergenerational settings and to test the developed evaluation material.

Employed Games. Guided by our state-of-the-art research in context of intergenerational games, we evaluated six games in our study that consist of five commercially available games and also a game prototype that was created by our research group. In the following, the five commercially available games are briefly described:

- IQ-Fit is a puzzle board game developed by smart games[3] to recreate different given shapes. Various 3D-puzzle pieces have to be placed on a game board in such a way that all the parts fit together without any holes.
- The Spore Creature Creator[4] is a software published by Electronic Arts in 2008. Players can create creatures by assembling various body parts in 3d space. Like professional digital creation tools, the 3d-models can be reshaped and textured. Finally simple animations can bee added to the creature.
- Bad Piggies is a puzzle game developed and published by Rovio Entertainment[5] in 2012, and is one of the many spin-offs of Rovio's well-known game Angry Birds[6]. The player's goal is to build a functional vehicle from a large collection of parts for a minion pig and to guide the vehicle trough a map to collect various items.
- Rugged Rover is a multiplayer game developed by the games studio Preloaded[7] for the Science Museum London. Players can design their own all-terrain space rover and test it in a rugged landscape on a fictional planet.
- Box Buddies[8] is a multiplayer puzzle game developed by students form the University of Applied Sciences Upper Austria Hagenberg Campus. Two players have to work together by moving obstacles to reach the entrance to the next level.

[3] http://www.smartgames.eu/.
[4] http://www.spore.com/creatureCreator.
[5] http://www.rovio.com/.
[6] https://www.angrybirds.com/.
[7] http://preloaded.com/games/rugged-rovers/.
[8] http://boxbuddies.rohschinken.at/en/.

The sixth game that was employed in the study was developed by our research group, called Mr. Robojump (see Fig. 1), includes unique game features such as tangible objects. In the game a robot has to be built out of various elements like propellers, springs and small jet propulsion to jump as high as possible. Players place cubes of different colors onto a 6×4 grid. The cubes are tracked by a camera that is placed above the playing field and their positions are translated to the application in real time. Once players are happy with their robot they can press "Start" to enter a simple 3d-scene. While jumping, player controls are limited to rotating the robot mid-air and short additional boosts that can be used up to three times. Using these tools, the players have to dodge a number of balloons on their way to the top. Players can retry as often as they want to or simply decide to try out a new robot design. High-scores are saved over multiple tries to create an incentive for experimenting with different setups.

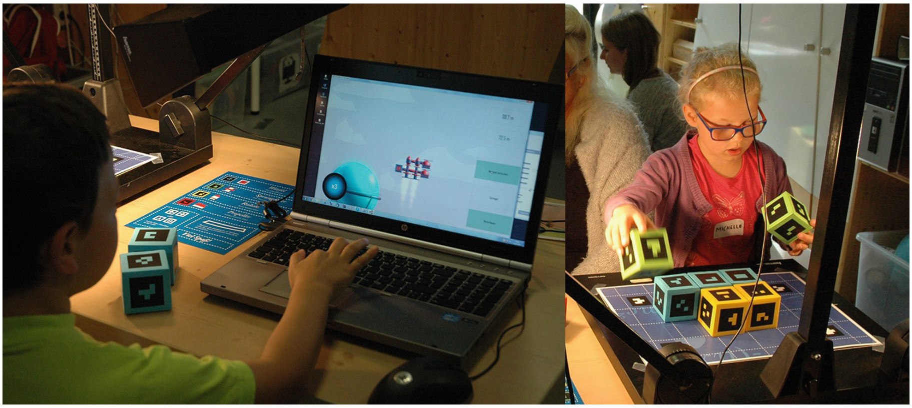

Fig. 1. Game prototype developed by our research group: Mr. Robojump; right: the player is constructing a robot via tangible objects; left: the player is playing with the newly built robot.

Participants and Procedure. Six teams took part in the study with each team consisting of a grandparent (aged 53–66 years) and a grandchild (aged 6–8 years). However, there was an exception as one team included two children (siblings). The participating teams reported doing something together on a regular basis ranging from once a week to even daily. While the gender ratio of the children was close to equal (four boys and three girls), none of the accompanying adults was male. Five of the seven children said to play computer games daily and the remaining two only very seldom. Only one adult engaged in computer games on a daily basis, the other adults reported to do this a couple times a week or less. Although the children were more accustomed to computer games, only one of the children named a computer game when asked for their favorite game. The majority of the children and all adults thought of board games.

At the beginning of the study, the participants filled out a questionnaire with demographic information and information regarding game and computer game experiences. Then the six teams were distributed into two groups and each group tested three of the six games. Each team played one game for about ten minutes and was then asked to fill in the questionnaire for the current game station (see Fig. 2). After finishing the third game, each participant was given the final questionnaire to evaluate the three games in relation to one another and the overall study experience.

Fig. 2. Old and young participants playing one of the 6 games (Spore). After each game evaluation session, subjects were asked to fill in a questionnaire.

An assistant was stationed at each game to instruct the participants on study procedure (e.g. reminding them to fill out the game station questionnaire or asking them to move on to the next game station), to support them if technical or game problems occurred, and additionally to observe the participants and answer the observer questionnaire. Following this, we divided the participants into four focus groups. Adults and children were separated and put into new groups of only children and only adults. All participants in one focus group had played the same three games (group 1: IQ-Fit, Creature Editor, Bad Piggies, and group 2: Mr. Robojump, Rugged Rover, Box Buddies). Their task was to evaluate the games they had played, note improvements or changes they would like, and decide together on how they would rate the games. The results were visualized on a poster. The children groups were supported by a study assistant who read the questions to them and helped with writing down their thoughts.

Measures. Based on the criteria derived from the literature and the outcomes of the preliminary investigations we developed a questionnaire for older and younger users. Especially, great care was put into designing a questionnaire suitable for young children. The questionnaire covered the same important aspects regarding game immersion experience as suggested in previous studies [6,7,16] and which are at the same time driving motivators (psychological needs) for situational well-being according to Self-Determination Theory [15], namely the need for relatedness, autonomy, and competence. In the context of our study situational well-being can be understood as equivalent to an enjoyable game experience. To ensure the suitability and validity of the questionnaire for young children, adapted questions from the Game Experience Questionnaire (GEQ) [4] were used (e.g. "How much fun did you have playing the game?", "How was the game: (1) boring (5) exciting"), along with an adaption of all elements of the Fun Toolkit [13]. The Fun Toolkit is a collection of measuring tools which is often and successfully used for scientific research with children [11]. It uses a five-point scale of emojis (from a sad face to a smiling face) to indicate enjoyment and offers a structured comparison of the games played (e.g. "Of the three games you played, which one was the most difficult?"), emphasizing the use of pictures. The comparison questions were used to check if previous answers to the individual games reflected in the overall opinion. In the following focus group session the participants had the task to evaluate the played games, note improvements or changes they would like, and decide together on how they would rate the games. The questions used were self-designed. In the observer questionnaire the assistants were asked to note down problems or difficulties the participants encountered during the game, to indicate to what extent the participants were active or passive players, and to give an estimation on how the participants enjoyed or not enjoyed the game (e.g. "How did the child appear to you during the game?" with answer options to tick like "bored" and "overwhelmed").

3 Results and Discussion

The best-rated games on the fun factor were Bad Piggies and Rugged Rover, scoring 5 of 5 points (see Table 1). All participants rated both games highest in regard to fun while playing the game. Both games are proven game concepts, which have undergone game development processes already and hence are in an advanced conceptional state. Apparently, the combination of first carrying out preliminary settings on game content, before starting the actual game run-through is a diverting and favored pastime for old and young. It is important to note, that during the run-through phase, both games offered minor possibilities to influence game play and outcome, hence fostering the feeling of control and competence, as well as autonomy, because the player is not just in the role of a passive bystander and at the mercy of artificial intelligence or game algorithms. The least fun game was Box Buddies with a mean fun score of 4.2. At the same time, participants reported it to be the most difficult game and hardest to understand. However, it was voted one of the most exciting games, alongside Mr. Robojump and Creature Editor.

The Creature Editor lacked a second game phase, in which the participants could have explored how their creation worked and reacted in a virtual environment. The demo version of the game only allowed for building your creature

Table 1. Mean values for game experience of all employed games (minimum = 1, maximum = 5).

	Game	Fun	Co-play	Difficulty	Excitement	Comprehensibility	Freedom
All	IQ-Fit	4.83	5.00	2.60	4.20	4.80	5.00
	Creature Editor	4.83	5.00	1.50	4.83	4.67	4.80
	Bad Piggies	5.00	4.83	1.83	4.50	4.83	4.60
	Robo Jump	4.33	4.43	2.83	4.86	4.43	5.00
	Rugged Rover	5.00	4.57	1.00	4.71	5.00	4.29
	Box Buddies	4.20	4.71	4.14	4.86	3.43	4.29
Adults	IQ-Fit	5.00	5.00	2.50	5.00	5.00	5.00
	Creature Editor	4.67	5.00	1.67	4.67	4.33	5.00
	Bad Piggies	5.00	5.00	2.00	4.33	4.67	4.50
	Robo Jump	4.00	4.33	3.33	4.67	4.33	5.00
	Rugged Rover	5.00	4.00	1.00	4.33	5.00	4.67
	Box Buddies	4.00	4.67	4.00	4.67	2.67	3.33
Children	IQ-Fit	4.67	5.00	2.67	3.67	4.67	5.00
	Creature Editor	5.00	5.00	1.33	5.00	5.00	4.67
	Bad Piggies	5.00	4.67	1.67	4.67	5.00	4.67
	Robo Jump	4.50	4.50	2.33	5.00	4.50	5.00
	Rugged Rover	5.00	5.00	1.00	5.00	5.00	4.00
	Box Buddies	4.25	4.75	4.25	5.00	4.00	5.00

without leaving the confined space of the editor. A child participant noted that the creature should have been able to move beyond the circle of the design interface, and the station assistant reported that especially the children always tried to move their creature beyond the circle to explore their creation in the world beyond. Nevertheless, the Creature Editor is the only game of which all participants, young and old alike, answered "yes" when asked if they wanted to play it again. Evidently, creative tasks with exploration possibilities seem highly enjoyable to both age groups.

All six games scored high on whether participants enjoyed playing it with their team partner or not, with mean scores ranging from 4.43 (Mr. Robojump) to a straight 5.00 (IQ-Fit, Creature Editor). It seemed to be not too important if participants were always very actively involved in the game to report high enjoyment because some grown-ups reported wanting to "just watch" the other (namely the child) play, as was the case for Creature Editor and Mr. Robojump. Moreover, grown-ups reported having only watched during playing Bad Piggies and Rugged Rover but still say they would want to play the game again, as well as graded the games with 5 of 5 points on fun and enjoyment. For children "just watching" was a total no-go. Overall, grown-ups reported to not want to play any of the games alone, while children reported that they would like to play alone, especially on the Creature Editor. According to the observer questionnaires, the most prominent difficulties for the older participants occurred at the beginning of games in the form of technical obstacles (like how to correctly use the controller for playing Box Buddies or how to operate the tablet touchscreen in an effective and meaningful way). In these cases it was necessary for the assistants to support the team, especially if the child did not take on the role of instructor. In some teams the child participant was skilled in using a tablet and, therefore, either showed the adult how to interact with the device or took over tablet control and let the adult just watch. The assistants often noted that adults seemed to enjoy watching and giving instructions from time to time while children explored and experimented. In the following focus group session, the participants evaluated each game once again in a group discussion and visualized the results on a poster. The results showed the same tendencies reported earlier on an individual level in the questionnaires. Adults, as well as children, noted that the Creature Editor lacked the opportunity to explore and watch how the creation worked in a broader virtual environment and hence the demand was to add "more level" to the game. If the game contained haptic elements, it was always positively mentioned in the evaluation. For example, although IQ Fit had been rated as very difficult by the children, the possibility to build and interact with 3D-objects resonated very positively with them. Furthermore, the most outstanding feature regarding Mr. Robojump was that real-life cubes were used to build the digital robot on the screen. A keyword often associated and mentioned with this block building principle was "creative". The term was also attributed to games like Creature Editor and Rugged Rover.

4 Conclusion

On the basis of the literature, our preliminary investigations and finally the results from the study, the following design criteria for an intergenerational col-located and collaborative game at the Welios Science Center have been identified. It proved successful if the game consisted of two phases, with the possibility of reruns. In the first phase, the player designs the primary game content with which she/he then plays and interacts in the second phase of the game. The first phase of the game offers ample chance to be as creative as one wishes but should include a rather basic set-up to soon start the second phase. To provide a sense of autonomy and control, it is advised to provide interaction and adjustment opportunities in the second phase, which can be minor or major depending on the participant.

In this way, cognitive overload can be prevented and success or failure can be improved respectively redeemed in a consecutive playthrough. This iterative learning process makes the game less frustrating and at the same time more challenging. Furthermore, with iterative loops the duration to play is variable and can be chosen individually by players, offering flexibility and autonomy. Consequently, an iteration should be rather short, but the overall playing time can be as long as the player chooses. Hence, it should incorporate possibilities of upgrades, improvements or further levels that can be reached to ensure engagement and enjoyment.

A game should not be too complex, technically and conceptually. Young and old participants evaluated the co-operative concept and control of Box Buddies as rather difficult on a technical, executive, and conceptual level. As a consequence, the enjoyment ratings of the game were rather low in comparison to the other games, despite the fact that players reported experiencing the game as exciting. To deal with this, tasks and responsibilities can be appointed to a specific player, for example technically more demanding tasks are the younger player's responsibility or cognitive tasks are appointed to the older player. This accommodates the preferences of older players to act as observers rather than active players who interact with the interface, whereas the younger players demand active roles. Additionally, different roles acknowledge different levels of experience and help to appoint the player with the appropriate level of difficulty and challenge.

Incorporating haptic, tangible objects into the game was positively evaluated by old and young. Despite manifold digital game opportunities offered recently, children still value interaction and engagement with actual objects they can touch and feel. Furthermore, the combination of tangible objects and their digital representation can be seen as a synthesis of traditional (haptic board games) and digital games, and their use might ease older people into the game experience.

In general, we argue that our approach supports the identification of design criteria (game mechanics, goals, etc.) for intergenerational games in a museum context that are not only fun, but also foster the communication between old and young players. We are aware of the limitations of the study due to the small sample size, but we conducted the study with due diligence and report the results as what they are without the pretense of inferential statistics. Our findings highlight that the inclusion of cooperative behavior, haptic elements, and several phases with the possibility of reruns is beneficial for the experience of intergenerational games. For future work, based on the study findings and the Mr. Robojump-concept we plan to create a more elaborate game prototype. This prototype should be evaluated over a longer period of time at the Welios Science Center to identify additional mechanics that contribute to the relation between the generations.

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PathoGenius: A Serious Game for Medical Courses

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Abstract. There are several systems designed for healthcare education. However, many of them lack formal testing and comparison in a real course setting. This work intends to introduce a tool for teaching, evaluating, and assessing medical students. PathoGenius is a gamified learning platform designed to help students to acquire knowledge in medical courses. We conducted a study with more than 400 students to evaluate PathoGenius. The results of the study yielded significant positive correlations between PathoGenius' activity data and students' final course grades. Qualitative feedback gathered from students also evaluated PathoGenius as quite helpful.

Keywords: Serious games · Education · Edutainment

1 Introduction

Enhancing and improving medical education is of major importance due to its direct impact on patients' safety. A study conducted in 1999 showed that from 44000 to 98000 deaths were caused by preventable medical errors [1]. There have been several approaches to support traditional learning techniques, such as virtual reality and serious games. One of the main pillars that educational serious games are based on is adding a certain degree of entertainment to the learning process [2]. Several approaches have been proposed to enhance medical education. One of the fields that has been tested with several games was Cytopathology [3]. Another area that educational games has been tested in was the self awareness against epidemic diseases such as HIV/AIDS [4].

In this paper, we present *PathoGenius*, which is a serious game designed for a medical course for pharmacy students at the German University in Cairo. The main idea of PathoGenius is based on a virtual tour that simulates the journey of any patient who seeks medical care. The tour will navigate the user through different rooms in a logical sequence throughout the whole medical investigation.

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In each room, relevant findings and info will be provided to allow the user to analyze the case and acquire a clear picture about the patient's condition while answering questions relevant to the topic studied. By adopting this strategy, users will be acquainted with the different steps in clinical practice and will actively participate in solving the corresponding medical case by applying the knowledge gained from the corresponding medical course. Most importantly, these educational targets will be achieved in a more enjoyable atmosphere, when compared to the traditional learning methods.

The research question of the current study is whether using the application PathoGenius enhances the academic performance of the users. To answer this question, two versions were compared with each other where one version contained more gamification elements. Moreover, we compared the performance of students who used the application versus those who did not. The results of the study yielded significant positive correlations between PathoGenius' activity data and students' final course grades.

The paper is organized as follows. In Sects. 2 and 3, the game and its implementation will be presented. In Sect. 4, results are analyzed. Finally, we conclude with a summary and future work.

2 Mechanics and Implementation

2.1 Mechanics

After logging in, users will need to choose one of the categories available in order to practice within the corresponding topics. The different categories have been defined according to the content of the medical course that the application is addressing (Fig. 1).

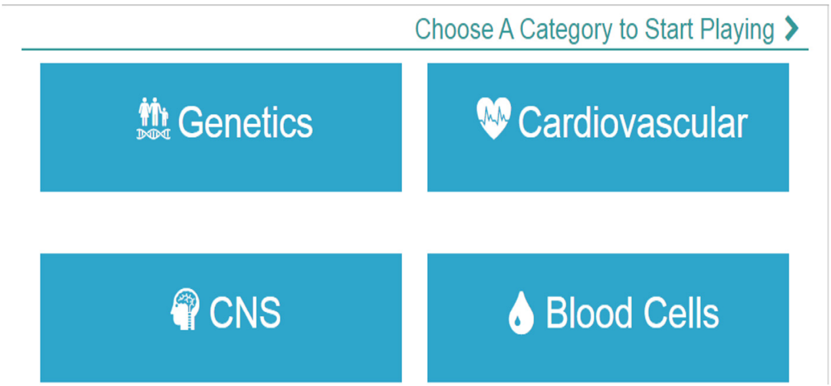

Fig. 1. The category selection

After selecting the category of interest, a case will appear randomly for the student to solve. This random process makes it possible to encounter a case that has been already solved by the user. In this case, a notification will be displayed to be able to choose among two options: either to solve this case again, for more practice, or to go back to the home page. By returning to the home page, the user can decide either to continue in the same category or to choose another one.

Once the case to be solved appears, the user will encounter the playground interface which is the main interface of the application. The interface starts with an introduction section, called the “initial description”. This section contains all the basic information about the patient as well as the reasons for seeking medical help. For the user’s convenience, this section can be collapsed but will remain available and can be expanded again upon one click, whenever needed, while navigating through the different rooms.

In addition, a brief summary of the case is available under the name “known so far”. This item cites the most relevant info that are collected throughout the case and that are automatically updated while navigating from one room to the next one (Fig. 2).

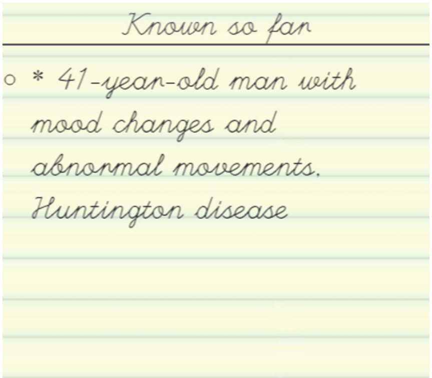

Fig. 2. The known so far section

Beside the “initial description” and the “known so far” items, the playground interface will allow the user to virtually visit the different rooms. In each room, the user’s knowledge can be tested by a multiple choice question comprising four choices, with only one correct answer (Fig. 3).

Upon selecting the correct choice, the corresponding box will be highlighted in green. In case a wrong answer is selected, the choice will be highlighted in red and the correct answer will be highlighted in green. This provides the user with an instant feedback about his answer for a better efficiency of the game. In case of hesitancy in choosing the correct answer, the user has the option of eliminating two wrong answers, which allows decreasing the number of choices to half.

Every time the question of each room has been answered, the relevant findings of the corresponding room will be added to the “Known so far” section, in a bullet

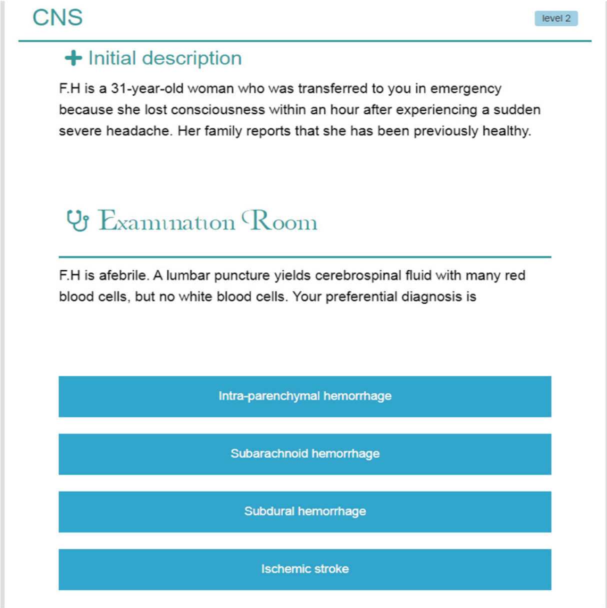

Fig. 3. The playground

points style. This section can always be accessed from the top left part. The main advantage of this section is that the user can recall at any time the findings of the previous parts of the case. This helps in analyzing all info available so far, to be able to solve the next question, while applying the knowledge acquired from the corresponding course.

After solving one room's question, the user can move to the next room by clicking on the "move to the next room" button. Once the user has navigated through all the rooms, the case will be closed by a general question about the disease described in the case. After each case, students should have practiced the medical steps of handling the corresponding disease and mastered its relevant manifestations as well as the underlying mechanism.

2.2 System Implementation and Registration

The application was developed as a web application to ensure its maximum availability across all platforms, since it only requires an Internet connection and a browser.

The application was implemented as a client/server application. The server was implemented using node js, while the front end of the application was developed using HTML, CSS and JavaScript. The main sample group, that the application was tested on, is the seventh semester Pharmacy students in the faculty of Pharmacy at the German university in Cairo. All students of this semester were invited to register and try out the application.

3 Gamification

3.1 Purpose and Distribution

As mentioned earlier, the main purpose of the application is to measure the effect of having a computerized tool in the medical education and its impact on the student's academic performance. In addition, we were interested to know whether adding some game elements to the application will influence the usage of the game and the user's performance. For this purpose, an additional version of the application, named gamified version, was created. This version has exactly the same scientific content as the main version but differs only by adding some gaming elements, such as scoring and ranking. To guarantee a fair student's distribution among the gamified and the non- gamified versions, students' registration to the application is alternated between both versions. In other words, if the first registered student from a tutorial group is assigned to the gamified version, then the second one from the same tutorial group will be assigned to the non-gamified version and so on.

3.2 Features of the Gamified Version

Interface. Among the most important gaming elements that were added to the gamified version of the application is the scoring feature that allows the user to gain points throughout the entire application, whenever questions have been answered correctly. Based on the total score, the user will be ranked against all other users and will be granted a new title whenever a certain level has been achieved. Moreover, the cases of each category have been classified in three levels of difficulty, level one, two and three. Questions having a higher level of difficulty are more challenging to solve and accordingly, more points can be gained upon solving them correctly. Each category includes the three different levels, and the transition from one level to the next one requires a certain number of points to be collected in each level. This allows the user to be aware of his progress in each category separately and to work on further improving his performance in some categories. For each participant, a profile page was created that appears upon logging into the application (Fig. 4).

This page shows useful information about the user's progress, the current title, total score and rank. Each category is represented by a matching symbol below which, the number of solved cases in each category is displayed. Furthermore, the profile page displays a progress bar for each category that shows the current level of the participant in each category and how close the user is to be promoted to the next level. The overall progress throughout the entire game is displayed by the "overall level" progress bar.

In order to know about the accuracy in answering the questions in each category, an accuracy chart is available under the "Stats" icon. The chart has one axis for each category and by hovering with the mouse on any axis, users can know their exact accuracy percentage in the corresponding category and can know which category needs more practice (Fig. 5).

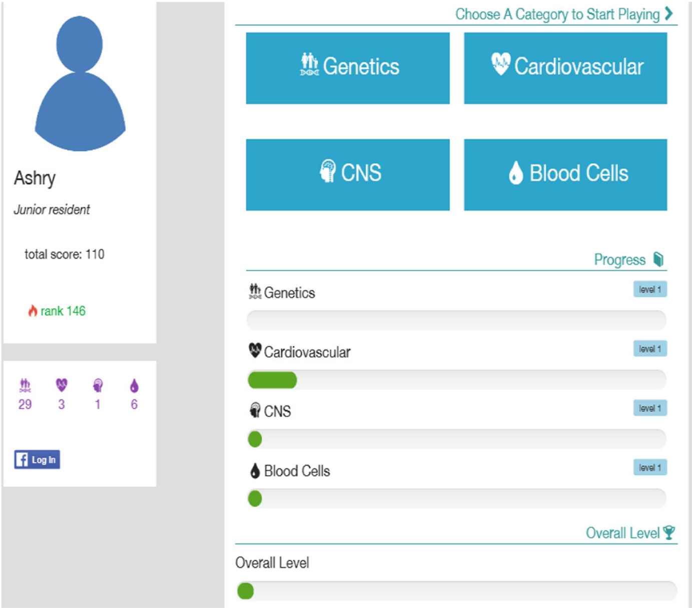

Fig. 4. The profile of the gamified version

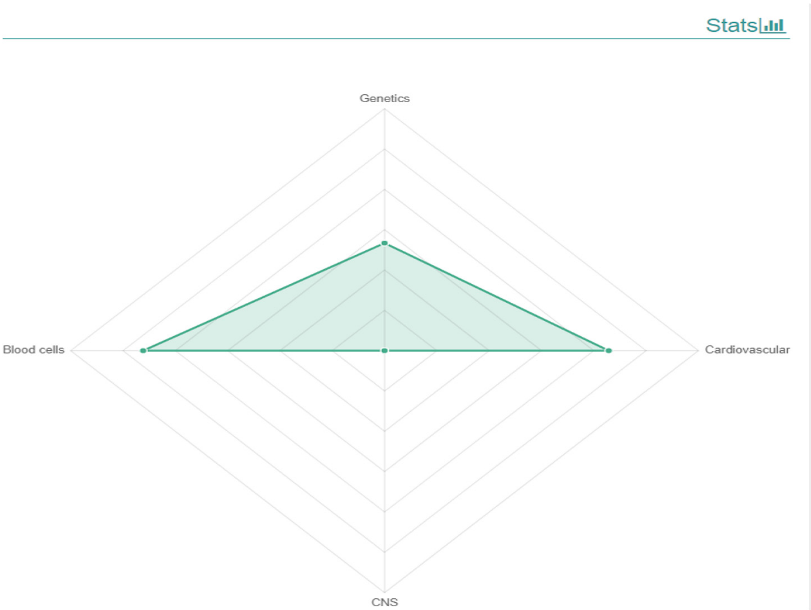

Fig. 5. The accuracy chart

Mechanics. Since the gamified version has exactly the same content and questions as the non-gamified version, the mechanics are very similar in both versions and the only differences are related to the scoring system and the progress of the user. The number of points collected from solving a certain case depends on the level of the case and are displayed on the left hand side. Since cases appear at random, it is possible that the user encounters a case with a higher level than the user's current level in the corresponding category. In this case, a notification will be displayed to choose between either to continue solving the case or to go back to the profile page and pick another case. The higher the level of the case over the current level of the player, the bigger the bonus score is. If a case that has been previously solved appears to the user, a notification will be displayed, allowing either to go back to the profile page and pick another case or to solve this case, as practice, but without collecting any points.

In the gamified version, the option to discard two wrong choices is still available, but on the expenses of losing points from the score collected so far from this case and not from the total score. Thus, using this option requires that the user has collected enough points in the corresponding case and this is meant to avoid the excessive use of this option.

4 Evaluation

4.1 Research Question

The research question of the current experiment is whether using the application PathoGenius enhances the academic performance of the users.

4.2 Experimental Design

The choice of the experimental design model of PathoGenius was based on the comparison between two main approaches:

1. Within-group design where all the participants are exposed to all the different treatments.
2. Between-group design where the participants are divided into sub groups each group will be exposed to a different treatment.

The "Within-group" approach has the advantage of ensuring the homogeneity of the experiment's individuals, thus eliminating any possible differences related to having different participants in the different subgroups. However, we believe that this approach is not the best one to adopt in educational experiments like in PathoGenius. In fact, by exposing the same individual to different treatments in the same field, some knowledge will be gained from the first treatment that will definitely enhance the performance in the next treatments leading to unreliable results. Therefore, the "Between-group" approach was adopted in this study.

The main challenge of the "Between-group" approach is to avoid any discrepancies between the participants of the sub groups that could affect the reliability of the experiment's results. Such discrepancies could result from a biased selection of the participants that will be assigned to each sub group or from differences in the participants' knowledge in the topic addressed by the application among the sub groups. To overcome these challenges, the following strategy was applied. Firstly, students were randomly distributed to subgroups upon registration without any selection criteria. Secondly, all participants of this experiment were Pharmacy students in the same semester, visiting the same university (The German University in Cairo) and taking the same curriculum. The medical course that was assessed in PathoGenius was taught by the same instructor and all course materials (lecture slides, tutorial slides and text books) were available to all students. Usually, in the between-group approach, a pre-test and a post-test are used to assess the amount of knowledge that was gained by the game [5]. In the pre-test, participants are tested prior to using any treatment. After that, they will be divided into different groups and subjected to the different treatments involved in the experiment. In the current study, no pre-test was conducted since the content of the course, assessed by PathoGenius, is new to all students. Instead, student's performance was assessed after conducting the experiment (the post-test) and compared between the treatment groups, that used either the gamified or the non-gamified version of the application and the control group that didn't use it.

4.3 Experiment Conduction

The target population of the experiment was seventh semester's pharmacy students in the faculty of pharmacy and biotechnology, German university in Cairo. A total of four hundred and two students were invited to use the application. By the end of the semester, the treatment group comprised 339 students while the control group included 63 students. The final exam served as the post-test of the experiment. Exam results of all students were collected and analyzed in order to assess the effect of PathoGenius on the academic performance of the users.

4.4 Results

The data collected after conducting the experiment was analyzed using SPSS (Statistical Package for Social Science) software in order to measure the effectiveness of the application. The following tests were done to serve this purpose.

Test 1. (1) Test 1: An independent sample t-test was conducted to examine the final exam grades (which serves as the post-test) of the registered and non-registered students. There was a significant difference in the grades of the students who registered in the application ($M = 67.41$, $SD = 20.084$) and the students who did not register in the application ($M = 43.52$, $SD = 26.381$). Conditions; $t(400) = 8.218$, $p = 0.00$ (Tables 1 and 2).

Table 1. Registered and non-registered students group statistics

	Type	N	Mean	Std. deviation
Final grade	Registered	339	67.41	20.084
	Non-registered	63	43.52	26.381

Table 2. Registered vs. non-registered students

	t-test for equality of means		
	t	df	Sig. (2-tailed)
Final grade	8.218	400	0.00

Test 2. When users of the gamified version ($M = 67.77$, $SD = 21.099$) were compared to users of the non-gamified version ($M = 66.88$, $SD = 18.494$), no significant difference in their performance was found. Conditions; $t(337) = 0.414$, $p = 0.679$ (Tables 3 and 4). However, when each of these groups was compared separately to non-registered ($M = 43.52$, $SD = 26.381$), both groups of users showed significantly higher performance than the non-users of PathoGenius. Conditions; $t(263) = 7.483$, $p = 0.00$ for the "gamified" version (Tables 5 and 6) and $t(198) = 7.194$, $p = 0.00$ for the non gamified version (Tables 7 and 8).

Test 3. We were interested to know whether there is a difference in the time spent on each version of the application, which could reflect enhanced motivation and engagement for one of the versions. Indeed, an independent sample t-test revealed that students who were using the gamified version ($M = 131.69.8$, $SD = 184.79$) spent much more time playing the game than the students who used the non-gamified version ($M = 66.86$, $SD = 18.54$). Conditions; $t(337) = 4.09$, $p = 0.00$ (Tables 9 and 10). These findings show that adding some gamification features has a positive impact on the engagement and motivation.

Table 3. Gamified version and non-gamified students group statistics

	Type	N	Mean	Std. deviation
Final grade	Gamified	202	67.77	21.099
	Non-gamified	137	66.88	18.494

Table 4. Gamified vs. non-gamified students

	t-test for equality of means		
	t	df	Sig. (2-tailed)
Final grade	0.414	337	0.679

Table 5. Gamified and non-registered students group statistics

	Type	N	Mean	Std. deviation
Final grade	Gamified	202	67.77	21.004
	Non-registered	63	43.52	26.381

Table 6. Gamified vs. non-registered students

	t-test for equality of means		
	t	df	Sig. (2-tailed)
Final grade	7.483	263	0.00

Table 7. Non-gamified and non-registered students group statistics

	Type	N	Mean	Std. deviation
Final grade	Non-gamified	137	66.88	18.494
	Non-registered	63	43.52	26.381

Table 8. Non-gamified vs. non-registered students

	t-test for equality of means		
	t	df	Sig. (2-tailed)
Final grade	7.194	198	0.00

Table 9. Gamified version and non-gamified students group statistics

	Type	N	Mean	Std. deviation
Total duration	Gamified	202	131.69	184.79
	Non-gamified	137	66.86	18.54

Table 10. Gamified vs. non-gamified students

	t-test for equality of means		
	t	df	Sig. (2-tailed)
Total duration	4.09	337	0.00

5 Conclusion and Future Work

PathoGenius is a serious game that was designed with the objective of enhancing the learning process. It was tested on pharmacy students in the seventh semester by assessing the knowledge acquired from the Pathophysiology course, a medical course that was taught in the same semester. Results showed a significantly better academic performance of game's users compared to non-users, as reflected by their grades in the final exam. Among the game users, those who used the gamified version, containing more game elements, showed a higher motivation and engagement, compared to the users who used the non-gamified version. The academic performance did not differ significantly between users of both versions. This can be related to the fact that the assessment was performed shortly after delivering the content of the course (in the same semester). Other trials may be required to further verify the effects of such educational games on the learning process. It would be interesting to test PathoGenius on the long term knowledge and not only freshly delivered knowledge. In addition, the design of the game could be improved by adding some graphical and interactive gamification elements. Moreover, due to the generic nature of the platform implementation, we are intending to test the game for other medical courses.

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Galaxy Shop: Projection-Based Numeracy Game for Teenagers with Down Syndrome

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Abstract. Teenagers with Down syndrome face difficulties in acquiring new skills specially in the tasks that need high cognitive abilities. In the recent years, serious games showed to be a promising assistive mean in the field of education. Augmented Reality (AR) technology is a growing research area that could be achieved by different ways for many purposes. The main focus of this study is investigating the effect of using a projection based game for Down syndrome teenagers in an educational context. This was done through implementing a game that aims at enhancing their numeracy skills for financially independent living. The developed interactive surface game was tested with a number of Down syndrome teenagers, and its effect on their learning outcomes was compared to the effect of the same game played on the normal technological mean they receive, namely the personal computers.

Keywords: Down syndrome · Serious games · Augmented Reality · Education · Numeracy

1 Introduction

Down syndrome teenagers exist across a huge part of our societies. According to DSA[1], Down syndrome continues to be the most common chromosomal disorder with a rate of 1 in every 700 babies born each year. Accordingly, the problem of promoting learning for students with Down syndrome has attracted much of the theoretical and practical research because of its importance and effect on the society development. Teenagers with Down syndrome differ in their educational achievements and cognitive skills. Research reveals that they follow the same educational progress as their developing peers who do not suffer from Down syndrome [4], only more steps and practice are needed in each stage to reach the planned educational objectives. Some studies show that exploiting the visual learning strengths of students with Down syndrome using the available technologies can promote their learning process [6].

One of the promising approaches to promote learning is the usage of games as an assistive teaching mean [5]. Some studies have identified serious games as a good way of education, as they help in increasing the motivation of the students to enjoy the

[1] The Downs Syndrome Association, United Kingdom.

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learning process [8]. Moreover, they can offer some factors that the regular teaching methods lack [2]. The usage of projection-based augmented reality (projected AR) to build interactive educational systems for different profiles of students is a well established research area [12, 23]. It is a growing field of technology which allows computer generated virtual imagery to exactly over-lay physical objects in real time so that the user's real world become digitally manipulable and interactive. Research has indicated that projected AR systems and environments could help learners develop skills in an effective way [24]. The combination of projection based technology and educational games might have the potential to create new type of applications that enhance the attractiveness of the learning process, and transform the classroom into an exciting environment specially for cognitively challenged learners, where they can become active participants [23].

In this study, the existing strategies built for teaching Down syndrome teenagers has been investigated, taking into consideration the input of the experts in the field, to build an engaging projection based AR system. This was done through implementing an educational game aiming at enhancing the numeracy skills of Down syndrome teenagers for independent living. [6] defined numeracy as "using mathematics effectively to meet the general demands of life at home, in paid work, and for participation in community and civic life". The game is called Galaxy Shop, it aims at teaching them the advanced numeracy skills needed in their daily life like addition, subtraction and multiplication, which enhances their independence in the different aspects like budgeting their money, splitting a bill, and shopping. The game was implemented using projection based technology, namely interactive walls, where the learner is able to learn through interacting with a projected image on the wall of the room instead of using the traditional teaching instructional means.

An experiment was conducted to evaluate the effect of the developed game on the learning process of the students. Two variants of Galaxy Shop were tested with a number of Down syndrome teenagers. The first one presented the projection based version of the game, and the second one represented the normal version of the game, where the conventional computer based mean was used. The tests were held to compare the effect of using projection based games on two aspects: the learning achievement of the participants, and their level of engagement during the learning process.

2 Projected-AR Game Based Learning Effects

In the recent years, many research studies have been conducted to explore the effectiveness of using serious games for learning [5, 9]. [10] elaborated that games help motivate students to continue the learning process for a longer period of time. Most of the studies has reasoned the potential of using educational games to the presence of the factors that the normal learning methods lack like having a system of objectives, goals, rewards, and rules of play [1, 8]. According to [1], interactivity is a critical element in effective educational games. Highly interactive games are considered to be the most effective ones as they give the learner the sense of freedom and enjoyment that creates a better learning experience without being bored or unchallenged.

Experiments for interactive learning provided by projected AR is increasingly recognized by researchers. According to [12, 24], it creates enhanced reality by bridging virtual and real worlds, it can be considered to be one of the tools providing students with an engaging technology mediated learning experience. AR could be used for cognitively challenged students as well. [13] reports that projected applications can improve students' spatial abilities, as they could receive real time feedback that may enhance their performance in cognitive tasks. The reason behind that is the existence of multisensory cues in projection based systems that offer the ease of use, engage the students, help them digest the educational material, and prevent errors through instant feedback [1].

Although there exist studies that show evidence about the positive effects of using projected AR in learning, some studies report negative effects and challenges for using this technology in the field of education. [12] reports that students could be cognitively overloaded by the large amount of information they get exposed to, and the complicated tasks they are required to accomplish. More-over, they can be confused and overwhelmed in an AR environment because of facing a situation of mixed reality. They might lose track of the real environment which is not suitable for some learners and may result in negative effects specially if they lack some skills like problem solving, mathematical estimation and collaboration [17]. Due to the previously mentioned challenges of using AR environments, Down syndrome students might be frustrated using such technology.

To Sum up, while projected AR technology offers new learning opportunities in the filed of education, it also creates various challenges for educators. Hence, further research and experimentation need to be held in order to evaluate the effect of embedding AR in education.

3 Related Work

Many research studies have investigated the potential of using projected AR technology and serious games for learning. The evidence provided about the impact of such games is mixed [2, 12, 17]. An overview of the existing work in this field is presented in order to highlight the points of strength, extract the research gaps and incorporate such aspects in the proposed design.

[19] is a study that was held to determine if computer assisted means of teaching facilitates the learning process of basic mathematical abilities in children with Down syndrome, as compared with the paper based teaching method. One group was taught using computers, while another group took the same training printed on a paper. The results of the study showed that computer assisted teaching is more effective than the traditional paper based method as it increased the mathematical abilities of the participants. [18] is a study that tackled the effect of using AR based educational games on children. The study introduced an educational game called TNT Adventure that is played using Kinect. It encourages students to collaborate in remote environments through making choices that determine the actions of two characters in their daily life. Each player is represented by a hand and an icon in the game. After testing the game in

three kindergartens, it was found that children are more motivated and collaborating healthily with each other upon interacting with the game.

[20] is an online serious game that helps students acquire general knowledge about electrical engineering. The participants were divided into two groups: the first one learned the content by playing the game and the other by actual text. The results showed that the males who played the game were better able to answer questions on the theory than the males who studied the text. For the females, there was no difference between both groups. Moreover, [21] introduced a math facts game that was deployed on handheld computers for second graders. They found that learners playing the game completed nearly three times the number of problems in as those using paper worksheets. [22] is a research study that investigated the impact of two teaching scenarios of an art course on 69 middle-school students in Madrid: the first one is based on slides and the second one is based on AR technology. The quantitative results of this study showed that AR technology usage had a positive effect on the motivation of the students and diminished the barriers found to apply AR massively on schools.

To sum up, the existing work shows the potential of using AR game based systems for learners. Such work included useful features that were harnessed in our design. Some gaps exist and need to be filled, among which: addressing Down syndrome learners through providing them with the needed teaching strategies, and adding the interactivity factor in the educational means. Moreover, most of the studies either tested the effect of using projected AR technology or the effect of serious games. There is a rarity in the studies that compare projection based methods with computer based methods. This raises a need for having a game that utilizes all aspects together, and embeds both methods in the same experiment.

4 Methodology

Students with Down syndrome face learning difficulties due to having have special developmental pro les. Research suggests that they learn better when they can see things illustrated [19]. This finding has been demonstrated across a number of areas, as teaching can be more effective when information is presented with the support of pictures, gestures or objects. Most students with Down syndrome struggle with basic number skills and their number skills are two years behind their reading skills [6]. Galaxy Shop is a projection based educational game that exploits their learning strengths through making use of visual supports that the technology offers. It helps them to be financially independent through introducing advanced numeracy skills in an engaging way. The game is implemented using projection based technology, where the learner is able to solve the different mathematical problems by interacting with a projected image on the wall of the classroom instead of using the normal hardware tools of computers like mouse and keyboard as clarified in Sect. 4.3.

4.1 Material and Structure

Galaxy Shop was implemented in a way to make it easy for the students with Down syndrome to absorb the educational content in the game. It is divided into three levels:

beginner, intermediate, and advanced. The beginner level represents simple addition and subtraction operations, the intermediate level represents more advanced addition and subtraction operations and the advanced level represents simple multiplication operations. Each level consists of two parts, the first part consists of a sequence of multiple choice mathematical problems represented visually to the player, where he is supposed to pick the correct answer out of three choices. This part of each level consists of a problem set consisting of five consecutive problems on the same concept (addition, subtraction or multiplication). The problem is presented on the screen in a form of five balloons in the galaxy sky: two balloons for the quotients and three for choices, one of them contains the right answer as seen in Fig. 1.

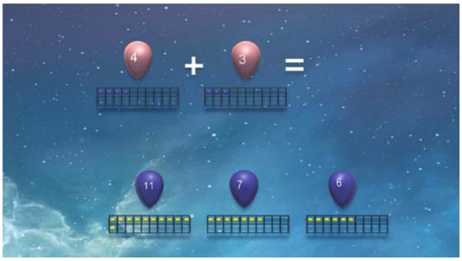

Fig. 1. Galaxy shop beginner level: cardinality based addition

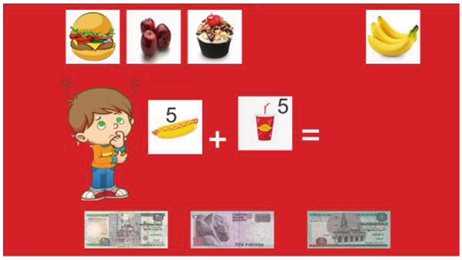

Fig. 2. Galaxy shop: real life application

The second part of each level is a real life application where the student is put in a situation in which he wants to eat or buy something and pays the price of what he chooses. The choices of money for paying is made with real Egyptian currency so the learner can relate to the situations he is exposed to on daily bases in any shop. The educators and experts in the field stated that the real-life application in each level is important for the needs of Down syndrome learners. According to [7] this is called "transfer in learning", which refers to the ability to apply knowledge in a different situation. Real life applications included in Galaxy Shop include buying food, beverages, shoes and candy from different shops in each level as shown in Fig. 2.

4.2 Game Design

Regarding the game design, it was tailored to meet both the educational and psychological needs of Down syndrome teenagers. Most of the fundamentals of game design were made based on the existing learning theories presented by [6] for DS students, in addition to the recommendations of the experts for this target group. Regarding the educational aspects, the first quotient is always larger than the second quotient, so that when having two numbers to add, the learner puts the bigger number in his head which is the first quotient and then adds up the second quotient to reach the answer. Moreover, there is a help panel at the home page of the game assisting the learner in the three levels. Also, the game is designed based on the cardinality system [6]. Hence, a rectangle containing balls representing the number exists below each quotient to help students use the cardinality method while solving the problem as shown in Fig. 1. Additionally, there are key mechanics for successful computer games for cognitively challenged children like: multiple exemplars, variety in methods used to teach concepts, on-repetitive trials, and customization [2, 8], these components were successfully embedded in Galaxy Shop.

Regarding the psychological aspects, motivation is one of the main features embedded in the game as it is considered to be one of the important keys of learning because it helps the student to be fully engaged in learning process [8]. According to [7], repetition plays a vital role in any learning strategy. Hence, Galaxy Shop was designed so that when the student answers correctly, the selected balloon color will change to green, reworks will appear and a panel containing the score is displayed in order to give the student confidence and motivate him to solve the next generated problem. On the other hand, when the student answers wrongly, the balloon changes its color and turns back to its place so that he tries till he gets the correct answer. To sum up, the main pillars of this game design are: using clear material, giving extra praise means, using hints, and avoiding score deduction upon wrong answers.

4.3 Implementation

Projection based technology is one of the most emerging technologies that can be used to create unique learning experiences through converting any surface into an interactive one [1]. Galaxy Shop is a projection based game that was built upon many stages. First, implementing the game based on the background of the target group, then integrating it with the projection based technology used, which is interactive wall, and finally testing if it is more effective than computer based means. The game was implemented by Unity game engine [14] and the interactive display was achieved using Touchizer [16]. It is a device attached to a projector that can change any surface into an interactive and collaborative work-space like walls, tables or any ordinary whiteboard up to 100 inch [16]. An infrared pen is used to tap on the interactive surface and interact with it. We decided to use Touchizer rather than other options of interactive surfaces implementations as the results for its calibration are very accurate. Moreover, it is suitable, portable, reliable and easy to use in the classroom for the teachers or at home for the parents. Integrating the projection based technology with the implemented game is simple and can be applied on any other game. The first step is connecting the Touchizer device to the computer, that is connected to the projector. Then, the calibration process is done using a software program, and the students are ready to play with it easily.

5 Experimental Design

This work experiments the effect of using an AR projection based educational game for Down syndrome teenagers on their learning process, compared to using the same game on normal computers. This was achieved through implementing Galaxy Shop, and testing it with a target group sample. The null hypothesis states that there is no difference in the effect of using Galaxy Shop on Down syndrome learners when they receive it on two different means: interactive wall; and normal computers. The first hypothesis (H1) claims that there is no difference in the learning gain level of the participants playing the AR projection based version of the game compared to the computer based version of it. The second hypothesis (H2) claims that there is no difference in the engagement level of the participants playing the AR projection based version of the game compared to the computer based version of it.

The model used is a between-group design one that has two independent sub-groups: control and treatment with equal number of participants. The treatment group used the 100 inch interactive wall version of Galaxy Shop, while the control group used the normal version on personal computers. Target participants were Down syndrome students who were chosen from centers and schools for special needs. The selection was based on the academic level reached in the curriculum, as they were required to have minimal mathematical skills like counting from 1 to 50. Their age ranged from 12 to 18 years old. However, age did not matter as much as the academic level of the learner, because different levels of severeness can be found across Down syndrome teenagers. The materials used in the experiment were questionnaires, hard copied tests for the participants, and consent forms for the parents. The experiments were held individually for each participant in normal classrooms. Teachers of the participants were asked to attend and required to fill the questionnaires needed in the evaluation phase.

6 Test Conduction and Results

This work is intended to be an extension for the study [15] that has tested the effect of serious games on children with learning disabilities. The objective is to construct various studies about using different assistive learning means for the educationally challenged groups. Hence, the same testing strategy was inherited and applied in this study in order to investigate the effects of different technologies on such groups.

A sample population of 18 officially diagnosed Down syndrome teenagers were randomly assigned into two groups (control group: n = 9, and experimental group: n = 9). Participants of both groups played the 3 levels of the game consecutively. In order to perform the comparison of the learning process between the two groups, learning gain as well as the engagement level of both groups were measured after using the corresponding learning mean. Analyzing the data comparison between the two groups was done using an independent t-test on SPSS (Statistical Package for the Social Sciences). The purpose of the independent sample t-test is to determine if there exists a significant difference in the learning gain as well as the engagement level between the independent groups included in the experiment.

6.1 Learning Gain Test

Procedure: Before using their respective version of educational technology, each participant had a paper based MCQ pretest in the material embedded in Galaxy Shop, the test consisted of three parts each representing a level in the game, the first part was about simple addition/subtraction, the second was about advanced addition/subtraction and the third was about multiplication; five questions each. An identical copy of the same test was given after using the perspective technology. Participants were asked to answer the test with no help from the teacher. To ensure the homogeneity level of the experiment, the structure of the test was compatible with the material embedded in the game. Learning gain was calculated by subtracting the number of correct answers that the participant got in the pretest from the number of correct answers received in the post-test. By comparing the learning gain of both groups, conclusions were drawn about the educational effectiveness of the interactive wall version of the game versus the normal computer based one.

Results: The results of the test between the two groups revealed that after the two interventions, the learning gain resulting from using the AR version of the game (M = 3.6, SD = 0.6) was significantly higher than the gain of the other group which played the computer based version of the game (M = 2.0, SD = 0.2) ($t(9) = 2.3$, $p < 0.05$) with a difference of 1.65 and standard error difference of 0.68. This rejects the hypothesis stating that there is no difference in the learning gain level of Down syndrome teenagers playing the AR projection based version of Galaxy Shop compared to the computer based version of the same game (H1).

6.2 Engagement Test

Procedure: An engagement test was held for the participants in both groups. It is a 5-likert scale standardized questionnaire inherited from [11] that was also used in the study held for children with learning disabilities mentioned before [15], it consists of 9 items that measure the overall ow of any activity through measuring two factors: control, and enjoyment. A hard copy of the questionnaire was handed to the teachers after the session. They were asked to fill it according to their observations of the teenagers while interacting with the respective learning means. By comparing the results of both groups, conclusions were drawn about the engagement level of the learners experiencing the interactive wall versus those who used the normal computer mode.

Results: The results of the independent t-test between the two groups revealed that the engagement level of the group of learners who used the AR version of the game (M = 4.54, SD = 0.32) was significantly higher than the engagement level of the other group that used the computer based version of the game (M = 4.01, SD = 2.48) ($t(9) = 2.2$, $p < 0.05$) with a difference of 0.53. This rejects the hypothesis stating that there is no difference in the engagement level of Down syndrome teenagers playing the AR projection based version of Galaxy Shop compared to the computer based version of the same game (H2).

6.3 Flow Test

Procedure: Similar to [15], a flow test was conducted in order to examine the acceptance of the participants to each level in Galaxy Shop. Flow can be represented as a channel between the skill and the challenge the user finds in any activity [3]. Users will be anxious if the challenge is higher than the skill, and will suffer from boredom in the opposite case. Hence, to have a good ow in any activity, a balance between skill and challenge is needed. Ratings of the skill and the challenge levels of each learner were taken after each level in the game. The questionnaire consists of two five likert scale questions: “How did the participant find this level challenging?” and “Is the skill of the participant appropriate for this level?”.

Results: For the flow test, Fig. 3 shows the skill versus challenge rates for Galaxy Shop, while Fig. 4 shows how far each level was from the desired ow level. According to [11], the distance is calculated by subtracting challenge from skill and multiplying the result by 0.25. The results show that during the first level the average of skill was higher that the challenge which means that this level was easier than expected for the participants. In the second level, the two lines intersect (skill = challenge), which represents a good ow of this level. Finally, during the third level, the challenge was greater than the skill which means that this level was more challenging than the previous ones.

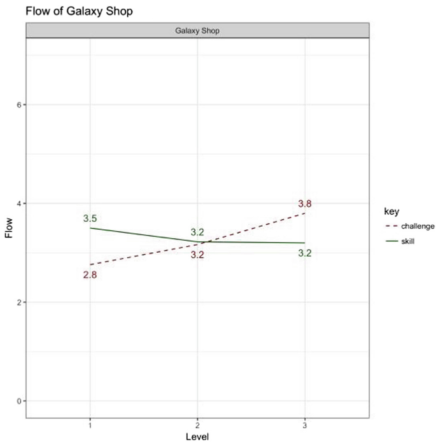

Fig. 3. Skill-challenge results

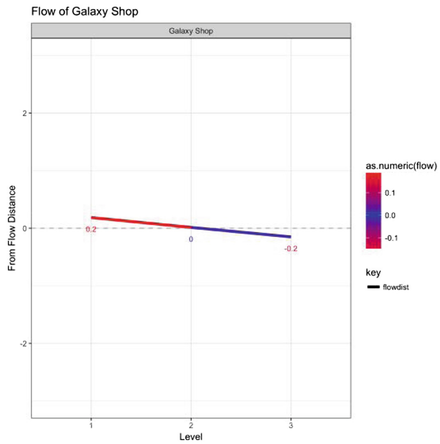

Fig. 4. Far from flow distance

6.4 Learning Gain and Engagement Correlation

One important perspective to investigate in this study was trying to find the correlation between the learning achievement of the participants, and the engagement level that they have experienced during performing the learning activity. The results in Fig. 5 show that there is a correlation between the engagement level of the learners and their learning gain. The group that used the computer-represented as a dashed line- had relatively low levels of engagement and corresponding low learning gain levels. On the other hand, the group who played using the interactive wall had high engagement levels as well as corresponding high learning gain rates. This gives some evidence that the difference in the learning gain between both groups happened due to the difference of the engagement level the participants have experienced, since it is the only changing factor in the experiment.

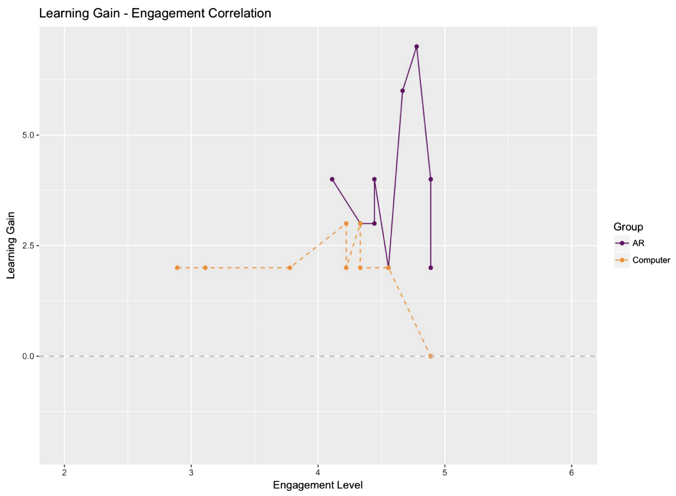

Fig. 5. Correlation between learning gain and engagement

7 Conclusion and Future Work

The usage of augmented reality to build interactive educational systems for educationally challenged learners is a growing research area. The main objective of this study was to examine effect of using AR projection based games as an interactive instructional mean for Down syndrome teenagers. Galaxy Shop is an educational game that was specially designed for Down syndrome teenagers to help them be financially independent during their daily life routine. The game taught them advanced mathematical skills namely addition, subtraction, and multiplication. It consisted of many real-life applications using real Egyptian currency options to give the learner the feeling of managing his own money. Two versions of the game were evaluated and tested with two different groups of participants using two different technological means: interactive wall and computers. The statistical analysis shows that playing Galaxy Shop on an interactive wall inside the classrooms is more effective than playing it on normal computers for the learning gain as well as the engagement levels of the participants.

This might be due to the presence of the interactivity factor that affects the enjoyment level of the learners, and accordingly their learning gain.

Further experiments using different AR based learning means need to be conducted in order to examine the effect of such technologies on the learners. Moreover, Galaxy Shop can be tested on long term bases so that deeper learning and behavioural outcomes can be evaluated. Finally, a concrete test of the correlation between the usability of AR means and the learning achievement of the users, in addition to an experiment that examines the relation between different developmental profiles and gaming preferences are needed.

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A Novel Serious Game for Trust-Related Data Collection in Supply Chains

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Abstract. Trust is considered an essential factor to develop and maintain business and supply chain relationships. However, it is hard to investigate its mechanisms due to the lack of supply chain trust-related datasets. This lack forces researchers to use artificially and often self-generated datasets which limit the validity of results and comparability with different approaches. Striving for the generation of less artificial trust datasets, this paper presents a novel serious game to gather trust information in a B2B supply chain setting.

Keywords: Serious games · Trust · Supply chains · Behavioral experiment · Data analytics · Docker · Online game · Multiplayer game

1 Introduction

This paper presents the finalized version of a new serious game aiming at the collection of data regarding the trust behavior of individuals in supply chains: the *Game of Trust*. Unlike a conventional simulation games for training or proof of concepts, serious games make it easier to collect, catalog and save the game data and other analysis without interrupting game flow.

2 The Game of Trust

2.1 Concept

The developed serious game was first introduced in [1]. Based on trust-related experiments like the Mango Chain Game [2], the Trust and Trace Game [3], and

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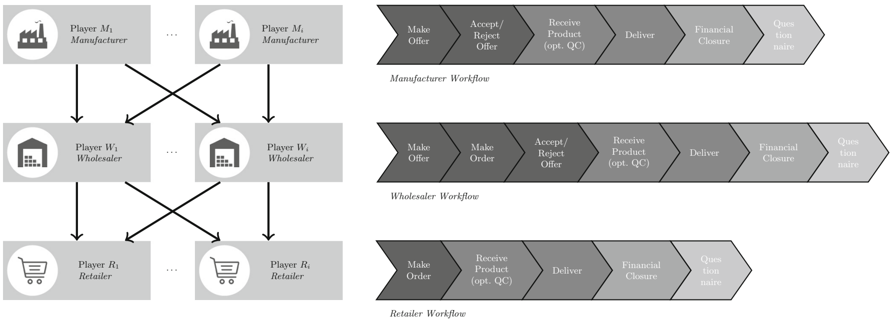
the Beer Game [4], the game provide insight into supply chain's trust relationships and interaction with neighboring tiers.

The *Game of Trust* followed the general guideline for designing serious games projects proposed by Lang et al. [5], adapting it in order to incorporate the requirement of a multi-player game. The game setting consists of a supply chain (SC) with multiple trading partners at each level. The research objective of the game is to collect data regarding the behavior of the players when they are exposed to the possibility of trusting or distrusting another player. The participants have to trade goods of two different qualities inside the supply chain with the possibility of hiding and revealing the mentioned quality. The game is composed of several rounds, each round divided in four phases: Negotiation, Delivery, Financial Closure and Questionnaire.

The *Negotiation* phase is a three stepped sub-process in which the upper tier SC member can make an offer to one or multiple members of the next lower tier (e.g. $M \rightarrow W$). This entity can then adjust or confirm the received offer handing back the final acceptance or denial decision to the offer-issuing entity[1] (Fig. 1).



(a) Supply Chain (b) Game Flow

Fig. 1. Game of Trust - game structure and dynamics

After successful completion of the *Negotiation* the *Delivery* phase is initialized. Each entity receiving a valid order is required to deliver the promised product quantities within this step. An important feature at this step is the option to freely combine deliveries from the inventories of both product qualities (in the following HQ and LQ). This allows to deliver products of lower price and quality (LQ) as the higher priced HQ products - a strategy to fulfill orders otherwise not dispatchable or to optimize earnings. In case an order is unfulfillable anyways it will be added to a list of backorders - associated with a fine for the inability to deliver on time. Besides delivering on its own, each entity will also

[1] Note that the offering entity will only be able to reject orders when they have been adjusted by the ordering SC member. Otherwise acceptance is mandatory.

receive any products ordered in the prior *Negotiation* phase[2]. To account for the ability of the delivering party to mislabel products, receivers have the option to perform a quality check on their received goods against a small fee. Finally, the inbound items will be added to the SC members warehouse - either according to the trusted or revealed label.

The actual interaction between the SC actors is then finalized by the *Financial Closure*. In this phase all delivery-based earnings will be offset against all costs resulting from inventory cost, backorder and lying penalties. As each players in-game success is evaluated based on the financial outcome, this phase will allow him/her to understand his/her current performance and potential opportunities for improvement.

Each round is then finally concluded by a short *Questionnaire*. To keep the time spent outside of the game flow minimal only a small set of closed-end questions will be asked. These help to assess each users subjective trust assessment of each interaction partner. While this has no further impact on the game, the obtained data helps to assess trust values computed from the transaction data for correctness/appropriateness (an overview of the computed values and used formulas can be found in [1]).

2.2 Implementation

To account for the experimental and educational purpose of *the Game of Trust*, a considerable amount of attention was paid to its design. Based on a fast, scalable and reproducible IT-architecture (see Fig. 2) the *Game of Trust* allows large multi-player experiments. These will not only help to advance trust related research in SC but also to explore yet underused application areas for serious games. The scalability and reproducibility is achieved by containerization via Docker [6–8]. It allows to create a runnable description of the whole required gaming infrastructure within a single, so-called `docker-compose` file [9]. This highly simplifies testing, deployment, scaling and hopefully also encourages other researchers to use and improve the *Game of Trust* given the low entry barrier.

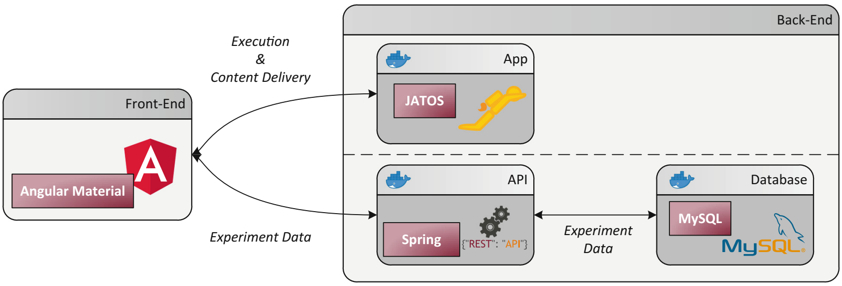


Fig. 2. *Game of Trust* - IT architecture

[2] Given the sequential nature of the *Game of Trust*, each entity will receive goods before having to deliver on its own.

The actual game was implemented based on the JATOS framework [10]. Developed to make online studies/surveys easier, JATOS already provides a lot of basic functionalities like user and session management as well as data exchange/synchronization. At the same time JATOS is completely based on web technologies like simple HTML and JavaScript (JS) and thus allows the creation of highly customizable 'studies'. The *Game of Trust* was then developed using the JS frameworks AngularJS [11] and AngularJS Material [12]. Using material design enabled the creation of a simplistic, yet visually appealing game with controls users are familiar with from their daily use of mobile devices and web applications.

All transaction data (*negotiations, orders, questionnaire results, ...*) generated during game play is stored within an adjunct MySQL [13] database located behind a REST API. While e.g. JATOS would have had an own data store, only this approach guaranteed the maximum flexibility in data collection as well as distribution for analytical purposes (see next section).

3 Trust Profiling with R-supported Data Analysis

While the *Game of Trust* allows researchers to generate lots of experimental data, the raw data alone provides little insight into the game and the underlying concepts. To get value out of the data careful analysis is required. In order to facilitate the execution of profiling and analysis tasks, the *Trust Profiling in R package* (`tprp`) was developed. It wraps functions to access the database, create (trust-related) statistics as well as appropriate plotting capabilities. Providing this well-defined and simple analytical API allows researchers to execute and analyze the experiment without in-depth statistical and programming knowledge.

4 Conclusion and Future Work

This paper presents an original serious game to collect data regarding the trust behavior of individuals in SCs. Its easy, fast, scalable and reproducible IT-architecture enables researchers a straightforward set-up and execution of experiments. The provided statistical toolkit allows for an immediate careful analysis of the collected data.

A first large-scale behavioral experiment using the *Game of Trust* is scheduled for October 2017. It is expected that the analysis of the trust dataset uncovers different relevant decision-making profiles, exposing how the participants subjectively perform trust assessments of possible interacting partners. The findings may also help to evaluate the Trust Support Mechanism suggested in [14] and its impact on the SC-related decisions (e.g. procurement, partner selection, information sharing, etc.).

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Generating Consensus: A Framework for Fictional Inquiry in Participatory City Gaming

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Abstract. Contemporary digital urban design games or 'city games' can function as a constructive instrument for exploration and discourse, serving as an essential interface between abstract decision-making processes and real world development decisions. Research suggests that city games are useful for engaging stakeholders, allowing them to explore a range of ideas. However when dealing with marginalized communities with low levels of cognitive consensus, one difficulty is that conventional city game approaches tend to engage pragmatic problems set in realistic contexts, rather than providing scope for discussion of the "soft city" or intangible aspects of a community. To address this problem, this paper proposes a new constructive gaming framework that incorporates Fictional Inquiry along with a "perceptual bridge" to help players contextualise a fictional proposition within their perception of real world problems. Fictional Inquiry differs from traditional participatory design practice as it temporarily changes or bypasses existing socio-cultural structures. The aim is to help marginalised communities learn to make effective decisions about intangible issues, and then to transform those choices into desired actions and outcomes. This paper illustrates the advantages of a perceptual bridge through the design of a new participatory design game the author calls "Maslow's Palace". This new conceptualised framework may be used as a catalyst to enable stakeholders in marginalised communities to foster a common vision through fictional inquiry as a prefix to pragmatic community design processes where consensus is required.

Keywords: City games · Participatory design · Design fiction · Fictional inquiry · Perceptual bridge · Consensus building

1 Introduction

"City games" can be used as an effective engagement strategy and advocacy tool for change, and as a viable platform for the increase of a community's consensus building capabilities. Experimentation through game play helps players to establish core beliefs about an issue; and in a collaborative multiplayer context, multiple users can form these opinions individually and then connect to share their opinions. Since the cost of failure in games is low, players may be emotionally willing to examine ideologies that are different than those to which they would usually be accustomed. Games not only have

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the ability to deliver messages, but also to simulate experiences that can be transformative, because participants can be absorbed in the games' environments and therefore often interpret game events as personal experiences [1].

Recent approaches to serious games in the realm of participatory urban design processes or "city gaming" have attempted to take advantage of simulation, engagement and communicative aspects of gaming. UN-Habitat's Block by Block programme (which uses Minecraft for participatory planning) and Cities: Skylines are examples of approaches to city gaming that endeavour to generate civic engagement from stakeholders centred on realistic projects [2]. Typically in the city gaming approach, real world sites are modelled as accurately as possible in the chosen game and participants or players are required to respond to these environments based on the provocation of the workshop coordinators – usually at the direction of some form of project brief. This has distinct parallels to both traditional participatory design, as well as to conventional table top city gaming approaches. This form of city gaming encourages participant negotiation centred on "realistic" design propositions, which results in pragmatic design responses that can be fleshed out further by design professionals. However this approach also often generates a number of problems such as confusion regarding pragmatic viability of workshop participants' speculative design outcomes. This may lead to disappointment and tension amongst players and participants.

While engaging, city gaming approaches often draw criticism for "gamifying" participatory processes and not having scope for the discussion of the "soft city" or intangible aspects of a community. In this way participatory city gaming works well for exploring ideas regarding well-defined, spatial propositions where the project is clear and the level of diversity within the participant group is low. But in communities where diversity of opinion is high, such as in informal migratory settlements, this approach can often be impeded by pragmatic impasses. Other difficulties include: the city gaming approach is not generally used as an analytical or discursive tool to find out about the problems that a community has and what they can do about those problems; the approach is not useful for discovering if individual preferences for solutions align with the rest of the community members; and due to the pragmatic approach to many city games, existing socio-cultural structures are usually retained and therefore, do not create an ideal environment for the creation of consensus through discussion on a level playing field.

Research shows that when communities are empowered through collective action, they see significant increases in "social status and self-esteem, along with incomes and working conditions" [3]. Alsop, Bertelsen and Holland define "empowerment" as a group's capacity to make effective decisions and then to transform those choices into desired actions and outcomes [4]. However, even if a group has the capacity to choose options, it may not be able to use agency effectively. Many marginalised communities are comprised of members from diverse backgrounds, who therefore enter the group setting with different assumptions, viewpoints, and interpretations of situations [5]. Although group members may have similar goals (i.e. reaching the best decision for the group), their views based on their diverse social backgrounds may interfere with the ability of the group to cognitively view issues in similar ways [6]. Through interaction and discussion, members are confronted with conflicting perspectives and must seek to reconcile dissimilar assumptions. Group member understanding (especially concerning the reasons regarding decision preferences, accepting others' viewpoints as valid, and integrating each other's perspectives into their own understandings of issues) positively relates to fostering greater cognitive consensus, facilitating better decision making and ultimately empowerment.

2 Fictional Inquiry and the Perceptual Bridge

2.1 Fictional Inquiry

In order to evaluate how city games might be better designed to allow communities to foster higher levels of consensus through discussion, this investigation looks at how city gaming can incorporate 'Fictional Inquiry' through a 'perceptual bridge'. Fictional Inquiry is a participatory design technique that uses partially fictional settings, artefacts, and circumstances to construct a shared narrative as a space for conducting collaborative design workshops. Through use of simple physical "props" to play out a scenario, participants are encouraged to imagine desirable/alternative futures to explore real world issues through a fictional lens. Fictional Inquiry differs from traditional participatory design practice as it temporarily changes or bypasses existing socio-cultural structures. Through a general narrative or novel conceptual framing of real-world ideas and problems, the physical and social settings of the participants are reconfigured. This allows designers to reframe the structures of meaning in a context, creating a filter to pragmatic impasses which can often thwart consensus building processes.

The technique has the same advantages of city gaming, as it is playful and engaging – allowing participants to tackle real world issues through an entertaining process – and also creates an environment that is well suited to imagining ideas for the future due to the low cost of failure. However, it departs from existing city gaming processes by introducing clearly fictional "props" and scenarios that enable participant groups to refocus their socio-cultural dynamics. Participants are confronted with their own existing practices and propensities, through discussion of questions or situations of conflict that might otherwise seem inappropriate; through this, the technique shifts focus from fixing existing problems to conceptualising desirable futures, and thereby opening up new lines of discourse and inquiry. Finally the technique creates space for reflecting on the content presented – space intended to provide "food for thought" to be discussed with the wider community and increasing the likelihood of initiating social change.

Dindler divides the Fictional Inquiry technique into three implementation phases: Preparation, Workshop and Analysis. This paper focuses on the Preparation Phase, which can be broken down into three categories: (1) identification of the purpose of the game, (2) development of the narrative and (3) definition of the plot [7]. The purpose of the game might be about prospecting/enacting ideas for the future, provoking discourse around specific and multiple contextual issues, investigating alternative presents or instigating social change. This differs from conventional pragmatic city gaming processes by trying to focus the game on less tangible realms of discourse. For example a conventional city game might be focussed on the location and design of a new building within a game world, while a Fictional Inquiry approach might try to explicitly open up discussions about the intricacies of community dynamics that necessitate the intervention in the first place. Fictional Inquiry then tightly couples this purpose to a general narrative to provide a backdrop for play activities. In order for this to be effective, participants need to be familiar with the narrative, universe and semantics. However, conceptual distance between the narrative world and the real world/current practice must be ensured, as distancing the narrative is the cornerstone in bypassing existing socio-cultural structures [8]. Plot sets the stage for action within the narrative by building tension, conflict and contradiction to which participants must respond. In order for participants to respond to situations in a realistic manner, participants are generally not given fictitious characters to portray. This ensures the inquiry can be focussed on the participants' own ideas, not those of fictitious characters, thus bypassing existing socio-cultural structures of the context, while preserving the motivations, skills, and knowledge of the participants.

While the approach establishes a foundation for consensus building within city gaming, a number of issues remain unresolved. One of the key factors responsible for the success of a fictional design project is the careful management of the fiction; if it strays too far into the impossible, i.e. presenting implausible concepts, the audience will not relate to the proposal, resulting in a lack of engagement or connection. Conversely if it is too familiar the fiction is too easily assimilated into the normative. In order for this to be effective, the first key factor is that Fictional Inquiry requires a 'perceptual bridge' to exist between the audience's perception of their world and the fictional element of the concept [8]. The second key factor is that the technique focuses on the framing of the fiction through narrative and simple props and not on the embedding of narrative within the design of the props or stages upon which the action (plot) can be staged. To this end there is often a lack of design criteria that may be used to design these props, and therefore game assets, and a lack of mechanics to scaffold the fiction or imply a 'world' within a participatory digital city game.

2.2 Design Fiction and the Perceptual Bridge

In order to design city games that enable players to increase levels of cognitive consensus through discourse centred on the temporality of a game environment and its mechanics, it is important to consider what type of futures or alternative presents the game will represent. Games might not only be asking players to consider "how things might be, but also why things are the way they are" [9]. Many practitioners often conceptualise what are termed propositions of "Design Fiction" within Voros's Foresight framework in order to position their design outcomes in relation to an audience [10][1]. This framework allows designers to locate their designs on a continuum of likelihood – beginning with the probable, or what is most likely to become reality and ending in the impossible, representing the designs hardest to perceive becoming reality in the future. Design Fictions are usually positioned between the plausible and the possible in order to break outside the realm of reality and pragmatics so they may ask

[1] For a detailed discussion about Design Fiction practices see [11].

provocative questions through design. If a design strays too far into the future or deviates too far when constructing an alternative present to depict a clearly improbable or impossible artefact, the design audience will not be able to relate to the proposition, thus resulting in a lack of engagement or connection. Auger argues that the designer has to create a "perceptual bridge" to fill the gap between the viewer's present state of mind – technical knowledge, psychological perception and cultural background – and the foreign proposition and its position within Voros's framework [11]. The plausibility of such fictions comes by achieving the right blend of factual authenticity from the present when scaffolding provocative diegetic visions [12]. To successfully achieve this, it is often useful to draw upon the familiar and mundane elements and typologies of everyday life, since due to a lack of knowledge of the future, people's expectations are typically grounded in what they understand today [13]. This approach is often discussed as designing the Uncanny, which seeks to contextualise a design within an existing typology, yet departs from it in very subtle ways to generate reflection and discourse [11]. There are a number of other aspects that help in the creation of a "perceptual bridge" – including narration to the audience about the designed object's fiction and its context (rhythm, plot, style) and framing the design within an aesthetic or spatial experience to communicate to the audience its place and relationship to real world systems [14].

A number of Design Fiction strategies may be adapted into the creation of a fictional enquiry approach to city gaming to scaffold cognitive consensus-generating discussion. To this end, 3d assets, spaces and game mechanics can be designed to:

1. consider the design's connection and position to temporality – from probable to impossible;
2. present players with alternative presents, futures, systems or worlds as a discursive provocateur;
3. engage the players through typological familiarity;
4. narrate the world in which players are situated through their design language;
5. raise questions instead of solve problems;
6. remove typical pragmatic contextual attributes that might normally constrain the design process or discussion about the design.

3 Building Consensus: A Framework for the Design of Fictional Inquiry in City Games

These six strategies can be conceptualised into a framework to guide the design of consensus building city games that incorporate both Fictional Inquiry techniques and the design fiction criteria developed for the design of digital 3d props to scaffold the fiction within the game environment. Figure 1 illustrates the perceptual bridge function as a two-way mechanism in which cultural structures are reinterpreted through a Fictional Inquiry approach to city gaming. It also embodies a number of important design considerations:

1. the target community for the fictional game is investigated/analysed in order to identify and understand its physical context and issues for the game to target, that directly feed into the purpose of the game, the narrative that frames the action in the familiar, and the plot design that encompasses the actions and discursive aspects of the game to set the stage for Fictonal Inquiry;
2. game environment, props, and mechanics are designed in order to encompass the various perceptual bridging techniques;
3. existing socio-cultural structures are left as the bridge is crossed into the fictional game world and are reinterpreted through the framing of the game;
4. interactive, multiplayer gameplay generates discussion and reflection around the real world issues embodied within the fictional world; and
5. discussions and ideas generated through the play of the game are taken back through the perceptual bridge via the functions of typological familiarity, narration and framing to be applied/conceptualised in the real world.

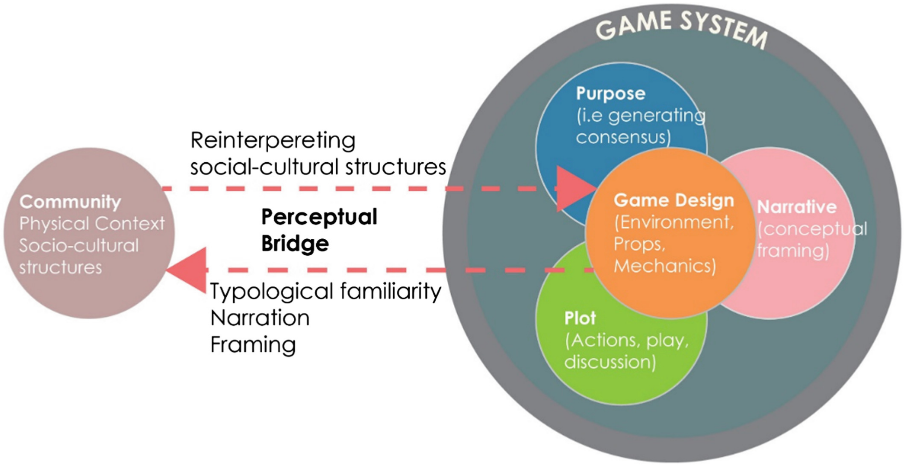

Fig. 1. A framework for fictional inquiry in participatory city gaming

4 Case Study Background: Maslow's Palace

This research investigation has incorporated this framework into the design of a new city game called Maslow's Palace, which is a turns-based multiplayer game intended to facilitate group discussions within the marginalised waste picker communities of Ghazipur (Delhi) and Shanti Nagar (Mumbai). Waste disposal sites with large waste picker communities, like Ghazipur and Shanti Nagar, are subject to massive rural urban migration that makes them culturally extremely diverse; they therefore struggle to gain political traction towards community development due to a lack of consensus and empowerment [3] (Fig. 2).

Fig. 2. The Shivaji nagar informal community at Shanti nagar landfill, Mumbai, India (2017).

5 Design of Game: Maslow's Palace

Maslow's Palace focuses on the problems and disparities of views within the Shanti Nagar and Ghazipur communities, to help them move toward a common vision. The game seeks to expose these differences to increase levels of consensus surrounding urban scale community issues and to foster empowerment by enabling groups to better understand each other's points of view regarding a range of problems to help them collaborate better in the future.

Maslow's Palace unfolds through gameplay situated on fictional islands that can be thought of as urban microcosms. Players are confronted with the challenges of built-in game logic (such as, all players must move their game character to a common area in order to open a door or place a specific module) and strategic discussion between players (such as, where to place modules based on personal importance to each player). Players are initially introduced to an open play level (Fig. 3), where they may experiment with "world building" and familiarise themselves with player movement, door opening and module placement. This level is visually designed to be situated at the less plausible end of the temporality spectrum, representing a significant departure from reality with the goal of levelling socio-cultural structures.

In subsequent levels, players are required to respond to the composition of modules they are placing. Through visual instructions, players are asked to build a tower five floors high in the centre of a fictional island community (Fig. 4). An inventory of modules is provided to the players comprising elements such as water tanks, houses, schools, medical facilities and public space elements (trees, cricket pitches, etc. that can

Fig. 3. Level one – open play that requires players to depart from reality.

Fig. 4. The introduction of familiar environmental components.

be placed at any time at any position). Players are instructed to place modules that are most important to the community at the first floor and the least important on the fifth floor. However in order to unlock the potential to place a new floor level module, all players must move their character to a "discussion zone" indicating that each player is happy with the current level. When all players are located in this zone the floor module may be placed. Game testing has shown that this mechanic is effective at generating a high level of discussion where players are required to reach a state of consensus on five occasions. Compositional feedback is provided to players in the form of a UI graph that tracks numbers of modules in the game grouped as public space, infrastructure, public amenities, residential and commercial modules. Players have been observed negotiating their "wants" in terms of module placement in relationship to creating a tower with an even compositional split in order to gain access to the next level.

The 3d game environment of Maslow's Palace has been developed with reference to an existing site context. As the game unfolds more familiar elements, such as typologically similar buildings and other environmental artefacts such as tuk tuks, are evident within the game environment. These game components are designed to parallel those in the existing research sites of Shanti Nagar and Ghazipur to provoke players to begin to think about their interactions in the fictional game environment with reference to their real world experiences, facilitating the formation of a perceptual bridge (Fig. 5).

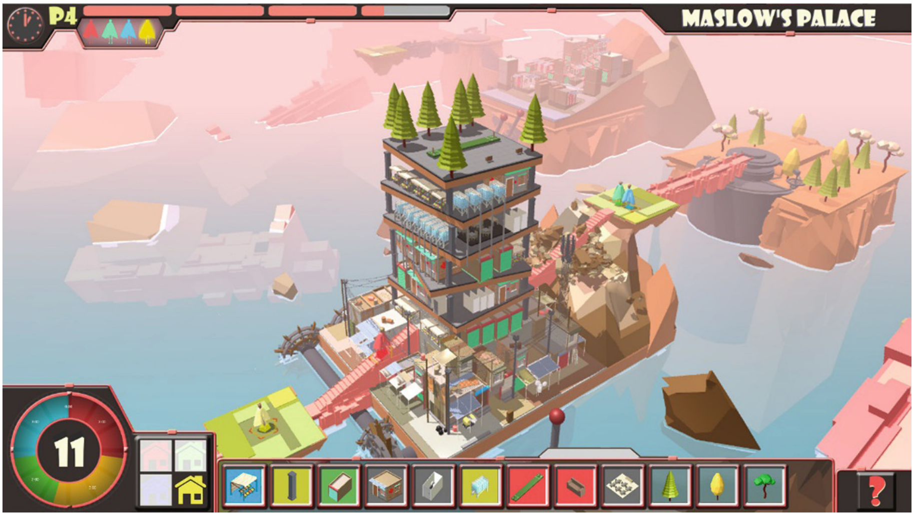

Fig. 5. Players constructing a tower in Maslow's Palace.

6 Generating Consensus: The Real World Feedback Loop

Play testing has shown that through collaborative gameplay within the fictional scenario, players engage in significant discussion in order to build consensus around a number of issues. Players often learnt to act collectively in order to make large changes swiftly. It was noted that through play, the game provoked players to define mediation strategies, as well as an overall "design" strategy. As more typologically familiar attributes such as familiar buildings were added, many players became concerned with the spatial planning aspects of placing modules. In one test, one player became fixated with having access ways for players to be able to readily move to a level exit door, while another player argued for a greater number of housing modules. This resulted in a discussion of values. In another test, a group of players were concerned with placing certain modules near building elements of the game environment that had no bearing on the game mechanic, but had compositional value to the players. This type of conversation became more apparent in later stages of the game in correlation with the introduction of more realistic environmental components.

Additionally, as the game attempts to represent urban scale systems at the building scale in order to make them more tangible, players noted and drew connections between different pieces of urban environment. Players were noted, for example, discussing the proximity of a water source to a player's in-game house. These observations show that players are conceptualising real world systems through a fictional lens – providing evidence of a perceptual bridge (Fig. 6).

Fig. 6. Players discussing gameplay in Maslow's Palace.

7 Conclusion

This constructed framework, and Maslow's Palace, is intended to be used as a catalyst to enable stakeholders in marginalised communities to foster a common vision through fictional inquiry as a prefix to pragmatic community design processes where consensus is required. It is acknowledged that the game framework cannot make a difference to people's situations in isolation. However this research has shown that the technique of applying a fictional approach to city gaming can generate a high level of discussion and build consensus amongst participant groups. Observations have shown that discussion can be bridged from the fictional game environment to embody real world issues and values of the game players. The approach has also seen players define discursive mediation strategies, which are invaluable for participants' active involvement in future real world development processes.

It must be remembered that the designer, when framing the design, needs to take into account the situation of the community that will be playing the game. A future or alternative present for a marginalised community will be very different from those living in a developed city. It is important that the designer not bias this.

The aim of the conceptualised design framework is to create a design system, foster debate amongst designers and facilitate productive participatory design processes through which designers can develop games that encourage user reflection, by enabling players and communities to reflect upon the multifaceted difficulties they face and empower them toward future action. Maslow's Palace embodies our reflections in the design framework and through the design of the game by providing a frame for the utilisation of fictional approaches to tackle real world issues. By designing city games in this way, a space for Fictional Inquiry players to consider a wide range of complex issues can be scaffolded – creating a space that can be explored fully within the safety of the elaborate worlds that games can create.

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A Platformer Serious Game with Dynamic Learning Contents

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Abstract. Video Games have always been a point of attraction for many people, especially for those in the younger age groups. Recently, the trend of taking advantage of this engaging field in education, to impart learning in some topics, is growing. Whereas Serious Games are generally designed for a specific educational topic with pre-defined and static learning contents and activities, we propose a serious game for children called "FunHomework". The game is based on features in commercial games and obtains its learning material from another application called "TutorApp", where both applications share the same real-time database. The TutorApp can be used for different subjects, giving educators full control over the learning contents of the game, and can also be used to monitor students' performance. With its dynamic contents, FunHomework will maintain its engagement and increase its usability.

Keywords: Serious games · Game-based-learning · Education · Platformer

1 Introduction

The use of games for learning has developed over several years. Serious games (SGs) are considered an interesting tool that combines entertainment with knowledge transfer. They have a purpose beyond entertainment, e.g., education, training, advertising, or supporting social change [1]. SGs offer considerable potential that can be used to facilitate formal and informal learning experiences in many contexts. Many studies have pointed to the constructive properties of SGs, such as their inducement and stimulus appeal, which can support various learning experiences.

One of the main advantages of using technology in education is producing a personalized learning experience. SGs can gauge the level of the students/players and cater to their learning style. Some students prefer verbal learning style of using words, both in speech and writing, where others may respond better to logical learning style of using logic, reasoning and systems. Such adaptation in classrooms is governed by the availability of time and resources. Due to the evolving learning styles of the Millennials and the way they learn, SGs can be a favourable vehicle to cater to their needs.

FunHomework is a novel game, affording the teacher control over the learning contents, making the game suitable for various subjects. To maintain its engagement and increase its usability, the game is developed using Procedural Content Generation technique, which generates dynamic contents and unique environment, every time the game is played.

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2 Background Work

Many researches have described the positive effects of games on child and teen players' learning [2]. Robertson and Miller [3] have empirically supported the constructive outcome of digital games, especially for the less-abled children. Using a game in classroom can motivate all the students, including shy pupils, to participate and contribute in class actively. The nature of games boosts diverse crucial skills for deep learning, such as metacognition, selective attention, etc. [2, 4]. Therefore, SGs can be considered an effective teaching tool that involves various learning principles, not just by virtue of being a game [5]. SGs have to be supported with educational principles and planned with educators, to guide the student through the learning material. Students should be given the opportunity to explore the games and cooperative learning should be encouraged.

Usage of SGs in formal education is making progress; however, most games were designed to achieve a specific learning goal. The games were structured in such a way that the learning goals are recognized and specified in the early stages of game design. SGs generally target specific topics (e.g. Math, Science, etc.). A game that is developed for the science subject in elementary schools will have almost static learning contents. As a result, it cannot be used for another subject, or even other topics within the same subject. Once the students master all the details and tackle the game, their motivation to play the game diminishes.

Despite the presence of games in formal education, it is still rarely seen in the regular classroom [7]. We argue that the reason for that is the gap between game developers and school teachers. A SG that is designed for teaching some curriculum, might not fit perfectly in another classroom that uses a completely or partially different curriculum. To have serious games in the classroom, they have to fit into the existing lesson structures and need to provide appropriate assessment. Currently, games are used often based on the criterion whether it makes the teacher's life easier, because the teacher chooses which game they are willing to use [6]. Teachers need to assess whether the game will enhance their students' learning, which can be time consuming. This is also another reason why serious games are not used in the classroom more frequently.

A study by Husain [8] introduced Serious Game design framework and an example of a Math educational game. Her SG targets Math of fourth graders and is made of three components: the game itself, a social network and a teacher reporting tool. She urged that some teachers are reluctant to use serious games in school and that we can increase usage of serious games as a resource, by involving teachers in game design and address their concerns. In her opinion, SGs should be games and not just drill and practice.

Mathbreakers [9] is a 3-D math exploration video game, where kids experiment with numbers and operations by playing with various toys and puzzles. Adventurers can chop numbers in half with a fractions sword, cast addition spells to zero-out negative enemies, and outsmart swarms of spiky integers, while developing number sense. The first release of Mathbreakers complements the standard math curriculum in San Francisco - USA for grades 1–6, including arithmetic, negatives, fractions, factoring, multiples and powers. The game is also supported by a dashboard, where teachers can assign lessons and track the progress of their students. However, teachers have no access to the learning material, as the curriculum is pre-set.

This paper proposes a serious game for elementary school students, called "FunHomework", where learning contents and questions are set dynamically by another application called "TutorApp", used by teachers. Each time the student plays the game, he/she finds new questions and challenges set by their teacher. Using TutorApp, teachers can add their own learning materials, which are then integrated into FunHomework and can be viewed and tackled by students during gameplay, which puts the game under the full control of teachers.

3 Game Components

FunHomework is a framework that consists of two applications; a Game "FunHomework", and a mobile application "TutorApp" for teachers. The basic goal of this framework is to provide for students an encouraging learning environment to submit their homework/activities results, and for teachers a simple and easy tool to manage students' activities and evaluate their performance. Both applications share the same Firebase real-time database to save, retrieve, update and exchange students' data and homework/activity reports. Firebase [14] provides a real-time database and backend as a service. The service provides an API that allows application data "TutorApp" and game data "FunHomework" to be synchronized across clients and stored on Firebase's cloud. Firebase also provides client libraries that enable integration with Android, iOS, as well as Unity3D game engine applications.

3.1 TutorApp

TutorApp is a mobile application to help teachers managing the learning contents of the game FunHomework. Using TutorApp, teachers will be able to organize students into groups according to their age/class or subject (Fig. 1a). They can also assign homework/activity questions to be done by students using FunHomework game (Fig. 1b). The application will be used by teachers and have the following functionalities:

1. Create a group for students to join, identified by a unique identifier GroupID.
2. Create a homework with a name and a description. Specifying the homework deadline is optional.
3. Add questions to homework, specifying the right answer for each question, as well as the mark associated with that question.
4. View the results of students within each homework and within the group as a whole.

3.2 FunHomework

FunHomework is 2D game developed using Unity3D game engine. The game can be classified as a Platformer game - one of most popular genres of video games. Games

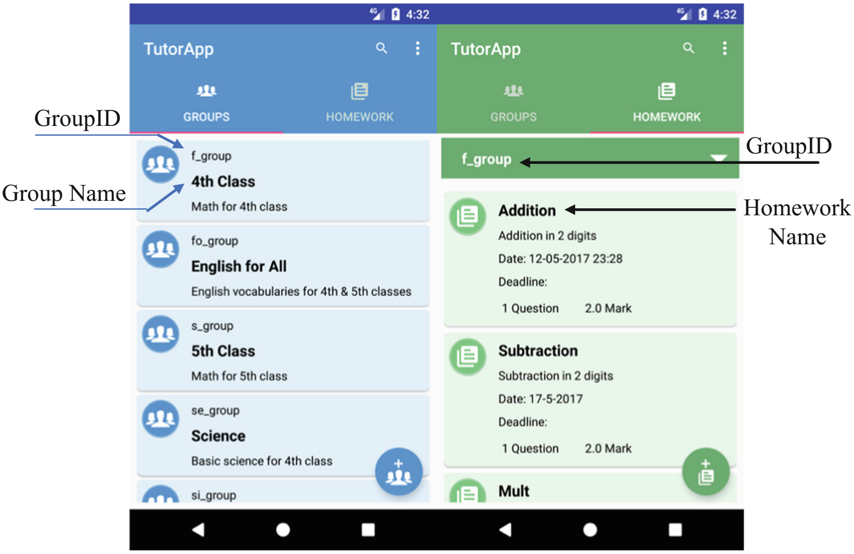

Fig. 1. TutorApp application; (a) Groups view (b) Homework view for group "f_group"

like Super Mario and Sonic, considered as the best-selling games of all time, are Platform games [13].

In the game's main menu, the players have to fill in their profile with data to be shared with TutorApp, which includes name, age, and student number if available. To view available homework/activities, the player has to join active group(s) created by their teacher. The group can be found by its GroupID as a unique identifier. (Fig. 2)

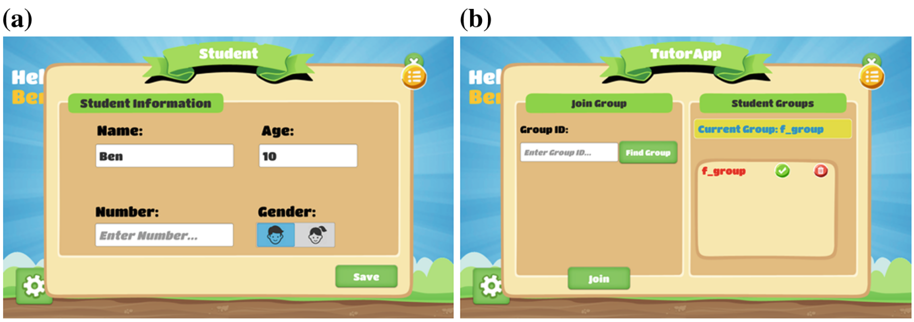

Fig. 2. FunHomework student's details; (a) Basic information (b) TutorApp details

The teacher shares the GroupID with their students which will enable them to find and join a specific group by that GroupID (Fig. 2-b). Once the student successfully joins their group, he/she will be able to view homework/activities assigned by the teacher (Fig. 3a). By selecting the "Play" button, the game starts (Fig. 3b) and the questions of the homework/activity are integrated into gameplay.

(a) (b)

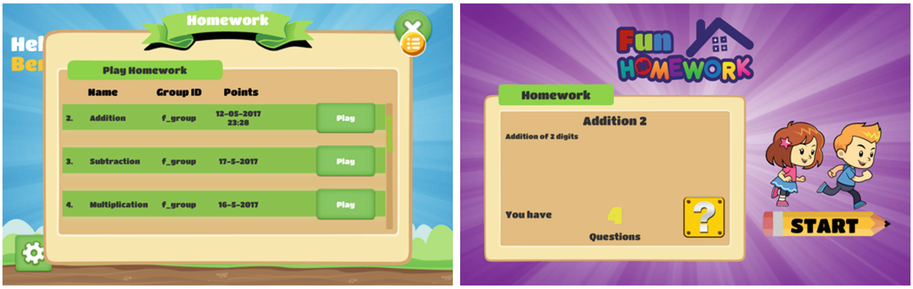

Fig. 3. Homework/Activities; (a) Available homework for group “f_group” (b) Homework “Addition” description

FunHomework involves guiding a player character to jump between suspended platforms and over obstacles to traverse their environment. The player controls the jumps, to avoid letting their character fall to their death or miss necessary jumps. During gameplay, the player has to fight and jump over enemies which launch projectiles. With their pencil weapon, the player can shoot enemies and gain more points. Along the way, the player can collect stars, before reaching a point where he/she is blocked by a wall, asked to hit a question block before he/she can go further (Fig. 4a). Once the question block is hit, question interface appears and the players can write their answer to the displayed question – which is loaded from TutorApp (Fig. 4b). Upon completion, the player can view their result which shows right and wrong answered questions accompanied by their marks and percentage out of total possible marks. The result screen also shows the points the player has collected by gathering stars and shooting enemies. The players can also see their position in a standings table of all students within their group, based on the average marks of all attempts. With two different player characters, one for girls and one for boys, the players can choose a character which represents their gender. The game presents the possibility of choice in character selection, which can be considered as a means by which the players could extend themselves into the world of the game.

(a) (b)

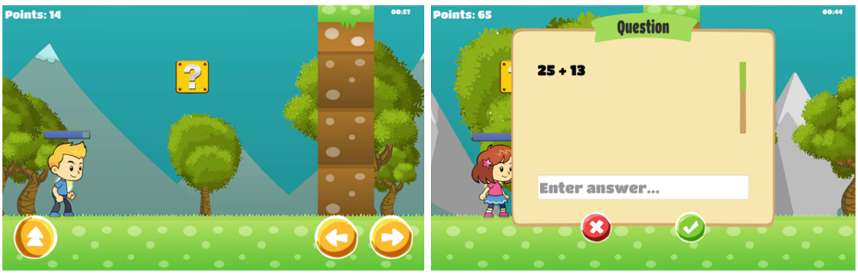

Fig. 4. FunHomework game; (a) Question point (b) Question user interface

4 Procedural Content Generation

Procedural content generation (PCG) is the programmatic generation of game content, using a random or pseudo-random process that results in an unpredictable range of possible game play spaces [10]. Due to the increasing cost of content design, we used PCG technique that can supplement design skills to rapidly populate the environment with randomly generated content. Using dynamic Instancing of In-Game Entities, we varied the parameters of in-game entities, to create a large possible number of entities with a small chance of repetition [10]. The dimensions of the environment depend on the number of questions of the activity/homework to be solved. The building unit we used to generate game contents is the question. Before and after each question, we generated an enemy selected randomly from a set of enemy entities (Fig. 5). Mountains and trees are also instantiated with Background Parallax effect from a set of entities, and placed with random spacing among question points and according to the dimensions of the environment. The same principle applies to walls, platforms, obstacles and stars to be collected. After generating the environment and its contents procedurally, the players find activity/homework questions spread evenly across their path.

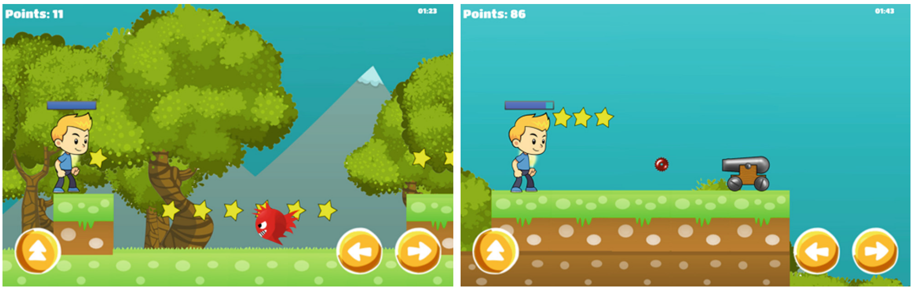

Fig. 5. Sample enemies

The result of PCG will be an almost completely different play environment, each time the player starts the game. The changing positions of mountains and trees and the different types of enemies settle the player in a new level, by restarting the game. This has not only saved design and development time, but also reduced the chance of player frustration, and maintained game engagement.

5 Reward System

The term reward system refers to the structure of rewards and incentives in the game that inspire intrinsic motivation in the player, while also offering extrinsic rewards [11]. Reward systems can be viewed as player motivators or as compromises for easing disappointment. In modern video games, reward systems also provide a social meaning within and outside of games [12]. In FunHomework, we tried to create a reward system that maintains game engagement and increases the healthy contest among students to play and do more homework. Listing students in a standings table kindles the competitive spirit in them, whereby they are stimulated to keep playing and solving problems, to improve their ranking. The reward system of FunHomework depends on three factors:

1. Number of right/wrong answers that the player make. The final grade of each homework is presented as a percentage and then added to the average of previous attempts.
2. Number of collected points. The player can collect points by grabbing stars, or shooting enemies and projectiles. Points are accumulated in the student's score and then used as a second factor, in case of a tie in the marks.
3. The time needed to finish the homework/quiz. The faster the task is finished, the more are the points to be got.

Once the player reaches the finish point, the result screen shows the outcome (Fig. 6a), where he/she can also view his/her position in a ranking table (Fig. 6b). The ranking table displays the players within the same group ordered by (a) their average result for all homework in this group (b) the sum of points collected during the play of all homework. For more motivation, badges are given to the first 3 players within the group. The first player wins the trophy, while the 2nd and 3rd places enjoy silver and bronze medals respectively.

(a) (b)

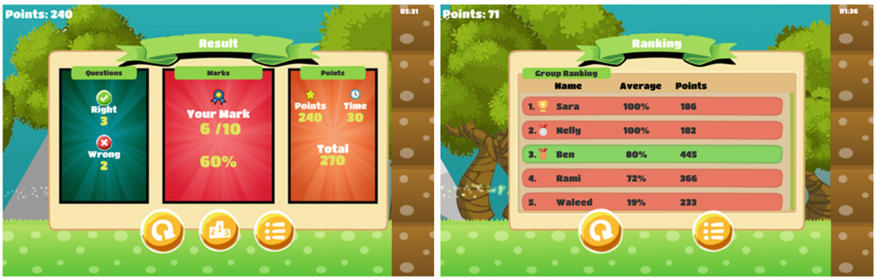

Fig. 6. FunHomework game; (a) Results Screen (b) Students' Ranking

6 Conclusion

Serious games are used in various domains; however, in the formal education sector, there are a lot of factors to be considered, as they might change the fundamentals of the current educational process. The teachers play an important role in this process, as they have the authority to choose the learning method. They also have the experience of the current learning process. For using serious games, they need to be able to adapt to a different learning process and be able to manage the reflection of new methods.

In this paper, we introduced FunHomework, a platformer game that gets its learning material from another application TutorApp. The game provides full teacher control over the learning contents, making it suitable for various subjects. FunHomework maintains its engagement and increases its usability, by using the Procedural Content Generation technique, which generates dynamic contents and a unique environment, every time the game is played. Providing a healthy, competitive environment, FunHomework can be used in formal education for students within the classroom or at home. The game should be published for personal computers as well as for mobile devices, to be available for students everywhere. While the initial feedback received from students, teachers and parents is promising, the game should be tested in and outside the classroom, to measure its educational impact on students' attainments.

As a suggested refinement for future work, Speech Recognition can be employed within the gameplay, to ease user input. This should convert the player's voice into written text and can help the player in submitting the answers with his/her voice more quickly, especially where answers contain long texts.

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I-Interact: A Virtual Reality Serious Game for Eye Contact Improvement for Children with Social Impairment

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Abstract. Eye contact is among the most substantial yet underrated non-verbal social communicative behaviors. Establishing and maintaining eye contact is quite challenging for children affected by social impairment. As a solution, we propose a virtual reality serious game to help improve eye gaze abilities for these children and facilitate the transfer of the acquired skills to real-world social interactions. The project comprised of the design, implementation and evaluation of a three levels game that emphasizes on different aspects of eye contact. According to the evaluation carried out in this research, a virtual reality gaming context is a promising strategy for gaze development of children with social deficiencies.

Keywords: Eye contact · Social impairment · Serious games · Virtual reality · Children

1 Introduction

How many times have arguments occurred because of an unclear text message? A mistakenly perceived as aggressive message can accurately be interpreted as sarcastic in case of the speaker wearing a sarcastic smile on his/her face. That same message may also be interpreted as caring if a deep, long and loving eye gaze with the listener is maintained. People regularly misunderstand our messages if presented only verbally which highlights the significance of non-verbal communication in our daily lives. Non-verbal social communicative behaviors constitute a vital and informative part of a conversation with their different forms of facial expressions, eye contact, body language and gestures.

Among the most important non-verbal communication channels is eye contact. Lack of eye contact namely gaze aversion may robustly obstruct daily communication processes. The adopted definition of eye contact classifies it further into two categories: dyadic eye gaze and triadic eye gaze [13]. Dyadic eye gaze is a term to denote eye to eye or eye to face interactions. Whether triadic eye gaze -which is frequently referred to as joint attention- represents a person's

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perception of another person gazing in a specific direction (i.e. in the direction of a certain object). Both forms of eye gaze are vital for social communicative encounters. For instance, dyadic eye gaze is important because looking directly into our interlocutor's eyes enables us to read their emotions. Consequently, the process of talking to people wearing dark glasses may be quite challenging [1]. Eye to eye gaze is used as a mean of getting feedback during a conversation, and its lack may also be misconstrued by others as inattention. Maintaining strong and stable dyadic eye gaze is a sign of the speaker's self confidence and increases his/her credibility to his/her listeners. On the other hand, triadic eye gaze is considered as an important factor in understanding other people's intentions, in other words mind reading [3]. Joint attention provides people with information about their environment, enables them to comprehend references, to point to objects and consequently learn new words [12].

Difficulty in eye contact is a clear sign of social impairment, characteristic of some developmental disorders such as autism spectrum disorders (ASD) [9]. Gaze aversion may also affect neurotypical (NT)[1] people with a mild degree of social impairment which makes them overly timid or less socially active than others.

Using conventional techniques to improve eye contact for those individuals such as verbal and physical prompting has proven to be ineffective [6]. Virtual reality (VR) serious games that comprise of virtual characters similar to real ones can help individuals with problems of eye contact to enhance it. It will make it more feasible to transfer acquired skills to real-world context afterwards. Implementing these games for children rather than adults may yield to better outcomes since they are still in an elementary stage of social development.

2 Related Work

As contended in [4], video games can support the development of social aptitudes when played in moderation to avoid gaming addiction issues. Henceforth, the field of serious games for social development has been widely explored recently with examples such as "Let's Build" [5] that aims at teaching children the notions of fair play, collaboration and leadership. Likewise in [4], the researchers modified the "The Elder Scrolls V: Skyrim" which is a previously developed action role playing game to enhance the social skills of autistic children particularly.

Several applications and games have targeted the development of one specific social skill which is eye contact. Samsung along with doctors and psychology professors from two universities in Seoul have developed the "Look at me" app. This app aims at training autistic children on a range of social skills among which is eye contact. Another popular game for helping autistic children establish appropriate eye contact (both dyadic and triadic) is "Ted's Ice Cream Adventure". The game constitutes of many levels that revolve around a bear trying to sell ice cream to his clients. The user has to identify when is the bear trying to talk to

[1] A term used to denote people who are not on the autism spectrum.

him/her through his eye gaze direction. In other stages, the user has to recognize where the bear's gaze is directed, for instance in the direction of a specific object.

In recent years, VR technology has been used to teach children everyday skills by providing them with a safe environment resembling real life [7]. VR allows social interaction with a less amount of stress, anxiety and fears of mistakes as in real life situations [8]. Virtual environments that we expose a child to are more controllable, we can modify the colors, characters, situations and scenarios accordingly to perfectly meet the requirements. Moreover, researchers showed that skills learned in virtual environments can be generalized to the skills in real life. In [7], a desktop VR game was developed in order to train children on mastering the street-crossing skill. The game was then evaluated and 3 of 6 participants showed successful transfer of the virtual street-crossing to actual street-crossing.

Among the experiments where VR technology has been tackled for eye contact improvement is [9,10]. In the former, an "Oculus Rift" as the VR headset, and a stereo camera were used. A fading prompt approach was employed to draw the attention of autistic children to the instructor's face and eyes. A virtual image of an interesting colorful object appears on the face of the trainer and it starts fading away until it leaves focus only on his/her face and eyes. The study showed that the fading prompt is an effective mean for intriguing the child and helping him/her with eye contact. In the latter, an eye contact reminder system which reminds people with autism to focus their eyes in the direction of a human speaker was implemented. This device performs a detection of the speaker's voice and a calculation of the sound direction. A real time message is then displayed on the head mounted display (HMD) to direct the user to look towards the speaker.

A framework implemented in [11] with the objective of developing social attention skills in autistic children uses a HMD to show images from a virtual classroom. This classroom contains a set of 3D virtual characters who are presenting educational material. Only one of these avatars is speaking at a time and will start to vanish if the child diverts their eye gaze from him/her.

"Coffee without Words" is also an example of a commercial VR game developed on "Oculus Rift" for ameliorating the eye contact skill. The virtual scene in this game is a coffee date with a female avatar who keeps moving her eyes in an attempt to encourage the user to initiate eye contact with her. No verbal communication is enclosed in the game.

To this end, existing work highlights the potential of using VR technology for migrating daily skills from a virtual environment to a real-world context. In our work, we have employed techniques similar to those explored in "Ted's Ice Cream Adventure". Nevertheless, we made sure to use 3D human avatars instead of 2D animals to help users identify the connection to similar real-world interactions. As discussed above, several existing applications are designed from a purely educational perspective. The absence of the amusement factor makes the application dull for children. Hence, arises the need for gamification to render the system more friendly and agreeable.

Some applications like the eye contact reminder system have illustrated their impracticality since the users need to carry the device around with them constantly. Developing an application/game to act as a training rather than an assisting tool is a substantial aspect considered in our project. Therefore, our work aims at creating a VR game that will be used as a training tool in a joyful way to help children ameliorate their eye contact capability.

Most of the above-mentioned applications that targeted eye contact [9–11] have focused primarily on the dyadic eye gaze capability. In our game, we will focus on both classes of eye contact.

It is also worth noting that VR technology has been rarely used in Egypt. This work is among the first formal comprehensive studies in Egypt to harness VR gaming for children afflicted with developmental impairments.

3 System Overview

Our goal in this research is to enhance eye contact for children with social impairment via a VR serious game. This can be a beginning stride to further build up their social communicative abilities. The game consists of levels that target both dyadic and triadic eye gaze independently.

3.1 Collaborative Design of "I-Interact"

Our proposed framework is directed towards children with social deficiencies. Considering the special targeted user group, it was decided to approach community experts. Contact had been established with a local early intervention center "Ebny Association for Special Needs and Autism", and a workshop structured into two sessions had been organized with them. The first was a brainstorming session with instructors and caregivers of the intended population. Our ideas were discussed with feedback and modifications from their side. Some of the advised design aspects were to use a reward rather than a scoring mechanism to designate a game win. It is more enthusiastic for youngsters to anticipate a celebration scene as a reward on the screen than an increasing score that they seldom comprehend. Also among the decisions that were reached collaboratively was to organize the game in levels with ascending difficulty. The first level is a preliminary introduction to the concept of looking towards faces/eyes. Moreover, each level is further subdivided into three stages with the first one as a primitive trial that introduces the level flow stream. The initial target age was 3 to 9 years. However, since social deficiencies are commonly accompanied by intellectual disabilities, older children with lower intellectual abilities may benefit from the game too.

During the second session, an informal test was conducted on a first prototype that has been implemented for one stage of the first level of our proposed game (the current platform includes three levels with three stages each). The objective of this test was to foresee the viability of our system by assessing the children acceptance and delight during the VR game experience. Three children participated in this preliminary study each with low, moderate and high computer aptitudes respectively. The game fascinated the three users equally. The participant with low computer abilities was not capable of playing the game, whereas the other two children could finish the level successively without external aid.

3.2 Game Flow Description

In order to guarantee the simplicity of our game "I-interact", prompts were limited, verbal, and in Egyptian Arabic dialect. The purpose was to dispense with the challenges that a child may confront in case he/she has other learning deficiencies (i.e. struggles to read or struggles to understand foreign languages). Virtual characters changed recurrently throughout the levels to enable the children to generalize the interactive scenarios to all human figures.

The game consists of three levels with three stages each. Both first and second levels focus on dyadic eye gaze, while the third is more concerned with triadic eye gaze. The levels were implemented in order to have a gradual impact. Therefore, the first level aims at just attracting the child's attention towards a human face and eyes without being explicitly prompted to look towards any of them. In the second level, the child is implicitly solicited to look into the eyes of a human character in an attempt to teach him/her to initiate eye gaze and maintain it for a few seconds. The purpose of the third level is to get the child trained on triadic eye gaze by enabling him/her to identify where the character's eye gaze is directed. The surrounding virtual environment is exceptionally primitive to avert confusion in both first and second levels. However, in the third level several distracting factors are added to render the level more challenging: two additional human characters and some furniture in the background. Scenes of some of the levels stages are shown on Fig. 1.

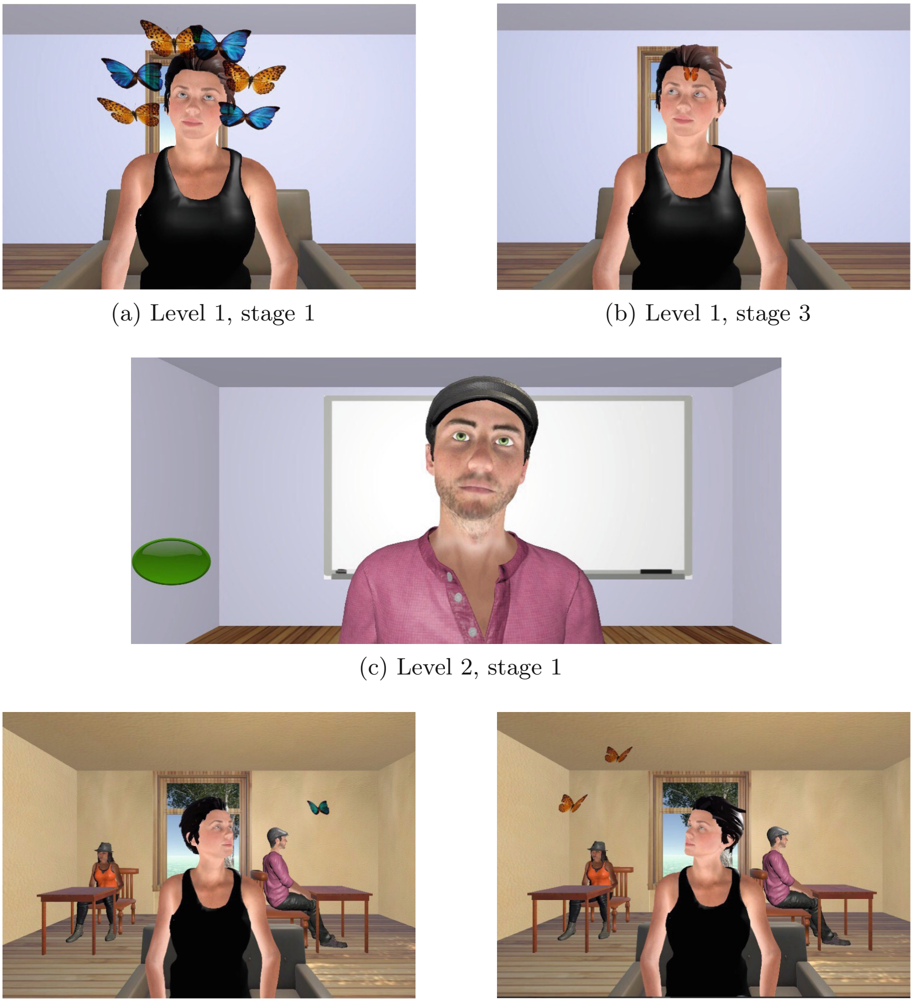
The levels are played in a sequential manner. Nevertheless, a player can exit a level in the middle and choose to start another one.

Below is a detailed description of each level:

Level 1. Consists of a female character who articulates a verbal request to the child. She asks him/her to remove the butterflies scattered around her face to prevent her distraction. The child performs the task by clicking on the butterflies.

The first level consists of three stages:

- **Stage 1:** six butterflies are organized in a roundabout shape around the young lady's face. The user has to get rid of them all in any order to enable the transfer to the next stage. This scene is presented on Fig. 1a.
- **Stage 2:** six butterflies appear consecutively on the girl's face. A new butterfly does not show up until the user disposes of the past one. In this phase, butterflies are nearer to the face than in the first stage.
- **Stage 3:** similar to stage 2, yet the butterflies are smaller and closer to the eyes as depicted on Fig. 1b.



(a) Level 1, stage 1 (b) Level 1, stage 3

(c) Level 2, stage 1

(d) Level 3, stage 1 (e) Level 3, stage 3

Fig. 1. Some of the different stages of the "I-interact" game

Level 2. Consists of a male character who asks the child about the color of his eyes which keep changing after each correct response. Eye colors alternate randomly between brown, green and blue. The user is stuck at the same scene until a correct answer is provided. The child performs the task by clicking on the correct color choice.

The second level consists of three stages with six trials each:

- **Stage 1:** only one color option is provided which is eventually the right answer as shown on Fig. 1c.

– **Stage 2:** the user has to select the correct option from two available color choices.
– **Stage 3:** the user has to select the correct option from the three available color choices.

Level 3. Consists of a female character who asks the child to identify and catch the butterfly that she is looking towards. Similarly to level 2, the user is stuck at the same scene until a right answer is given. Similarly to level 1, the child performs the task by clicking on the designated butterfly.

The third level consists of three stages with six trials each:

– **Stage 1:** As depicted on Fig. 1d, in this stage only one butterfly is present in the scene which is eventually the right answer.
– **Stage 2:** the user has to catch one of two butterflies by distinguishing which one the character is looking at.
– **Stage 3:** like stage 2, however, the two butterflies are closer to each other as displayed on Fig. 1e.

Every level stage ends with the celebration scene represented on Fig. 2. The scene is unified through the game and is accompanied by cheering and clapping sounds.

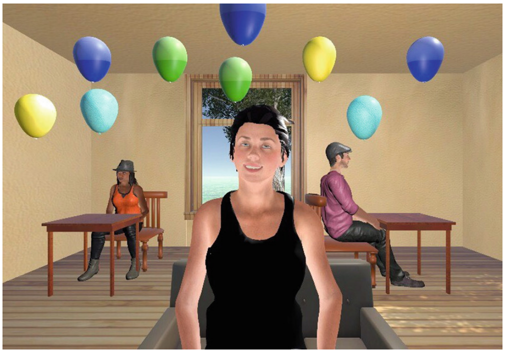


Fig. 2. The celebration scene of level 3

4 System Evaluation

With a specific end goal to get an accurate impression of our game, we evaluated it through two user studies. The first aimed to measure the effectiveness of the game in enhancing the eye contact skill. The second was performed to measure engagement levels in immersive VR gaming using HMD for people with disabilities. The motivation for this was that immersive VR technology using

HMD has rarely been used in Egypt for people with disabilities and developmental impairments. Therefore, it would be beneficial to gauge their acceptance of it which will help predicting the effectiveness of the technology in the future. For consistency and center-related recruitment reasons, all selected users for this second study were autistic.

Our samples for both studies consisted of four users each. They were all recruited through the Egyptian association "Ebny Association for Special Needs and Autism". The average age for the first study was approximately 8 years, as opposed to an average age of 14.5 years for the second study. The reason why the average age for the second study is higher is that it is not encouraged to use HMD for children under 13 years old. The majority of our selected users were autistic, thus, most of them were males. This is because more males are diagnosed with autism than females with a ratio of 4:1 [14]. A detailed presentation of our recruited samples is shown in Tables 1 and 2.

Table 1. Participants for the eye contact improvement study

ID	Age	Gender	Condition	Computer skills
P11	8	Male	Autism	Basic
P12	7	Male	Autism	High
P13	3	Female	Social behavior problems	High
P14	13	Male	Autism	High

Table 2. Participants for the immersive VR engagement study

ID	Age	Gender	Condition	Computer skills
P21	14	Male	Autism	High
P22	14	Male	Autism	High
P23	15	Male	Autism	Moderate
P24	15	Male	Autism	High

4.1 Experiments

Eye Contact Improvement Test was organized in six sessions over a period of 3 weeks. Each session was of a duration 15–20 min. In order to quantify eye contact improvement, pre- and post tests were performed to assess eye contact levels. The pre- test was performed in the first session before they started playing the game, whereas the post test was performed after they played the game for the last time in the last session. The pre- and post tests were identical and were inherited from standard tests implemented to gauge eye contact levels such as the one in [2]. The procedures for both tests started by the child's teacher calling his/her name and identifying if the child exhibited the convenient eye contact by looking directly into the instructor's eyes. This trial is repeated for ten consecutive times, one trial for every ten seconds. The instructor recorded the results by writing a positive or a negative sign in front of each trial on the corresponding test paper.

The flow of the six sessions went similarly afterwards. Each child played the levels of the game which were loaded successively. Initially, the children were intended to play only the first two levels, since our eye contact assessment is used for testing dyadic eye gaze only. However, we allowed the children to play the third level or even sometimes play the three levels twice in the same session. This was only in the event that they were exceptionally intrigued and did not have any desire to leave the game.

Their teachers were present by their sides amid all sessions to provide additional assistance if necessary. The game was played on a touch screen notebook powered by an Intel i7 core processor and with embedded speakers for the sound effects.

Immersive VR Engagement Test was a one session test for each participant. The duration of each session was 20–30 min length. In order to assess participants engagement and delight in the immersive VR technology, each session was partitioned into two sections. During each section, the user played one of the two versions of the game. The first one was played on a touch screen notebook powered by Intel i7 core processor with embedded speakers. The second was played on a HTC Vive HMD, its controllers and a pair of stereo speakers that were used for sound generation. All users were accompanied by their instructors throughout the session to provide additional assistance if necessary. After each part of the session, a hard copy of a standardized survey derived from [15] was filled by the teacher. The test questionnaire evaluated the overall engagement of the user during the corresponding game version through nine points with five available Likert scale responses.

4.2 Results

Results of the eye contact improvement test are depicted on Fig. 3 which presents the number of positive eye contact trials before and after the game intervention.

The results show that all participants have showed an improvement in eye contact with the exception of participant P14 whose eye contact behavior did not change. Furthermore, with respect to other participants, P13 specifically has shown a clearly significant improvement (+4 in comparison to +2). This can be attributed to the fact that P13 is the only participant with no disabilities, rather only social behavior problems. This might make it easier to alter her social conduct in case she was sufficiently intrigued which she clearly was.

Immersive VR technology using HMD has yielded to a slight positive effect only in a single case of the four participants in the immersive VR engagement study. It was clearly noticed that the reason behind that is that they did not feel in full control while using the HMD controllers. Results for this study are shown in details on Fig. 4.

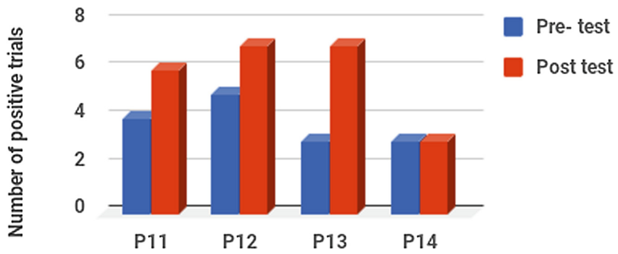


Fig. 3. Results of the eye contact improvement test

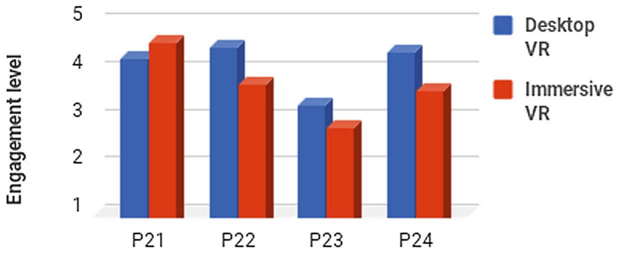


Fig. 4. Results of the immersive VR engagement test

4.3 Discussion

As previously discussed in Sect. 4.2, the eye contact improvement study yielded positive results. Due to our target group being extremely special, recruitment of the sample was quite challenging. It was noticed that in order for a participant to play the game, it is preferable for him/her to have at least moderate computer skills. Children with social impairment that have moderate/high computer abilities rarely exhibit problems in the eye contact skill. Therefore, our sample was exceptionally small. Two participants started the study, nonetheless, they dropped out early. One of them had ADHD[2] and thus was never able to fully concentrate on the game. The second had very low computer aptitudes and was not under any condition pulled in by the game. It is important to note that only one user (P11) had basic computer skills and yet has completed the study with positive outcomes. For this particular user, progress in his engagement level was noticed in each session.

Although no study was carried out to test the transfer of the eye contact behavior to real-world context, it is anticipated that our framework can likewise perform satisfactorily in this regard. P11 kept kissing the virtual characters each time they show up on screen. When asked, his teacher affirmed that this is his behavior in real life towards individuals he likes. The same participant was constantly waiting for the celebration scene and used to get energized, cheer and applaud along when it begins on the screen. This also confirms the convenience

[2] Attention Deficit Hyperactivity Disorder which is a disorder characterized by symptoms such as inattentiveness, hyperactivity and impulsiveness.

of the proposed design aspect to utilize a reward rather than a scoring system to denote a game win.

The results for the immersive VR engagement study were not quite positive though. P23 expressed unequivocally that he truly enjoyed the Dektop VR version versus the immersive VR adaptation. All users in this study were chosen to have an explicit interest in technology and a range of moderate to high computer skills to be capable to manage the HMD and the controllers. Nevertheless, three out of the four users did not feel in full control while playing the game. They additionally often got bored when playing the immersive VR version because it took them so long to perform the required tasks. This suggests that immersive VR gaming for people with disabilities may still need a lot of training with them before we can see positive outcomes out of it.

5 Conclusion and Future Work

The motivation behind this project was to develop a VR serious game to enhance eye contact capacities for children with social deficiencies. To achieve our objective, we conducted a workshop with specialists in the field and then developed a three levels game that handles different aspects of eye contact. In order to evaluate the adequacy of our platform, we directed a user study for the targeted children. Eye contact levels were assessed before and after six sessions of playing the game. The results of this test guarantee the viability of our framework for the purpose it was created for. In the future, longitudinal studies that test the migration of the acquired eye contact capabilities to real life communication encounters can be conducted. It is important to note that our user study focused on testing the improvement of dyadic eye gaze only, future user studies can additionally assess the progress in triadic eye gaze.

A second user study was performed to investigate the potential of immersive VR technology in the participants overall engagement in the game. This study did not render positive outcomes which is ascribed to the lack of control that the users exhibited amid the immersive VR experience. Better results can be achieved in the future by implementing different adaptations of the game that demand less control driven input. Providing more training for people with disabilities on the VR headset and it controllers will also prove fruitful on the long run.

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A Case Study into the Use of Virtual Reality and Gamification in Ophthalmology Training

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Abstract. In collaboration with doctors and medical students a novel ophthalmology training solution based upon virtual reality (VR) and gamification was developed. Fifteen fourth year medical students at Birmingham City Hospital (UK) helped evaluate it. Evaluations were based upon the Technology Acceptance Model and related to how well users learnt to use the app, their satisfaction with it; if it helped them learn ophthalmology and their view on the teaching approach used within it. Responses were rated on a five point Likert scale (completely agreed to completely disagree). Results represent those that agreed or completely agreed with the questions. Students agreed they could easily learn how to use the app (n:14) and it was clear how to use (n:15). The feedback systems supported both this (n:11) as well as learning how to perform eye examinations (n:13). Users felt the app improved their understanding of the processes involved in ophthalmology (n: 14); their ability to recognize main landmarks of the eye (n:14) and abnormalities (n:15). They felt the app would give them confidence to perform eye examinations on patients in future (n:12) and it would increase other students' confidence too (n: 15). Users found the app enjoyable to use (n:15); would use it in future (n:13) and would like to learn other clinical skills in this way (n:15). A rigorous User-Centred approach has been used to successfully develop a novel ophthalmology training tool. The approach used will help inform others interested in developing VR educational tools.

Keywords: Virtual reality · Gamification · Ophthalmology · Medical training · Technology Acceptance Model

1 Introduction

During their training medical students will be required to become proficient in a range of clinical skills which may be challenging to learn. One skill that medical students find difficult to perform are eye examinations [1], meaning that an important diagnostic procedure can become underutilized [2]. Previous studies have shown that simulations using medical photographs have helped students understand ophthalmology procedures before moving onto working with patients [3, 4] by incorporating gamification [5]

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students have also reported that it can improve their engagement with their learning of challenging and difficult clinical topics too [6, 7].

Successful adoption of new practices and technologies can be very dependent upon the active involvement of users. User-Centred design aims to ensure that risks are mitigated against rather than relying on retrospective fixes to poorly designed systems which are more likely to be under used or misused [8]. Subsequent evaluation provides confidence that the systems are effective and Fit-For-Purpose which is becoming an issue with medical apps as concerns have been raised about their proliferation without any suitable testing and validation [9, 10]. Finding appropriate evaluations of technologies in clinical settings can be challenging as technology is quick to change. Regular access to trainee doctors to help with testing can be difficult too. All of this can mean that if evaluations are not conducted in a timely manner the system could soon become Out-Of-Date. However there still needs to be a high level of confidence that the system produced is useable, accurate and efficacious. The Technology Acceptance Model [11] offers one potential solution to the challenges associated with testing in clinical settings in a way that has been previously validated in other settings. This paper describes how a novel ophthalmology training app was developed and evaluated in collaboration with doctors and medical students. It was built using commercial smart phone technology and affordable virtual reality (VR) head mounted displays (HMD). By incorporating actual clinical photographs and utilizing gamification an app was produced which was intended to be both clinically accurate as well as being both fun to use and educational.

2 Methods

2.1 Collaborative Design

In order to identify how HMD VR could be used in clinical training preliminary discussions were conducted between two clinical teachers (DC and LT) together with a medical student and two technologists (ASW and JO). After demonstrating how VR works it was decided that an ophthalmology training app could be developed which could take advantage of its functionality. Real-Life use of an ophthalmoscope is influenced by numerous factors for example patients find it hard to keep their eye still or the student does not have a big enough field of view to identify important land marks in the eye. Therefore the app would be designed to help students understand overcome these type of problems by incorporating different types of movement, orientations and visual field restriction. The addition of gamification and education strategies would be used to make this difficult to master technique fun to learn and structure the way the students' learn the systematic step wise processes used when examining the back of the eye.

2.2 Development Hardware and Software

The app was developed using Unity 3D 4.6.6, C# and the Microsoft.NET framework version 4.5.1+. Other software included the Java Runtime Environment version 8+, Java SE Development Kit version 8+, Microsoft Visual Studio 2013 premium, Android stand alone SDK and the Google Cardboard SDK for Unity. A custom text to speech synthesis program was coded by one of the authors (JO) using C# and the Microsoft Speech Synthesis API.

2.3 Deployment Environment

Google Cardboard 1 and Ritech II Virtual Reality HMDs were used in the development. The app was tested on HTC one 801N and Samsung Galaxy S5 phones. Google Cardboard 1 or RITECH II require the phones to have both gyroscope and magnetometer (digital compass), this is so the HMD's external button can interact with the app. Google Cardboard II and Ritech Riem3 Plus are also supported. These substitute the magnetic button with a lever on the HMD that touches the mobile phone's screen. Figure 1 shows the Ritech Riem3 Plus HDM and mobile phone as well as the stereoscopic view of the retina displayed by the app on the phone.

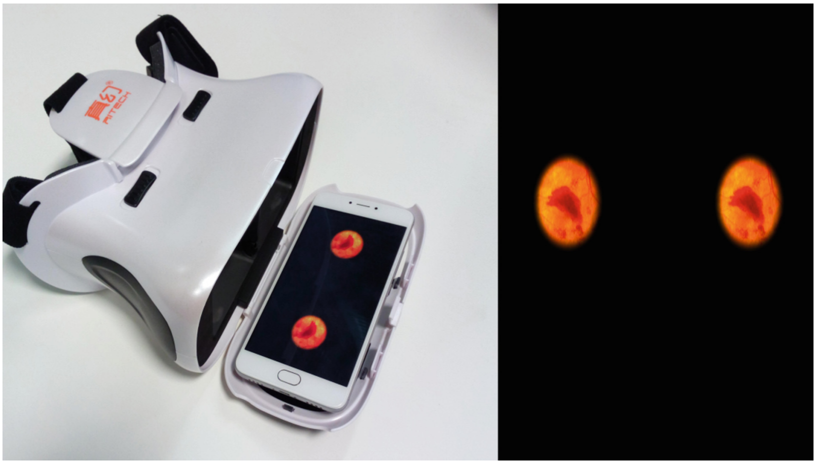

Fig. 1. Ritech Riem3 and smart phone [left]. Stereoscopic view of retinal images with haemorrhage [right]. The fixed aperture size in the app restricts what the user can see mimicking the actual view through an ophthalmoscope

2.4 The Ophthalmology App

The app has five levels including a tutorial, red reflex, retinal navigation, pathologies and quiz. It uses a range of authentic clinical photographs of both normal and abnormal eyes. Audio, visual and text provide instruction on how to use it; how to perform eye examinations and also gives descriptions on the different types of pathology that can be found in the retina.

The Tutorial Level. This requires the user to look around and search for objects in the 3D world learning how to navigate the environment. The user has to press the HMD button in order to interact with objects which are the main form of interaction between the program and the device. If the user fails to press the button with sufficient force audio cues prompt the user to press the button harder until it activates. As the button is the primary way of interacting with the program an alternative mechanism was required for the user to access the menus. Given the limited functionality of the Google Cardboard SDK the best option available was to have the user tilt the phone 90° in order to activate app's menus.

The Red Reflex Level. This requires the user to orient the virtual ophthalmoscope's light to make the retina visible. In order to successfully complete this level the user has to position the virtual light until the red reflex appears in the avatar's eyes. By using the HMD trigger they can also zoom in and out of each eye in order to get a more detailed view of the retina.

The Retinal Navigation Level. The user receives audio visual information explaining how to navigate four quadrants of the retina by following its main blood vessels. Users are assisted by audio cues informing them when they have reached specific way-points. The user is required to correctly identify the optic disc by using the HMD's button to click on the relevant area. Subsequently they can click on the retina to simulate how the patient would look into the ophthalmoscopes light in order to see the macula in greater detail. Finally the user is given a narrated overview of the steps they have just completed.

The Pathologies Level. Audio visual narrations are given on common pathologies of the eye. These include cotton wool spots (Fig. 2), haemorrhages and papilloedema. The user is given an overview of the abnormality before being shown annotated images describing how they occur. The user then has to identify that pathology in another image without accompanying explanations. At the end of this a narration explains each of the abnormalities again. The user can then test their knowledge in the quiz level.

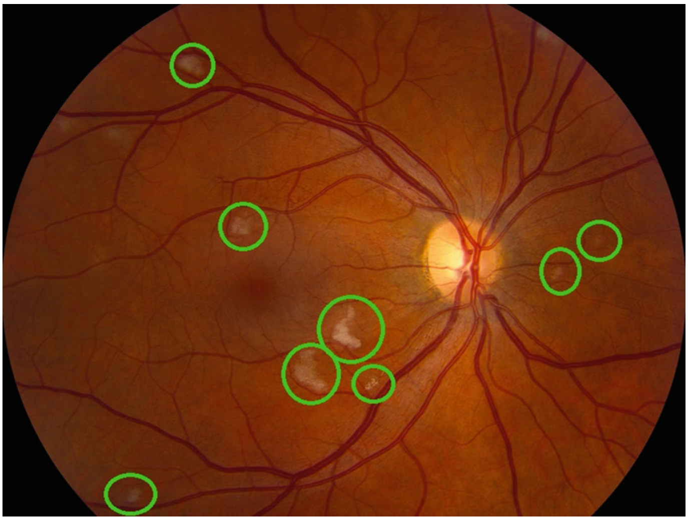

Fig. 2. Retinal image with cotton wool spots highlighted for the user

The Quiz Level. The user is shown eight random images of eyes which could have no abnormalities, cotton wool spots, swollen optic disc or haemorrhage. The user has to examine the eye using the processes they have previously learnt and then identify whether it is normal or exhibits one of the pathologies. If the user incorrectly identifies the image they are provided with feedback which explains the pathology they have just been looking at and what characteristics they should have identified. Figure 3 describes the process followed by the user.

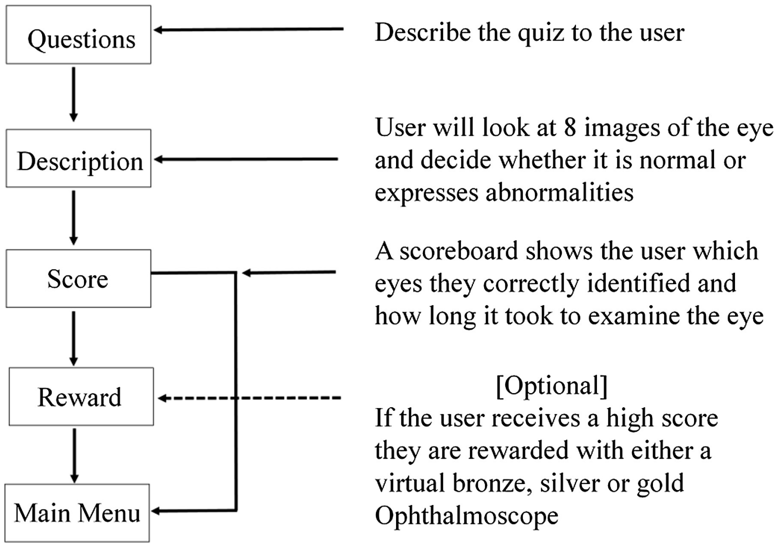

Fig. 3. Flow diagram illustrating the processes involved in the quiz level

Gamification. A scoring system within the app awards points for successfully completing each of the activities within the level. A reward icon is also awarded signifying they have successfully completed the level. At the end of the quiz the user sees a scoreboard within the app showing them the number of correct identifications they have made together with the average time they took to identify them. There is an optional award of another badge signifying their overall level of achievement in this quiz (bronze, silver or gold). Table 1 summarizes the levels, a description of the procedures the user needs to follow and the reward system that was implemented.

Internal Usability Testing. This was conducted with eight members of staff in the Faculty of Computing, Engineering and the Built Environment, Birmingham City University (UK). Each was asked to test prototypes of the app and provide feedback on it. They had no previous experiencing of using VR and did not have a medical background. Items evaluated included rating its ease of use, determining whether the tutorial was explanatory to them, the quality of feedback given in the app, and how long it took them to complete the program. They were also asked to identify any problems with the app's functionality.

Table 1. Scoring and rewards systems for each level

Level	Description	Gamification
Tutorial	Teaches the user how to use the app and interact with virtual objects	No points or rewards for this level
Red reflex	Simulates the process of correctly orienting the ophthalmoscope relative to the eye resulting in the retina becoming clear to the user	25 points awarded for correctly achieving the red reflex in each eye. Total 50 points for completing level. Reward icon for successfully completing the level
Retinal navigation	Background information is provided on the procedures. The user learns to correctly navigate the retina and identify important landmarks such as the optic disc	25 points awarded for identifying the optic disc. 25 points awarded for navigating each of the four quadrants of the eye. Total 125 points for completing level. Reward icon for successfully completing the level
Pathologies	Narrated description and annotated images describing how three types of abnormality occur within the retina. The user has to identify that abnormality in a new image	25 points awarded for correctly identifying cotton wool spots, haemorrhage or papilloedema. Total 75 points for completing level. Reward icon assigned for completing the level
Quiz level	The user is presented with a random image of the retina. User has to identify the pathology by selecting from a list of options which include no abnormalities, cotton wool spots, swollen optic disc or haemorrhage	There are 8 questions in total. Each successfully answered question is scored by dividing 50 by the average time taken to complete each question in the quiz (in seconds) Optional quiz rewards: Gold ophthalmoscope 350 + total points scored in the quiz Silver ophthalmoscope 300 + total points scored in the quiz Bronze ophthalmoscope 250 + total points scored in the quiz

External Usability Testing and Evaluation. This was conducted with the assistance of fifteen, fourth year medical students. They were surveyed for their opinions on the app as part of one of their routine clinical teaching sessions at Birmingham City Hospital (UK). All of them voluntarily agreed to help provide feedback on the app as a teaching tool. Questions were based on 1. How well they felt that they learnt how to use the app, 2. Their satisfaction with it, 3. How well they felt the app helped them learn ophthalmology and 4. Their views on the teaching approach used. Users' responses were rated on a five point Likert scale which ranged from completely agree to completely disagree. Table 2 shows the themes and questions.

Table 2. Survey of medical students' views on the app

Theme	Statement
Learning to use the app	Learning to use the app would be easy for me I can learn to use the app quickly and easily I would find it easy to control the app so it will do what I want it to Working with the app is clear and understandable to me I found that the feedback system supported my understanding of how to use it Overall I find it easy to use the app I would find it easy to understand how to use the app in future
Satisfaction with the app	I find using the app enjoyable to use I would use the app in future as the technology is appealing to me I am completely satisfied with the app
Learning ophthalmology	The app improves my understanding of ophthalmology processes The app improves my ability to identify the main landmarks in the eye The app improves my ability to recognize abnormalities within the eye The app will give me the confidence to better able to perform this task on a person in future The app makes me curious to learn more about ophthalmology and the eye
Teaching approach	I found the teaching approach used within the app informative I found that the feedback system within the app supported my learning about ophthalmology I would use the app in future as the teaching approach is appealing to me I believe that app will increase students' confidence when performing these tasks on a patient in future I would like to be taught other medical skills in this way in future

3 Results

3.1 Internal Usability Testing

Of the eight users (Birmingham City University) who agree to help evaluate the app 7 of them felt that it was easy to use giving it an average rating of 4.4/5. All felt the tutorial level was clear and helped them understand how to use the app. All testers successfully worked through all of the levels with a mean time to completion of 7.43 ± 3.1 min.

3.2 External Evaluation and Feedback

The app was rated positively (combining agree and totally agree responses) by all of the medical students (n:15). Figure 4 shows the responses to their views on how well they managed to learn how to use the app and their satisfaction with it. The respondents to the survey agreed that learning to use the app would be easy for them (n:14), they could learn to use it quickly and easily (n:15) and control how to use it (n:13). They felt that working with the app was clear and understandable (n:15), with the built in feedback system supporting their understanding of how to use it (n:11). Overall they found the app easy to use it (n:15) and they would know how to use it again it future (n:15).

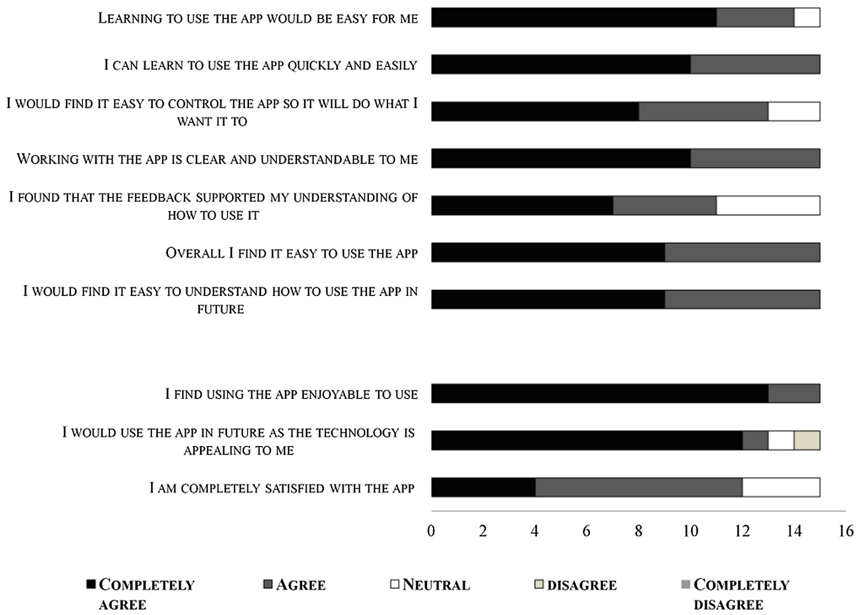

Fig. 4. Rating the app for learning how to use it and user satisfaction

All users found the app enjoyable to use (n:15) and they would like to use it in future as the technology is appealing to them (n:13). The majority (n:12) were completely satisfied with the app. Figure 5 shows the medical students' views on how well they thought the app helped them learn ophthalmology and their views on the teaching approach used within the app.

The users felt that the app improved their understanding of the processes involved in ophthalmology (n:14), their ability to identify the main landmarks in the eye (n:14) and recognize abnormalities (n:15). They felt that the app would give them confidence when performing an eye examination on a person in future (n:12). The app made them more curious to learn more about both ophthalmology and the eye (n:13).

With respect to the teaching approach used within the app they found it informative (n:13) with the app's feedback system supported their learning how to perform eye examinations (n:13). They would use the app in future as the teaching approach was appealing to them (n:15). They felt that using the app would increase students' confidence when performing these tasks on a patient in future (n:15) and that the teaching approach would be useful in order to learn other medical skills in this way (n:15).

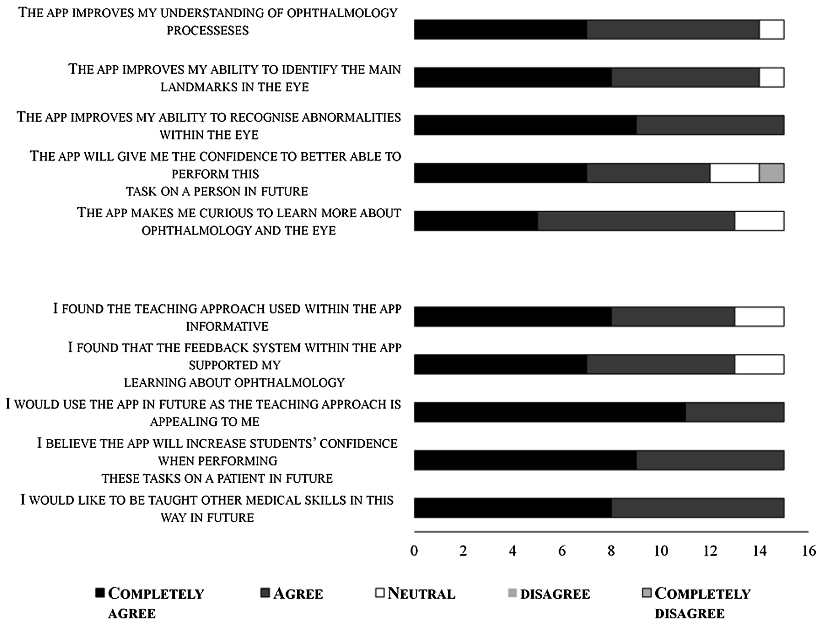

Fig. 5. Rating the app for learning how to perform ophthalmology procedures and teaching approach

4 Discussion

In this study the authors have shown that by collaborating with doctors and medical students VR apps can be developed that offer a way of engaging students in learning about complex clinical topics. The medical students who helped us had little prior experience of VR, therefore we set out to create an app that was fun, easy and intuitive to use. Key to supporting how to self-learn how to use the app was the introduction of a tutorial level which was fun to engage with, so that less technical users felt comfortable in learning how to use it and did not become frustrated by trying to learn too many complex actions too quickly. By carefully staging the following levels more complex clinical processes were taught building on them each time. At any stage the user could repeat the level as many times as they liked before moving onto progressively more difficult tasks

Regular usability tests were conducted both with naïve users who were not medically trained and had no prior experience of using VR as well as with medical students themselves. The results showed that all users could successfully learn how to use the app with minimal formal training. The evaluations also proved to be useful as they quickly highlighted that the external button mounted on the HMD (Google cardboard 1 and Ritech II) could be problematical with users not always using sufficient force to activate it. This prompted the introduction of audio cues which encouraged the user to apply more force to activate the button. Audio feedback was also incorporated as it was identified that 2D text in a 3D environment could be difficult for all users to read. The audio cues and narratives also minimized disruption to the flow of activities when conducting investigations of the eye, helping and guiding the user whilst they concentrated on performing the required tasks. The initial usability tests also highlighted that the time needed to complete the activities within the app was also important as the battery life of the mobile phone is limited restricting what can be done for example the total number of levels available.

Although this app was successful in the trials reported in this study the knowledge base associated with ophthalmology is very dependent on understanding other clinical elements too. Therefore the app is not meant to fully replicate the process of using an ophthalmoscope rather it is used to help demonstrate how to perform the step wise systematic processes used when examining the back of the eye and how to correctly identify any important pathology. Gamification (scores and rewards) was incorporated into the clinical skills training element of the program in order to make the learning experience fun, adding competitive challenges to encourage students to work towards correctly performing the required processes and to try and motivate them to continue to engage with the app. Gamification in combination with the audio narratives were also used to provide feedback so that the user was aware that they had correctly followed the required steps.

Evaluation was based upon the Technology Acceptance Model [11] rather than a controlled trial format which is standard practice in clinical research. It was felt that in these early studies that this would be more efficient, would require fewer medical students and would still give important feedback on both the students' perceptions of the app and most importantly whether they felt it improved their confidence in being able to perform eye examinations. Using a previously validated assessment tool meant that there was confidence that the app was Fit-For-Purpose resulting in it being introduced as a teaching tool into the hospital relatively quickly. This evaluation procedure proved to be both helpful and informative in the development of the app. More in-depth studies we wish to make in future include comparing students' use of an ophthalmoscope after standard teaching and standard teaching plus use of the app as well as identifying whether that app had any impact on any summative assessments where students have been required to demonstrate their understanding of how to use an ophthalmoscope to identify clinical pathologies.

5 Conclusion

In this paper the authors describe the successful development of a novel VR based ophthalmology training app that has been developed to assist students in their understanding of ophthalmoscopy and eye pathologies. The creation of the app was intended to give students more confidence when subsequently practicing these skills on real patients which is a key outcome of their clinical training. The evaluation with the medical students showed that they found the app easy to use, they were confident that they would be able to understand how to use it again in future; the teaching approach used in the app was informative and supported their learning about the procedures used in ophthalmology. The authors found that overall satisfaction with the app was very high and that the students felt more confident in being able to conduct this procedure on patients in future.

6 Ethics

The Faculty of Computing, Engineering and the Built Environment at Birmingham City University (UK) ethics committee were informed about the study. This type of student survey is standard practice in Birmingham City Hospital (UK) when medical students' views on new approaches to learning and teaching are being sought. It would not be expected to be placed before its ethics committee however the medical school were aware of the project.

Acknowledgements. We would like to thank Sandwell and West Birmingham Hospitals Trust (Birmingham, UK) for supplying the images of the eyes and the information about the pathologies.

Conflict of Interest. The authors declare that they have no conflict of interest.

Virtual Reality App. A demonstration version of the VR app can be requested from the corresponding author.

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Players' Performance in Cross Generational Game Playing

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Abstract. This study investigates how the player performance can be analyzed when playing exergames. This analysis aims to enable people with different physical capabilities to play against each other and have fair opportunities to win, contrary to the current implementations of exergames where the winner usually is the player who has better performance (e.g. faster response speed). By implementing this technique into exergames, an older adult will be able to play against a younger one and win.

Keywords: Cross generation · Games for elderly · Exergames · Player performance

1 Introduction

As the population ages in many countries, it is expected that the number of senior citizens will increase dramatically [1]. It has been well documented how an older adult suffers from age related impairments which can make it difficult for them to be involved in social activities. Not having the appropriate level of action capability can limit the extent of social opportunities that older adults can share with the others. This in turn may further compounds the loneliness they may feel. Recent research however, has suggested that computer games may offer a new way of engaging older adults in both social and physical activities and may in turn positively impact on the emotional well-being of senior citizens [2].

Computer games are a way of socializing across family generations, with grandparents for example using game playing activity to engage in a common activity and share the experience with their grandchildren [3]. Computer games can enhance communication, interaction, and relationships between children and parents, and also between patients and doctors [4]. Older adults play games as an entertaining activity to compete with their children or grandchildren [5], as they are interested in having the opportunity to spend more time with their grandchildren [6]. Kinect and Wii mote games are a very good way of facilitating social interaction between family members. However using body movements as a means of control can add an additional layer of complexity on the way these games are played. This is because players will move more muscles and perform higher rate of physical activity. In such games, it is usually the players who can move better and faster who wins the game, which instantly creates a

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barrier to engagement and competitiveness for people with lesser physical capabilities. Fitness games are not always fun, because they sometimes create an unbalanced challenge when a player falls far behind another skilled player and is not able to compete any more [7]. Individuals will increasingly engage in physical activities if they are reliant not only on their self-efficacy, but are also supported by collective efficacy [8]. If movement based games are embraced as a normal social activity, then using these games will become part of an individual's daily life. However, the community will not embrace these activities if a significant portion of its population is neglected; therefore, including older adults to be an active part of this activity is important to transform movement-based games to be a normal activity in social communities. Giving the older adults full control will increase their immersion in the game; such activities will help older adults to feel better about their physical capabilities because they recognize that they can achieve something. As a result, this will encourage older adults to play and move more often. Playing against a younger adult will make the rehabilitation process not only more enjoyable, but also a social activity where older adults can play with their grandchildren, friends or even with clinicians in the clinic as players are more engaged when they are familiar with their opponent [9].

In this study we were interested in how to design cross generation movement based games for older adults to encourage them to move and exercise so they can stay healthy. For an older adult to be able to use such games they need to be engaged with the game by making the game as much fun for them as possible but also by providing them with meaningful play [10].

2 Related Studies

Studies show that video games can engage parents and children together in game play. Engaging both old and young people in computer games can benefit both parties [11]. There are some studies that dealt specifically with intergeneration game playing with family members. The study in [5] reported on the design process and the design rationale of a movement based mini-game. The game was designed so that it could be played by senior and younger players together. In this study no difference in the performance of old and young players were found. The study argues that designing for enactive interaction results in ease of use. Enactive interaction is a term coined by Bruner (1964) and is based on the stored knowledge by the motor system of the user in the form of motor responses [12, 13]. This will help seniors who lack experience with computers to play games because they do not need to learn how to memorize complex mappings between the in-game actions and the buttons, instead they can use their experience from life to perform actions and gestures. An example of an enactive interface is swinging the arm to play a table tennis video game. The results of their study indicate that enactive interfaces can be used to help senior players to respond and perform gestures in the game. Similarly, study in [14] shows that designers should consider using familiar mental models that older people developed from past experience so that the tools and the information presented relates to past knowledge. Another study in [15] developed a mobile phone application in order to facilitate social support for exercise. The application allowed the users to share their daily steps count with friends and family members, the study was conducted with a group of five women who wanted to increase their physical activity levels. The results indicate that the group who shared their activities with friends were more likely to reach their goals. Based on this, there is evidence that sharing physical activities with others increases engagement and the attainment of the desired goals. To encourage gameplay within family generations, the study in [16] developed an intergenerational family entertainment system called Age Invader that focuses on physical and social interaction. They created a physical game space arena using a mixed reality floor system. Their objective was to facilitate interaction between family members that have different skill levels in using technology. In their findings older adults could precisely understand the game and had better game experience due to the physical nature of the gaming system. In addition, older adults who usually express concern about computers enjoyed playing in an interactive system. The effort level of all players in the game was set according to their physical capabilities; this ensured that all players were challenged appropriately resulting in the game being enjoyed by two different family generations who would not normally play together. The study in [17] presented a prototype game called Curball to be played between an older person and a child. The aim of this study was to design an enjoyable collaborative game for two different generations. However, it focused on game design elements such as how to roll the ball, how to design the levels, and how to make the game easy to learn. It also explored how to make the game playable by using handicaps to control the difficulty of moving the ball. Also in [18] an intergenerational case study was conducted to explore intergenerational game design where children and the elderly play together. The study reported on the design implications for intergenerational games. Findings indicated that the rules of the game are deeply related to the social interaction and that the game rules should encourage cooperation.

The golf handicap system ensures that players of all abilities compete on a level playing field; handicaps in golf allow a golfer's score to be calculated based on the golfer's best previous performance. The player has to post at least 20 scores to get an accurate handicap index. Every two weeks the local golf association updates the handicaps and issues a new handicap index for each player. This index is based on the player's performance on the golf courses; with golf courses having a set of tables based on the slope rating from each of the tees. To calculate a Handicap in Golf the course rating is first of all subtracted from the gross score. The result is multiplied by 113 and divided by the slope rating. Then the lowest 10 of the last 20 differentials are averaged and multiplied by 0.96. The result is the handicap index [19].

3 Design Concept

Research showed that social interaction is one of the main motivations for players to play computer games and that who play for social interaction are competitive players [20–22]. Exergames can provide family members with a social activity that requires active participation. For older players to be part of this activity they must be competitive players. Older adults have a strong desire to play with their grandchildren, and reciprocally grandchildren enjoy playing with their grandparents [18]. To improve the social interaction the game rules must be designed so that they encourage maximum participation among players. A game that is designed for cross generation play should have balancing teams by requiring different skill sets to bridge the divide between teams [5]. Designing an exergame, which takes into account the different physical capabilities players, can enhance their presence to allow them to play against each other. This means that the system is, by definition, inclusive. However, it should also be noted that this system not only allows players with different physical capabilities to play the game, but also allows them to play against each other using fairer game based rules. Some systems, which are designed for diverse users, will respond differently based on each user's need. If two users with different physical capabilities used such a system at the same time, the system will respond to them differently, which would create an unbalanced environment and may lead to two different experiences. To make a movement-based gaming system inclusive and playable by both younger and older adults at the same time the game should respond the same way to both players and give each player a fair representation of his/her performance. This can be realised by measuring the skills of each player separately without comparing them to each other. In this case the game should compare the same player's current performance to his/her best and average performance within the same gaming session. For example, a game may require two players to perform a "run in place" action; the player who runs faster achieves more points. This will mean that the player with superior physical capabilities will always win. In order to maintain the controlling and challenge factors for both players, we should measure the performance of each one separately; so that the player who keeps running at a rate close to his/her best performance will be the winner.

The suggested system should allow people with different physical abilities to play, compete, and have a fair chance of winning. Each player's performance is measured according to his/her best performance. The system compares the current actions to the previous ones and decides how close this action is as a percentage to the best action (100%). The player who performs more actions that are close to his/her best will be more likely to win the game.

4 System Description

The game that was designed to test this model is a table tennis game. This game was chosen because it does not involve complex movements that cannot be easily performed by older adults, the game rules are clear and easy to understand and it also offers an enactive interface that most players are familiar with. We used the MS Kinect sensor as the input device to detect player movements. We used the Kinect's full body skeleton tracking, as it gives relatively good results for tracking the hands, in XYZ coordinates, which can in turn be used efficiently in a gaming context.

5 Calculating Performance

The table tennis game requires interceptive actions that are similar to the real action used to play table tennis in the real world. However, in the real table tennis game information about where and when to intercept the ball, including extra information about hand adjustments needed to steer the racket to its final position, are also very important [13]. In this virtual game the extra information is not required as there are no rackets held in the hands or the players or tracked by the Kinect, instead hand position is used to control the position of a virtual racket. This reduction in information should make the virtual game easier to play. The only action that is required from the player is to decide when and where to intercept the ball and the speed with which they need to swing their hand. However, extra information can be added to the virtual game such as the trajectory of the hand before and after it intercepts the virtual ball.

It is important to decide how performance will be measured. In this case we tracked the player's hand movements and also recorded the velocity and range of motion in x, y and z axes. Other metrics that can be measured are angular velocity and response time. Each of the three axes are measured separately, which gives a better approximation of performance for different game contexts. These calculations are performed per drawing frame with a frame corresponding to 0.008 s, however the Kinect sampling frame rate is 30 Hz at maximum which will update the Kinect data once every 0.033 s.

Velocity in each axis is the change in distance in meters that the hand moves between successive frames, while the range of motion is the value in each axis relative to maximum and minimum values that the hand could reach. To find the current performance we used the following equation:

$$\mathrm{P} = \mathrm{W}_1.\mathrm{P}_{\mathrm{velocity}} + \mathrm{W}_2.\mathrm{P}_{\mathrm{range}} \tag{1}$$

where:

- P: current performance
- $\mathrm{P}_{\mathrm{velocity}}$: Velocity Performance
- $\mathrm{P}_{\mathrm{range}}$: Range Performance
- W_1 and W_2: weight values that are taken from a predefined table, where $\mathrm{W}_1 + \mathrm{W}_2 = 1$. Their purpose is to weight which is more important Velocity or Range in different game contexts.

To calculate velocity and range performance the following Pythagorean equations were used:

$$\mathrm{P}_{\mathrm{velocity}} = \sqrt{Vx^2 + Vy^2 + Vz^2}. \tag{2}$$

$$\mathrm{P}_{\mathrm{range}} = \sqrt{Rx^2 + Ry^2 + Rz^2} \tag{3}$$

6 Best Hit Algorithm

After calculating the P value in each frame, a simple algorithm we called Best Hit is used to keep track of the current performance relative to the best action, with Fig. 2 illustrating the steps in this algorithm, When the player hits the ball with a velocity greater than the maximum, the ball will be reflected with the highest power. The first hit will be always set as the initial value as best performance with any other successive hits with greater values being set as a new best performance value and will launch the maximum power.

7 System Implementation

Figure 1 shows a screenshot of the game, the screen is split into two parts, so each player can see his/her own perspective of the table. Players control the racket by either their left or right hands. The range of motion is calculated based on how far the player can stretch his hand to the left or the right without changing his location. This value is relatively mapped on to how far the racket can travel in the virtual environment.

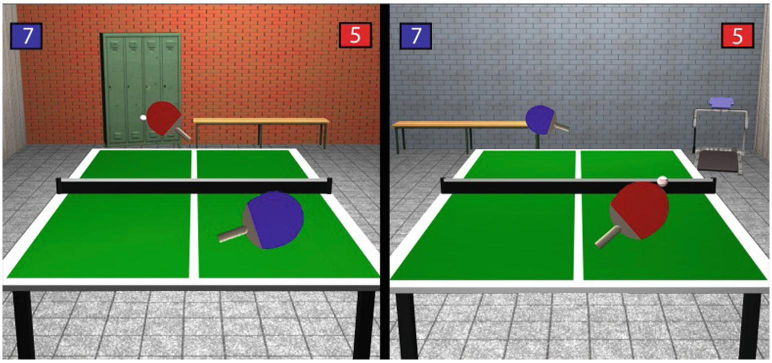

Fig. 1. A screen shot of the table tennis game

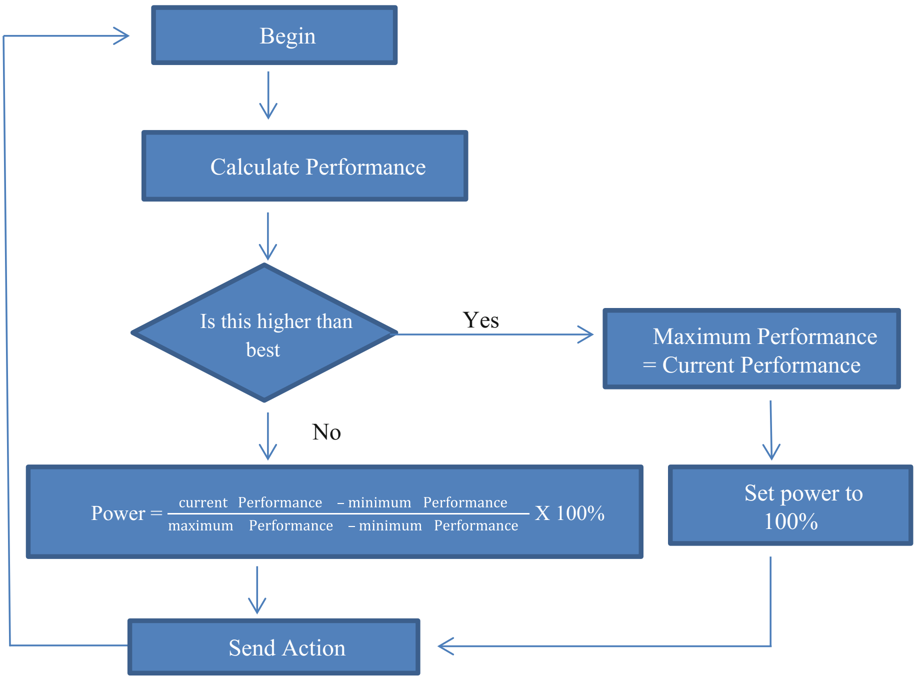

Fig. 2. The Best Hit Algorithm

Whenever the player stretches his hand further, a new maximum value is created, and the rackets inside the virtual environment will reach their limits.

The values of W1 and W2 are taken from a pre-defined value, which is chosen based on the game context. The values have been set to give certain actions more effects in a specific context. Table 1 shows these pre-set values and the associated game context.

Table 1. Pre-defined values for constants W_1 and W_2 and their gaming context

Context	W1 value	W2 value
Initial ball hit	0.9	0.1
Ball slowing down in the middle	0.75	0.25
Ball flying outside table tennis surface	0.25	0.75
Ball flying fast in the mid area	0.5	0.5
Ball reaches above 90% its Y limit	0.4	0.6
Ball is deflected on the opposite side of the racket	0.75	0.25

8 System Evaluation

To evaluate the system a game playing session was arranged, two groups of participants were recruited, a young participant group, and an older participant group. Two versions of the game are used; version A, with the best-hit algorithm applied, and version B where no algorithm is used. In each round a member of the young group played against a member of the older group, scores and numbers of successful hits were recorded. All of the participants played both versions A and B.

8.1 Participants

A group of 5 participants took part in the study and were divided into two groups, an older adult group (1 Male and 2 Females; M = 84.7 years, SD = 2.31 years), and a younger adult group (2 Males, M = 30 years, SD = 2.83 years). The older participants were recruited from local sheltered accommodation. All of the participants had previous experience playing movement based games. A Timed up and Go test was performed by each participants to evaluate his/her physical capabilities. The test records the time each participant needed to stand up correctly from a sitting position on a chair with arms then walk a distance of three meters, turn and come back and sit correctly in the chair. The mean time taken for the older participants was 13.4 s (SD = 1.52 s). While the mean time taken for the younger group was 8.7 s (SD = 0.14 s). According to the interpretation of the test a normal person will need less than 10 s to perform this test [23]. Table 2 summarizes the all participants' information in the two groups:

An adequate play space that gives each player enough area to move freely was allocated. The game was projected on a big white screen in front of the players (see Fig. 3 which shows the playing area).

Table 2. A summary of the scores of the TUG test for all participants.

Participant code	Age	Gender	Physical capability (timed up and go test)
Group 1 older participants			
P1	82	Female	11.7 s
P2	86	Female	14.7 s
P3	86	Male	13.7 s
Group 2 younger participants			
P4	28	Male	8.8 s
P5	32	Male	8.7 s

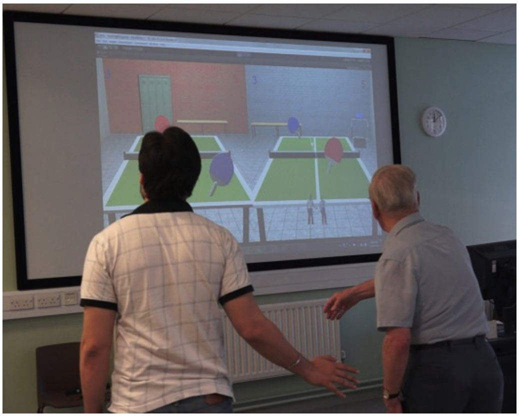

Fig. 3. An example of an older adult playing against a younger adult in the gameplay area.

8.2 Gaming Sessions

In total, the game was played ten times, five matches played with the best-hit algorithm implemented, and five without using it. When the algorithm was not being used, the performance measure is based on which player is moving faster. Enabling and disabling the best-hit algorithm was hidden from the players; the algorithm was turned on in one session then turned off in the next. In each match a randomly selected participant from the older group played against a randomly selected player from the younger group. The players were only informed about the use of the algorithm when all playing sessions were completed. Final scores showed that older adults won three sessions out of five when the algorithm is applied, while they lost all five session when it was not as indicated in Table 3.

Table 3. Gaming sessions final scores

	Older group	Younger group
With best hit	3	2
Without best hit	0	5

Table 4 shows the detailed score in each match and their duration. Duration was calculated based on the number of total racket hits by both players. In the rounds where the best hit algorithm was applied, the older adult scored a total of 52 points in five matches with an average of 10.4 points per match, compared to the second round when they scored a total of 28 points with an average of 5.6 points per match. The average match duration in the first round was 78.6 racket hits, while in the second round the average duration was 179 racket hits.

Table 4. A detailed summary of the match results with and without the best-hit algorithm.

	Older group	Younger group	Match duration
With best hit implemented			
	(P1) = 13	(P4) = 7	80
	(P2) = 13	(P4) = 7	59
	(P3) = 5	(P5) = 13	67
	(P1) = 13	(P5) = 8	83
	(P3) = 8	(P4) = 13	104
Total	**52**	**48**	**393**
Average	**10.4**	**9.6**	**78.6**
Without best hit			
	(P2) = 3	(P4) = 13	164
	(P3) = 8	(P5) = 13	261
	(P3) = 4	(P4) = 13	116
	(P2) = 6	(P4) = 13	296
	(P1) = 7	(P5) = 13	58
Total	**28**	**65**	**895**
Average	**5.6**	**13**	**179**

8.3 Performance Profiles

During each match the performance of both players was tracked. Figure 4 shows the younger adult performance and the older adult performance in one of the matches when the algorithm was not applied, while Fig. 5 shows the same performance if the best-hit algorithm is applied. From Fig. 4 we notice that the younger participant outperforms the older participant, while in Fig. 5 we notice that their performance is becoming more balanced. We can also notice that the younger participant has reached or exceeded his maximum performance 7 times, while the older adult could do it only once. We notice also that the younger performance deviates more from its mean than the older participant.

There was 41 times where performance was calculated during this match for each participant. The younger performance means and standard deviation are (M = 6.62, SD = 3.56) where the older participant's performance means and standard deviation are (M = 4.69, SD = 1.95). The assumption of homogeneity of variances was violated, as assessed by Levene's test for equality of variances ($p < .05$). An examination of the

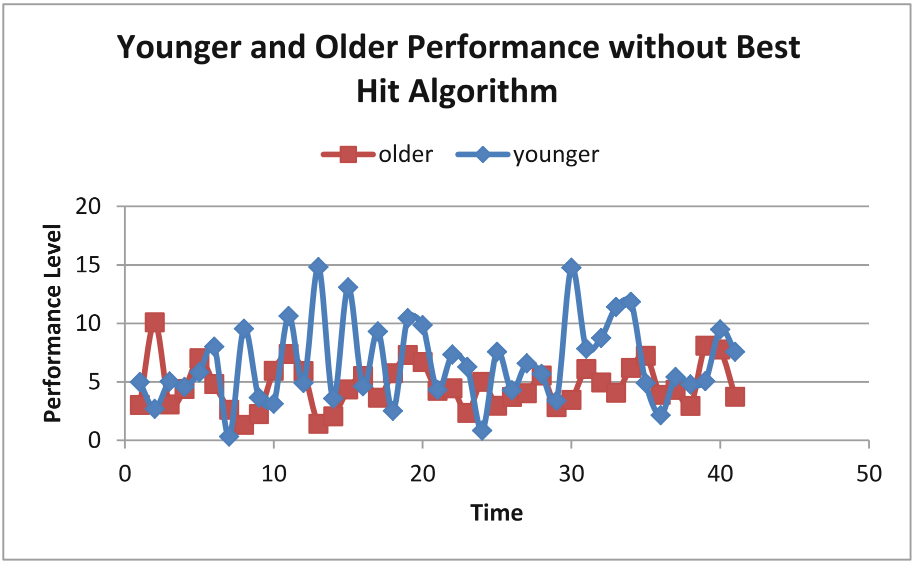

Fig. 4. A graph showing the calculated performance for a younger participant versus an older participant performance over time without using the best-hit algorithm

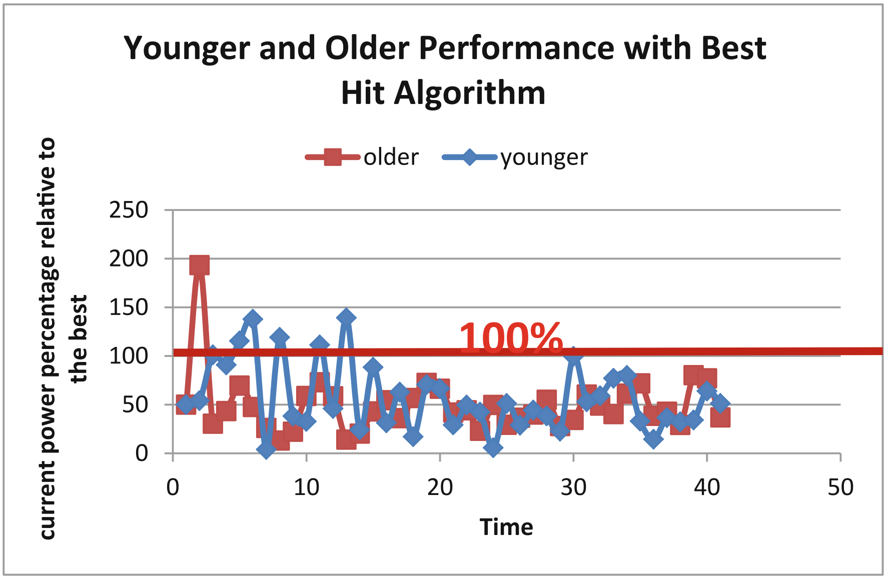

Fig. 5. A graph showing the calculated performance for a younger participant versus an older participant performance over time using the best-hit algorithm

performance values reveals that the results of Mann Whitney U test shows a statistical difference between younger performance and the older performance ($U = 574$, $Z = -2.614$, $p = 0.000 < 0.05$) with younger performance mean rank of 49.00, and older performance rank of 35.17.

Another Mann Whitney U test was conducted to determine if the differences in performance between the younger ($M = 57.25$, $SD = 34.71$) and the older participants ($M = 49.29$, $SD = 28.97$) were significant when the Best Hit Algorithm is applied. Again, the assumption of homogeneity of variances was violated, as assessed by Levene's test for equality of variances ($p = .048 < 0.05$). The test revealed that there was no statistically significant difference in mean performance between older and younger participants when the best-hit algorithm is applied ($Z = -0.886$, $p = 0.376 > 0.05$), with younger performance rank of 43.83 and older performance rank of 39.17.

9 Discussion

In the sessions where the best-hit algorithm was used, older adults won 3 out of 5 matches compared to no matches when a standard performance calculation was used. This primary result shows how older adults can be fairly brought into a more evenly competitive field. This is also supported by the number of points scored by both groups in the two matches. For example, the older adults scored 52 points while the younger adults scored only 48 points, suggesting the game was balanced and the competition was high. In the second round, where the best-hit algorithm was not used, the number of points scored by older adults was 28 points while younger adults scored 65. The competition was not very high and younger adults easily won all the matches.

By analyzing the performance profile of a younger versus an older player before applying the best-hit algorithm we noticed that the performance of a younger adult outperformed that of an older player ($p < 0.05$). When applying the best-hit algorithm we noticed that the performance of the younger players was initially better than the older participant, but as time progressed they became more equal to the older players ($p > 0.05$). Furthermore, the average match duration in the first session was 78.6 hits while in the second one it was 179 hits. A hit is calculated each time a player hits the ball with the racket. We observed a noticeable decline in the number of hits in the rounds when the Best-Hit algorithm is applied. This happened because the players were able to beat their best-hit several times in every match. When this happened the ball is set to the maximum power, which makes it more difficult for the opponent to hit it back. The players beat their best hit because the previous values where calculated only based on the current match. No previous values have been used from other matches for the same player. This scenario made the total time of the match shorter even though the score itself was more competitive. To avoid this scenario the algorithm should be able to track user performance across matches. Another point that needs to be considered is when the average performance becomes very close to the maximum value during game play. In this condition the player can make an average hit that is set very close to the power maximum. To resolve this issue another variable should then be used to track the minimum value, and the average value.

10 Conclusions

In this paper we showed that by applying a Best-Hit algorithm in exergames older adults are more able to compete with the younger players. This appears to increase their levels of engagement and creates a better experience for them. This technique can allow older adults to play more competitively and should allow them to play against their children and grandchildren and still be able to compete. The results from cross-generational gameplay showed that older adults could compete with the younger adults in the movement-based game. Rehabilitation can be converted to a family social activity where older and younger players can play together enjoyable movement-based games. Each member can compete and win regardless of their actual physical ability. Allowing older adults to play with their family members will encourage them to move and exercise more often. This process may open new doors for rehabilitation and re-shape the process by making it a more social activity.

The Best-Hit algorithm still needs more evaluation, it will be beneficial to test the gameplay over a long period of gameplay to see whether the difference of performance between younger player and older will decrease if the older player gains more experience and be more confident with the game.

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The Med Life - A Medical MMORPG

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Abstract. According to a study published May 2016 in British Medical Journal, medical errors are the third largest killer in the US. It estimates that more than 250,000 Americans die each year due to medical errors. WHO's European data shows that adverse events related to medical errors and healthcare occur in 8% to 12% of hospitalizations. "The Med Life" or "TML" is an original game idea being developed as world's First Medical MMORPG with the objective of providing a rock solid platform and revolutionary content environment to help in the reduction of medical errors. According to a study published May 2016 in British Medical Journal, medical errors are the third largest killer in the US. It estimates that more than 250,000 Americans die each year due to medical errors. WHO's European data shows that adverse events related to medical errors and healthcare occur in 8% to 12% of hospitalizations. "The Med Life" or "TML" is an original game idea being developed as world's First Medical MMORPG with the objective of providing a rock solid platform and revolutionary content environment to help in the reduction of medical errors.

Keywords: World's first medical MMORPG · Medical simulation games · Health management games

1 Background

1.1 Problems

Medical error is the third leading cause of death in the US. People criticize gamification for taking a less than serious approach to medical education. Game play has suffered under misconceptions of being easy, irrelevant to learning, and applicable only to very young children. Medical application and games are scattered on many different websites and databases; hence it is very difficult to track and access for the user learner.

1.2 Aims and Purpose

The Med Life has been conceptualized as an extensive platform for medical training to enhance the learning of skills, values and attitudes related to accessible and attainable health management practices. It has been developed with the transcendent objective of working as a contributing factor in the reduction of medical errors by virtue of its utility in upgrading the medical skills of learner-players. It aims to fortify medical education,

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by delivery of practically enthralling game plays designed with the view to offer prime opportunities towards self-directed learning, in an optimally engaging and thrilling virtual environment.

Critical Hypothesis: Medical Errors can be reduced by practicing the skills in a virtual learning environment by using video game designed on medical problems and procedures. Being the brainchild of a philanthropic mindset, it has been designated with rigorously achieved potentiality to deal with the blow of two major global issues that have shaken the healthcare industry—shortage of doctors and medical error, by paving way in the production of highly competent doctors, skillful enough to diminish the fault line of medical errors.

2 Methodology

2.1 Psychological Theory Base

The game is based on the self-determination theory [SDT] [1] and is strongly focused on intrinsic motivation with a serious attempt to combat the aforementioned range of problems that spring up with the cultivation of such an extensively planned medical game concept (Fig. 1).

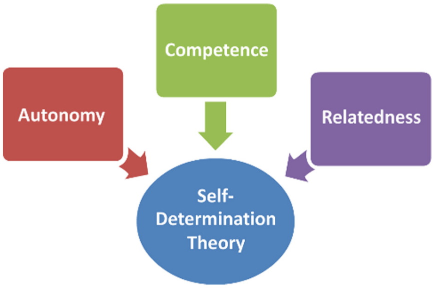


Fig. 1. Self determination theory

2.2 Virtual Environment

The Med Life provides a medical environment to pack in all the content in one single place, so that it can become the powerhouse of information for the players, both practical and theoretical. It establishes a unified platform on a global level for medical students and young doctors to join in, get in touch with each other, play together and discuss profession and important things. It put forth different medical problems and procedures. Players are briefed about the problem and acquainted with the tools in hand. For a skillfully performed procedure, the player is rewarded while he has to repeat the game until he gains expertise (Figs. 2, 3 and 4).

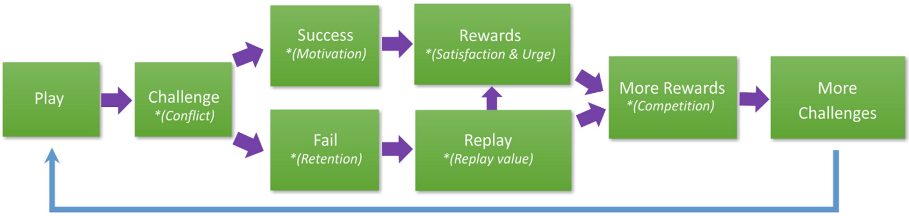


Fig. 2. The Med Life reward system

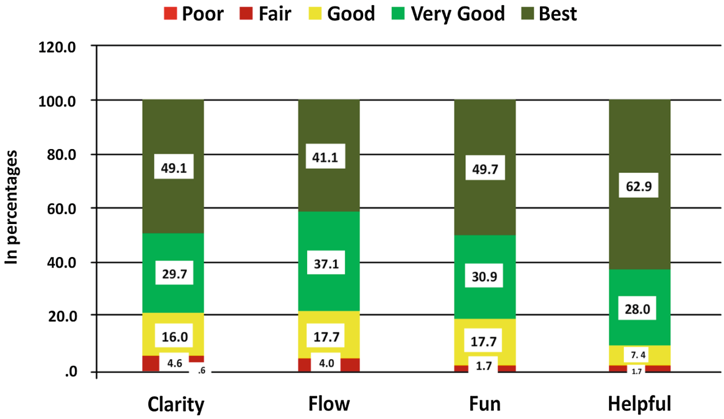


Fig. 3. Item wise game evaluation

Overall Score in %	No.	%
Exact 100	54	30.9
80-90	71	40.6
60-79	45	25.7
below 60	5	2.9
Total	175	100.0

Fig. 4. Overall game evaluation on the basis of total score

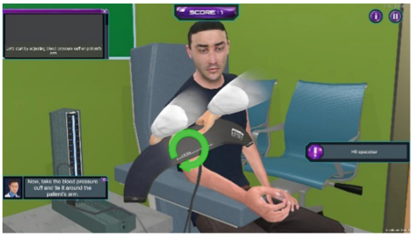
3 Observation

3.1 Results

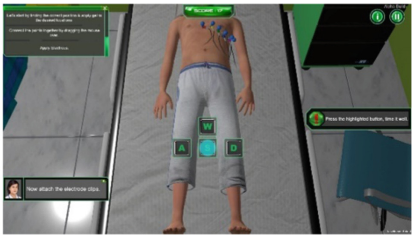
Various parameters that were assessed in the students' feedback were analyzed and it was found that 49% felt the games had clarity, 41% felt that flow was good, 49.7% found them to be fun, whereas majority of students i.e. 62.9% agreed that games were tremendously helpful in enriching their learning experience. The overall gaming experience was evaluated and majority of players (72%) found it to be a satisfying one, giving it a scoring of >80% on a scale of one to hundred.

4 Conclusion

"The Med Life" is an original game idea and is world's First Medical MMORPG. Unlike other serious games, "The Med Life" brings a highly interactive, immersive and engaging way of learning while playing. As such, it is diversity to its peak. The content inside "The Med Life" game universe is designed carefully and is based on the principals of OSPE (organized structural practical examination). The game brings players from different parts of the world in one single place and presents the organized structure of the medical studies for its users to benefit from.



1. Player via ***mouse controls*** *is interacting with patient to evaluate his blood pressure!*



2. Player via ***keyboard inputs*** *is performing the ECG procedure on the patient*

Reference

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Recommendations to Leverage Game-Based Learning to Attract Young Talent to Manufacturing Education

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Abstract. This paper addresses the problem of under-representation of young people in Science, Technology, Engineering and Math (STEM) education in general, and manufacturing education in particular, as European and global phenomenon. The main objective is to analyse characteristics and different limitations of so called conventional initiatives to attract young talents to STEM and manufacturing and to furthermore propose how ICT and game-based learning approaches can address respective challenges. The paper presents an online serious game EcoFactory aimed at raising the awareness of sustainable manufacturing targeting young children in late primary and middle school. It furthermore provides lessons learnt from the evaluation of the EcoFactory and proposes recommendations for designing game-based initiatives in order to attract young talent to STEM and manufacturing education. They are aligned to the requirements of four target groups, i.e. game designers, STEM initiative designers, decision makers and teachers. In summary, game design should be based on pedagogical scenarios and co-creation processes; should focus on particular STEM subjects without causing major changes to school curricula and content; and should create and/or involve wider community with feedback and experience sharing mechanisms.

Keywords: Game-based learning · STEM · Manufacturing education · Awareness raising

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1 Introduction

Europe has been one of front runners in the race to manufacturing excellence. The manufacturing sector currently accounts for 15.0% of its gross domestic product (GDP) and provides about 33 million jobs [1]. Furthermore, disruptive technological breakthrough is changing the face of manufacturing industry on a global scale, evolving from a more labour-intensive set of mechanical processes (traditional manufacturing) to a sophisticated set of information-technology-based processes (advanced manufacturing) [2]. The respective changes in manufacturing together with a shift to greener technologies pose significant challenges with respect to the need for specific engineering skills or of specific occupations in manufacturing [3]. Some of the major priorities are: the adaptation of the educational content and its delivery mechanisms to the new requirements of knowledge-based manufacturing; the provision of integrated engineering competencies (including a variety of soft skills); the promotion of the innovation and entrepreneurship spirits, as well as an interdisciplinary thinking and reflecting the increasing integration of different areas of knowledge in manufacturing [4, 5]. While investments in new technologies offer the opportunity to re-shore manufacturing in Europe, a lack of respective skills can create a bottleneck in this process.

Nevertheless, European manufacturing enterprises are reporting difficulties in finding proper skilled employees and many describe the mismatch of skills as a crisis that show no indication of improving in the near future, requiring action to avoid disastrous effects in the long term [5–7].

1.1 STEM Leaking Pipeline

Science, Technology, Engineering and Math (STEM) education is recognized as of critical importance for the European Union [8]. The demand for STEM talent in jobs continues to rise, especially as the STEM qualified population is now rapidly ageing [9, 10]. The shortage of STEM graduates and the decline of interest leads to problem of "skills gaps", which is also evident in the manufacturing sector. The STEM leaking pipeline demonstrates that the interest in STEM is declining steadily throughout education, leaking students at various stages of their education [11–14]. Two main factors influencing declines in students' interests towards STEM are (1) lack of context and failure of the traditional STEM classroom pedagogy [15, 16] and (2) shortage of attractive STEM career prospects [17].

1.2 Conventional Initiatives to Attract Awareness in STEM Education

Authors have analysed several initiatives and programmes that have employed promising practices to increase student interest in STEM [18–21]. Table 1 describes the initiatives that demonstrated measurable increases in student interests which served us as the inclusion criteria. However, certain limitations can jeopardize their overall success, in particular those related to limited scalability and dependency on effective facilitation/mentorship (common among all eight initiatives).

Table 1. Conventional initiatives to attract awareness in STEM education with success rate and limitations

Initiative	Short description	Success rate	Limitations
BioTech career pathways	High School partnered with a hospital, college and veterinary school to offer two opportunities for students to be exposed to biotech and other STEM careers. A six-week internship for juniors included observing surgeries, using advanced radiography, performing necropsies and tissue harvesting	High school seniors' and juniors' average rating of their level of awareness of, interest in and motivation to pursue STEM related careers was higher after their internship and workshop experiences	Limited scalability High running costs Low accessibility Dependent on effective facilitation/mentorship
DIGITS	Professionals employed in STEM fields (STEM ambassadors) visited sixth grade classrooms together with involving hands-on experiences	Results of pre-post surveys of students showed a measurable improvement in students' positive attitudes toward STEM subjects and jobs. The strength of students' agreement with statements that math, science or technology (each asked separately) was "interesting" or "fun" increased as well as the percentage of students who viewed STEM jobs as fun and exciting	Limited scalability Moderate running costs Low accessibility Dependent on effective facilitation/mentorship
Engineering is elementary	Over 200 elementary teachers were trained in this curriculum, which uses hands-on, inquiry-based experiences to encourage learning in STEM subjects, particularly engineering and technology	A review of raw data indicated there was a positive shift in students' sense of self-efficacy in math and science. Student responses demonstrated more positive views of becoming an engineer on the post survey.	Limited scalability High running costs Low accessibility Dependent on effective facilitation/mentorship

(*continued*)

Table 1. (*continued*)

Initiative	Short description	Success rate	Limitations
		While only 25% of students initially agreed with the statement "When I grow up I want to be an engineer," 35% agreed with this statement after the program	
Got math?	Elementary and middle school students participated in a series of math after-school instructional activities. Students then visited local businesses where they had the opportunity to apply the math skills learned to a real-life situation	Pre-post survey results showed a measurable increase in students' sense of self-efficacy regarding math	Limited scalability High running costs Low accessibility Dependent on effective facilitation/mentorship
STEM summer camps	Middle school students participated in two, five-day long camps: "Sustainability and the Environment" and "Biotechnology and Forensics." The camps were designed to engage students in fun, hands-on, content-based inquiry science that would develop their subject knowledge and awareness of careers in STEM fields	The percentage of students who stated they viewed science as "fun" rose after participation in each camp, from 45% to 66% after the Sustainability camp and 61% to 72% after the Forensics camp	Limited scalability High running costs Low accessibility Dependent on effective facilitation/mentorship
Career fair	Career fair introduced high school students to STEM careers and professionals. 15 to 25 area business/employer representatives participated as exhibitors, provided displays with information about their companies, and talked	Nearly eighty percent (79%) of students who responded to a post-program survey reported the fair helped them realize that the math and science they take in school will affect their future career options. Over one third (35%) indicated they	Limited scalability High running costs Fair accessibility Dependent on effective facilitation/mentorship

(*continued*)

Table 1. (*continued*)

Initiative	Short description	Success rate	Limitations
	with students about potential career opportunities	were thinking more about going into a high-tech career than before the fair. More than two thirds reported the career fair made them realize that a STEM career could be interesting	
Family science programs	Middle school students and their parents participated in hands-on learning activities together. Activities were led by STEM professionals introducing students to STEM careers. Programs were offered in out-of-school environments with activity topics, timing, and frequency varying greatly	Students surveyed after the program reported that their interest in and understanding of STEM subjects and careers increased as a result of their participation	Limited scalability High running costs Fair accessibility Dependent on effective facilitation/mentorship
Saturday STEM academy	Eighth-grade students and their parents participated in STEM-related activities over four Saturdays. Each day involved a field trip to a different location to participate in hands-on activities and meet STEM professionals. The program was to increase underserved	Two-thirds of student respondents to a post-program survey agreed they were now more motivated to "study math and science in high school" and "to prepare myself to go to college." All students agreed with "Math and Science is important for me to be successful in life" and over 80% of agreed that the subjects of math, science and engineering are important and interesting	Limited scalability High running costs Low accessibility Dependent on effective facilitation/mentorship

2 Game-Based Approaches to Attract Awareness in Manufacturing Education

Game-based learning (GBL) approaches are considered to have added value for teaching and raising awareness in STEM subjects as they facilitate collecting, recording and analysing data; enable students to carry out safe and quick experiments not otherwise possible in the classroom due to lack of equipment or risk of danger; the simulation and visualization of 3D structures in science; and modelling in mathematics [13]. They have furthermore the potential to support students' engagement by presenting a range of activities that they can associate to their everyday experience and by increasing their proactive personal initiative when approaching science [22]. While it is possible to find efforts in the wider STEM environment [23, 24], only some very contextualized actions have been tested so far specifically addressing manufacturing domain [25]. The authors are contributing to the research field by presenting and evaluating an online serious game EcoFactory aimed at raising the awareness of sustainable manufacturing targeting young children in late primary and middle school.

2.1 EcoFactory

With the ever-increasing evidence of climate change, the concept of sustainable manufacturing is progressively more important in society. The aim of EcoFactory was to raise awareness and interest of middle school children in manufacturing education, namely in sustainable manufacturing. Considering the inherent complexity of the subject matter, the decision was to adopt co-creation methodology, involving teachers, students, game designers, developers and subject matter experts. Consequently, all decisions reported in this section were the result of discussions and formative evaluation studies involving multiple stakeholders, including children of the target age group (between 8–12 years old). As with other serious games, the first step was to determine the storyline underpinning the user experience, which in this case consisted of challenging the child with the clear goal of building a sustainable manufacturing company.

The first design decision was to map explicitly the three dimensions in the gameplay, resulting three distinct areas that are inter-dependent (see Fig. 1):

- **Product Design**. At the start of the game, the child chooses one of three products to manufacture. In the design, the child decides what materials to use in the production, naturally there are trade-offs in terms of cost vs environmental impact.
- **Shop floor Design**. The choices made on the product influence what manufacturing processes are available to the child and they choose the relevant technology. These choices have an economic impact on the company, affect the environment and establish requirements of the workforce in terms of skills required.
- **Human Resources**. The child needs to ensure they have the necessary workforce to start production. The mismatch between the technology and skills of the labour force have an impact on the production. However, the decisions done in HR affect the satisfaction levels of the workforce.

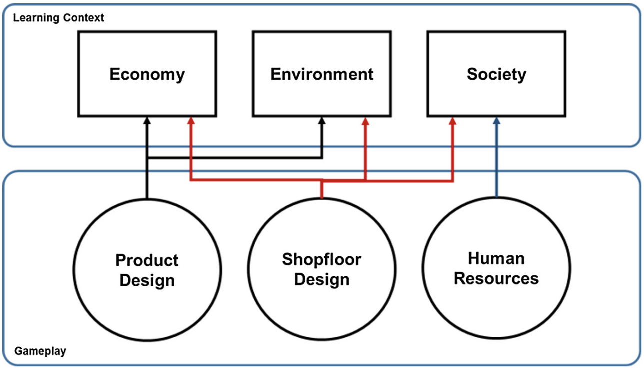

Fig. 1. Three key gameplay areas of EcoFactory.

Although the initial design included gameplay involving sales and marketing, where the child could make decisions on price point, budget for marketing, and determining aesthetics of the product, the result of formative evaluation demonstrated it added undue complexity that would not increase enjoyment and detracted from the main goal of understanding the interplay of the three dimensions. Consequently, it was decided that there would be no simulation model representing the market and all manufactured goods would be sold at a fixed price.

Taking into account that the serious game is to be used mainly in a classroom setting, one needed a simplified game flow (see Fig. 2) that would last no more than 30–40 min of gameplay consisting of three turns. Each turn requires the child to make decisions that will affect the product design, shop floor design and human resources. At the end of the turn, the simulation advances 5 years, thus the designed product is manufactured according to the chosen production technologies. During the 5 years simulation, a probability engine may trigger macro-economic events that deviate the results of the simulation engine (e.g. a strike action, which stops the production for a period of time; war in the middle east, which raises the production costs thereby

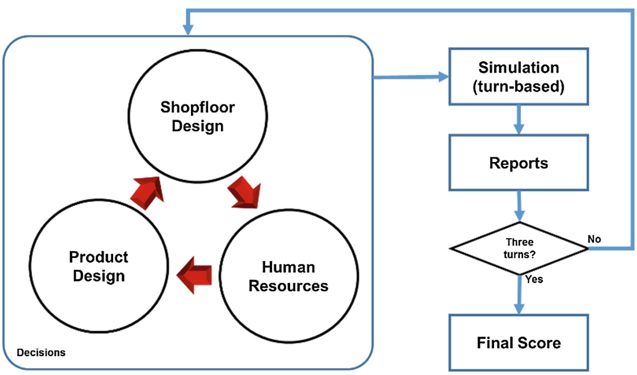

Fig. 2. Simplified game flow.

reducing the profit margin). In-between turns, the game provides insightful reports along the three dimensions of economy, environment and society.

The decision to have turn-based was also due to the need of shortening the cause-effect cycle between decisions and the impact on the environment. The shop floor screen, depicted in Fig. 3, was carefully designed as indicated by the legend.

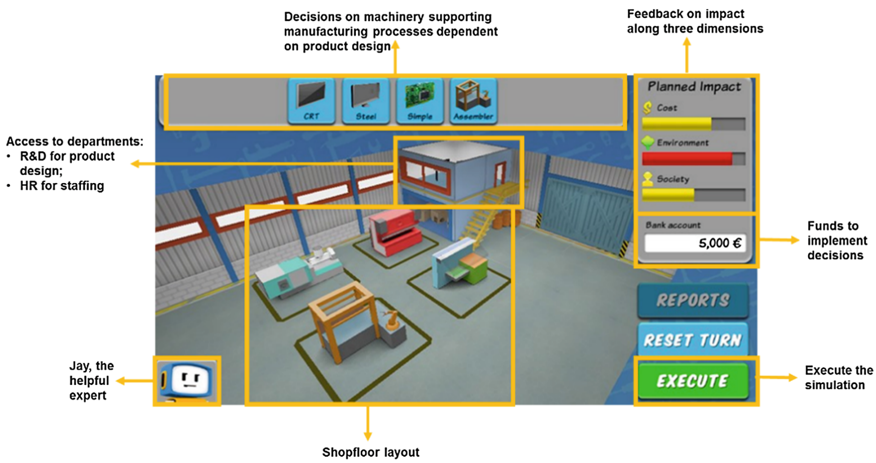

Fig. 3. Shop floor gameplay screen.

It is important to denote that during a turn, the decisions taken are not final until the child clicks on the execute button to implement the chosen decisions. The consequence was that feedback on decisions was unclear and children had difficulty with the causality, thus it was necessary to provide insight into the likely impact of the decisions along the three dimensions (planned impact).

Another key decision point was the design of Jay, the helpful assistant. The first version of EcoFactory did not have an assistance, but due to the discussions with teachers, it was clear that an assistant would be required. The initial design of having a human character was discarded by children in favour of a friendly robot that had the name of jay. From the shop floor, one can go to the R&D department to design the product, or to the HR department (Fig. 4) to hire workforce.

With the human resources, most children struggled with the notion of firing staff, even though it would be necessary for cost reduction as the enterprise was upgraded with new manufacturing processes that required higher skilled staff. As a result, one added the alternative of training existing staff to increase their skill level.

At the end of each turn, the child is provided reports on how the enterprise did in the five years elapsed. As evidenced in the snapshots of Fig. 5, there are three categories of reports:

- **Recent Impact**. The design choice was to provide visual feedback on the cumulative effect on the three dimensions of sustainable manufacturing. In the case of

Fig. 4. Human Resources gameplay screen.

environmental impact, the decision was to have visual metaphors for production waste and production emissions. The inclusion of more environmental factors was deemed confusing by children.

- **Charts**. The inclusion of charts was deemed irrelevant by subject matter experts considering the target age group. However, when discussing with teachers and children, it was agreed that the charts could be included, with some simplification.
- **Highlights**. This documents the events that were triggered and would have an unexpected impact on the production;

Fig. 5. Feedback reports.

Once the three turns are played, the final score (Fig. 6) is provided to the child with regards to how well they did according to the three dimensions of sustainable manufacturing.

2.2 EcoFactory Evaluation

An evaluation [26] of the impact of the use of digital game-based learning was carried out in two classes encompassing a total of 43 students were randomly chosen from a public middle school in Northern Italy. All the students were in 6th grade, between 11 and 12 years old. The participants were free to leave the study at any time. The adopted methodology was based on a blended approach of simplified questionnaires and

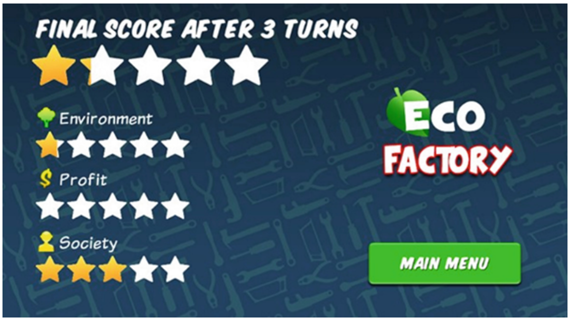

Fig. 6. Final summary score.

concept drawing, where children were asked to make a pictorial representation of their understanding of a manufacturing plant – "Draw a Factory" (DAF) (see Fig. 7).

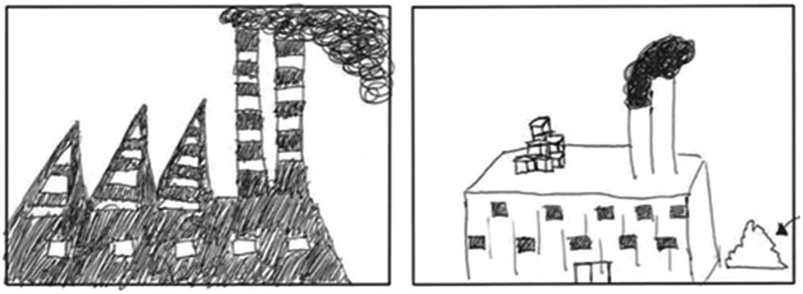

Fig. 7. Example of Pre and Post drawing a factory of an 11 year old girl.

The results of the pre-DAF tests show a participants' awareness of manufacturing that is in general without huge misconceptions but still far from today's reality. Anyway, the view of manufacturing of the students is consistently biased and old-fashioned, especially with respect to environmental and social issues. When thinking about a factory, the participants or didn't include any reference to the impact on the environment or included references only to pollution aspects (e.g. smoke, chimneys). On the other hand, none of the participants was able to mention any reference to any ecological settings (e.g. eco-efficient equipment and eco-friendly products), depicting an image of manufacturing that doesn't reflect the modern developments of the field but that is rather tied to its recent past. With regard to the social aspects, it is clear for students the fundamental presence of human beings in order to operate industrial production. Nevertheless, when mentioned, the conditions of the workers in a factory are considered as dangerous and unhealthy. The idea that manufacturing is closely related to economic activities is evidently represented, even though its relationship with costs and revenues was not provided. Eventually, the description of manufacturing equipment and activities (e.g. design of the product, testing) was usually correctly represented, confirming the view of the factory as an organized and labour-intensive place.

Even though the development of the awareness and interest towards a topic is affected by a complex combination of different factors [27], the effectiveness of GBL initiatives for the attraction of youngsters not only to engineering [28] but also to manufacturing should be considered. Indeed, GBL was able to present, without the interaction of a mentor, advanced manufacturing concepts necessary to increase the awareness of youngsters towards the domain and, on that basis, the interest towards the discipline. The interaction with the DG proofed to be effective in the drawn representation of participants ideas, stimulating their creativity [29] and the correct description of new concepts. The fun element [30] was able to build an increased motivation towards the concepts learned, increasing the proactive feelings of the students for manufacturing. The involvement of the participants was guaranteed through the implementation in the DG of the main principles of GBL, namely a sequence of objectives and tasks to be performed [31] in order to solve a problem and the possibility for them to continuously test their own hypotheses thanks to the provision of scores about their actions.

3 Lessons Learnt and Recommendations

3.1 Lessons Learnt from Evaluation of EcoFactory

The EcoFactory was deployed in middle school classes, which upon reflection, provide four key lessons to consider when developing serious games to support raising awareness of manufacturing education:

- Teachers in primary and secondary schools are driven by the national curricula, thus there is a challenge with regards to acceptance as manufacturing themes are not part of the national curriculum. However, children are capable of engaging and discussing their new-found knowledge, thus increasing their motivation and engagement with STEM.
  - It is recommended that themes on manufacturing should be anticipated in the STEM pipeline.
- To support the teachers, it is recommended to create and refine pedagogical scenarios that provide clear guidelines on how the EcoFactory can be used in a classroom setting.
  - It is recommended that pedagogical scenarios are developed with clear goals concerning the target audience.
- The evaluation studies provide clear evidence that EcoFactory actually contributes to raising awareness and interest in manufacturing education.
  - The use of co-creation methods and tools involving teachers and children contribute to the good design of serious games.
- The governments are making significant investments in public schools, but the digital preparedness varies significantly from one school to another. In addition, the poor digital literacy of the teachers may represent a barrier to the use of serious games in the context of a classroom.

– One should not make assumptions of the ICT infrastructure within classroom, thus it is best to design for having groups of students that share one device running the game.

3.2 Recommendations for Designing Game-Based Learning to Attract Young Talent to Manufacturing Education

Developing recommendations that derive from the lessons learnt evaluating the EcoFactory serious game we have identified four key target groups that should be directly or indirectly involved in designing game-based initiatives to attract young talent to manufacturing education: (1) game designers and developers, (2) STEM Initiative Designers and Executers, (3) decision makers (e.g. head masters), (4) teachers. In addition, as explained in previous chapters, students (children) are directly involved in the co-creation process and therefore form an important part in the overall design process. Each set of recommendations is therefore aligned to the requirements and specific characteristics of respective target groups. The complete set of recommendations is aiming for a scalability, low running costs and maximum impact while avoiding facilitation through experts.

1. Game Designers and Developers:

- Design and development should be based on pedagogical scenarios.
- Initiatives should research and co-create with the students the ICT-based environment that accommodates the social structures of the targeted age group, encourages reflection and supports the involvement of adult facilitators.
- Apply co-creation with teachers, parents, and students to impact their awareness and create interest for several reasons:

– The storyline needs to meet the interests of key target group (students of specific age).
– Presentation must be adequate to support understanding and learning (chose the right language and visualization for that target group).
– The game and the gameplay should be as self-explaining as possible.
– It should be convenient for teachers to give advice or hints for playing the game.

- Apply formative evaluation to ensure (a) game enjoyment and (b) raising interest; both on the level of addressed target group (students of specific age).
- Decouple facilitation and mentorship from creating impact (impact needs to be created by the gameplay).
- Demonstrate the practical relevance of the manufacturing content that is being taught.

2. STEM Initiative Designers and Executers:

- Focus solely on one specific STEM subjects (e.g. manufacturing only).
- Spend more efforts in preparation/development rather than in execution of the initiative.

- The developed deployment model should not have major intentions of changing fixed school curricula or content in order to achieve effective sustainable integration into existing educational practices.
- Design single awareness creation actions that do not need support from external experts to ensure higher scalability and accessibility.
- Initiative should be from teachers' perspective easily accessible, should require little additional preparation and could be straightforward incorporated into the school or out-of-school activities. The everyday teachers' work structures should allow smooth and effective implementation of the initiative.
- Integrate mechanisms for automated feedback.
- Make sure teachers have high quality support materials.
- Provide incentives to schools and/or teachers taking up the initiative.
- Create a wider community and foster exchange among participants.
- Provide updates based on feedback from community.

3. Decision makers (e.g. head masters):

- Ensure schools are properly equipped so that teachers can run awareness creation actions. Increased access to computers does not automatically lead to a higher frequency of use in teaching practices.
- Adapt learning plans giving teachers the freedom to run awareness creation actions.
- Provide incentives to schools and/or teachers.

4. Teachers (awareness creation action executers):

- Assess and evaluate the impact of the awareness creation actions.
- Engage in a STEM community and exchange on experiences.

4 Conclusion

Manufacturing industry plays a pivotal role in the European economy, being responsible for employing more than 33 million people and generating 1.620 billion euros of added value. Nevertheless, European manufacturing enterprises are struggling to find the right quantity and quality of skills to meet the sector's needs and many describe the mismatch of skills as a crisis that show no indication of improving in the near future. There are many root causes for the skills shortages and mismatches affecting manufacturing industry, ranging from aging workforce to inefficient training delivery, but a critical cause is the lack of uptake of manufacturing engineering as a career by young talents.

Game-based learning is valued for its ability to diversify the learning process and make the study of STEM in general and manufacturing in particular more attractive and appealing. Nevertheless, only some very contextualized actions have been tested so far specifically addressing the manufacturing domain. Therefore, this paper contributes to the research field by presenting and evaluating the online serious game EcoFactory aimed at raising the awareness of sustainable manufacturing targeting young children in late primary and middle school. The underlying principle is to consider the production of manufactured products through cost-effective processes (economic dimension) whilst minimising the environmental impact in terms of saved energy and resources (environment dimension). However, there is the third dimension of improving the impact on society by increasing the well-being and satisfaction of the employees of the manufacturing company.

The EcoFactory evaluation studies provide clear evidence that the use of co-creation methods and tools involving teachers and children contribute to the good design of serious games and to raising awareness and interest in manufacturing education, and this is in line with the findings of similar studies, and thus, even though more evidence should still be collected, the preliminary results obtained are encouraging and could address the respective limitations of conventional approaches to engage young talents in STEM in general and manufacturing in particular.

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An Evaluation of Extrapolation and Filtering Techniques in Head Tracking for Virtual Environments to Reduce Cybersickness

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Abstract. Currently, numerous users who employ HMD devices such as the Oculus Rift develop symptoms similar to motion sickness. Recent literature defines this phenomenon as cybersickness, and one of its main causes as latency. This contribution aims to analyze the accuracy of different extrapolation and filtering techniques to accurately predict head movements, reducing the impact of latency. For this purpose, 10 participants played a VR game that required quick and subsequent head rotations, during which a total of 150.000 head positions were captured in the pitch and yaw rotation axes. These rotational movements were then extrapolated and filtered. Linear extrapolation seems to provide best results, with a prediction error of approximately 0.06 arc degrees. Filtering the extrapolated data further reduces the error to 0.04 arc degrees on average. In conclusion, until future VR systems can significantly reduce latency, extrapolating head movements seems to provide a low-cost solution with an acceptable prediction error, although extrapolating the roll axis movements remains to be challenging.

Keywords: VR · Cybersickness · Extrapolation · Head tracking

1 Introduction

Cybersickness is a term used to refer to the cluster of symptoms that users experience during, or after, Virtual Reality (VR) exposure [1]. It is also known as Virtual Simulator Sickness [2], Visually Induced Motion Sickness [3] and Virtual Reality Induced Symptoms and Effects [4]. Cybersickness is not a disease, but rather the physiological response to an unusual stimulus, similar to motion sickness or seasickness [5]. The reported incidence of cybersickness amongst users of VR is varied, but it is generally accepted that, at least, 60% of participants in a first VR experience will suffer its symptoms to some degree, and although most users adapt to the environment after few immersions, approximately 5% will never do so. The degree of intensity depends on the nature of the VR environment, and previous works have shown it ranges between 60% and 90%, with 5–30% of participants having to discontinue research evaluations due to strong symptoms [6, 7].

The effects of cybersickness can be expected as soon as 5 min once the user starts playing [8–11]. These symptoms disappear once the user stops employing the VR

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googles, but users seem to remain sensitized for hours [9]. Its aetiology is at this point unclear, with three different theories coexisting: That cybersickness is caused by a sensorial discrepancy between the vestibular, visual and proprioceptive systems, that it is the physiological reaction to being incapable of maintaining postural stability, or that it consists on a false interpretation of neurotoxin poisoning [12]. Cybersickness is caused by the perception of self-motion, also known as vection. Head-mounted devices such as the Oculus have already been proven to cause vection and sickness [13], but the way through which vection acts is unknown, and symptoms vary greatly from user to user.

Currently, several factors that have an impact in cybersickness have been identified, and works to analyze the possible causes, as well as to provide design guidelines to minimize cybersickness are under way [14]. For example, personal factors such as habituation [15] or age [16], and task-related factors such as movement speed or controllability [17]. However, it is clear that the most relevant factors are the technical ones, namely the size of the field of view [18] and latency [8]. Research shows that latency values of over 40 ms rapidly cause cybersickness, and higher latencies cause it to appear even faster. Currently, it is generally accepted that latency should be kept at 20 ms or lower, but the reality is that in order to completely cast cybersickness aside, latency should be as close to zero as possible.

Therefore, latency reduction techniques are currently of great interest to reduce cybersickness. Interstingly, in 2013, Prof. Steve LaValle published an article in the Oculus Rift Developer Blog about the possibility of further reducing this latency by extrapolating head position values [19]. However, to the best of our knowledge, such an approach has not been evaluated so far.

The goal of this work is thus to evaluate how accurately is it possible to predict head movements with currently available HMDs, and which is the best method to do so.

This study was performed in the framework of the LOEWE-VR Diagnostics System research project of the TU Darmstadt, in collaboration with the Game Studio DECK 13 Interactive[1] and Software Developer KTX[2]. The aim of this project is to study the possible technical, personal and environmental causes of cybersickness, detect it as it occurs in real time with biosignal analysis and game parameters such as head speed and acceleration, and correlate both biosignals and game variables, with the aim of providing developers with a tool that will help them reduce cybersickness in their released product. Particularly, this study is a first implementation on an array of solutions that may, in the future, reduce the incidence of cybersickness in VR by reducing the disconnection between real and virtual movements.

2 Related Work

The impact of head movements and task-related factors in cybersickness has already been subject of several studies, since it is currently fairly clear that mismatches between real and virtual head movements are a strong cause for cybersickness [20]. For

[1] Deck13.de.

[2] Ktxsoftware.com.

example, an evaluation with a HMD and two virtual rollercoasters showed that more complex and realistic environments have a greater incidence of cybersickness [21]. Additionally, environments in which locomotion is performed with head movements cause more cybersickness [22]. Research also shows that oscillatory movements cause more cybersickness than linear movements [11], and abrupt turns are believed to increase cybersickness [23], as well as increasing the number of degrees of freedom or providing wider steering maneuverability [23]. Sudden vection also causes cybersickness [24] as does an increase in navigational rotating speed [25]. On the other hand, involuntary movements do not seem to be problematic [26]. Finally, replacing sudden movements with smoother ones, such as stairs for ramps, seems to reduce cybersickness [27], otherwise, compensating head movements is also a possible solution [20]. Head rotations have also been proven to increase nausea [28], and specifically increasing head movements in the vertical direction [29] or looking at one's feet [26].

Evaluations on how rotations in different axes (pitch, yaw and roll) differently affect cybersickness were performed on [11, 28]. Although rotation in all axes increases cybersickness, it seems that rotations in the roll axis are slightly more problematic. Results also show that rotations on two simultaneous axes also increase the risk of cybersickness [30].

By convention, the head rotation vectors are defined as pictured on Fig. 2.

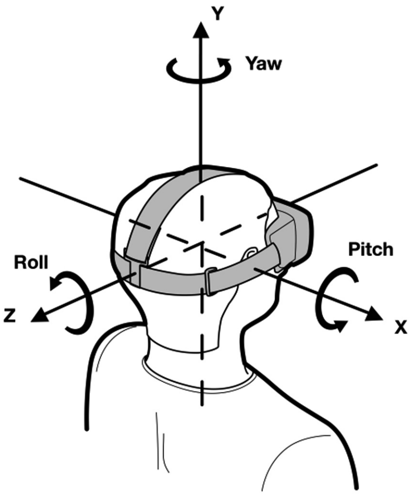

Fig. 1. Head rotation vectors in VR [31].

3 Methods

In order to perform the evaluation, a VR game was developed using the Unreal Engine tool[3] recreating a first person shooter scenario. This scenario was chosen because this genre requires continuous, subsequent rapid head movements in several directions. The

[3] Unrealengine.com.

game also makes use of the Victory plugin[4] to save the head rotation data. In this game, the player is static, and required to move his head on more than one axis simultaneously in rapid successions to destroy projectiles thrown at him (see Fig. 1). The projectiles are created randomly both in trajectory and number to obtain as varied head movement data as possible. The game was developed for the Oculus Rift Developer Kit 2[5], which has a refresh rate of 75 HZ, that is, 13.33 ms. Therefore different scenarios with increasing refreshing rates (13, 15 and 20 ms) were considered. Since prediction error can be expected to be higher as latency increases, if any of these methods is sufficiently accurate at 13 ms it can be expected to be even more reliable on future devices with even lower latencies.

Fig. 2. Screen capture of the game employed in the evaluation.

By using the mentioned Victory plugin, head tracking data measured by the integrated Oculus Rift head tracking system was saved in a.txt file following a csv structure (Time, Pitch, Yaw, Roll), where values are expressed in milliseconds and arc degrees respectively. These files were then imported into Matlab[6] to perform the extrapolation, filtering and analysis of the results.

A total of n = 10 users participated in the evaluation. Each user played the developed demo for 80 s and three times, pausing for a few minutes between each attempt in order to minimize the effect of cybersickness on the results as much as

[4] Github.com/EverNewJoy/VictoryPlugin.

[5] Oculus.com/dk2.

[6] Mathworks.com.

possible. This provided us with a total of approximately 150.000 head position vectors, which we then proceeded to import into Matlab.

After importing the data, the pitch, yaw and roll head rotations were extrapolated with three different refresh rates: 13, 15 and 20 ms, attempting to predict the next value, and comparing the extrapolated result with the real value measured by the HMD head tracking device. Additionally, different filters typically applied to smoothen signals (Savitzky-Golay, Moving Average and Local Regression) were implemented and evaluated.

During this work, five different extrapolation methods were considered: Linear, Polynomial (2nd and 3rd degree), Conical, and French curve. However, we quickly noticed only the first two methods provided reasonably accurate extrapolations. We assume the 3rd grade, Conical and French curve methods do not resemble the nature of head movements, since the extrapolation error was of the order of 1000 times higher, and therefore we decided to focus our evaluation to these two first, most accurate methods. We also noticed that extrapolation does not seem to work in the roll axis, at least in the scenario designed in this evaluation, typical of first person shooters, since head movements in the roll axis were infrequent and irregular, and thus could not be extrapolated. We decided to remove roll axis extrapolation from the evaluation as well.

The formulae used for the extrapolation are as follows, with $y(x_k)^*$ being the extrapolated value and $y(x_k)$ the measured value:

Two-point linear extrapolation:

$$y(x_k)^* = y(x_{k-2}) + \frac{x_k - x_{k-1}}{x_{k-1} - x_{k-2}}\left(y(x_{k-2}) - y(x_{k-1})\right)$$

2nd degree Lagrange polynomial extrapolation:

$$y(x_k)^* = \sum\nolimits_{j=0}^{2} y_j \cdot l_j(x_k),\ l_j(x_k) = \prod\nolimits_{0,m\neq j}^{2} \frac{x_k - x_m}{x_j - x_m}$$

Average absolute error:

$$\varepsilon = \frac{\sum_{k=2}^{n} |y(x_k)^* - y(x_k)|}{n}$$

4 Results

Evaluation results are presented in three, subsequent parts. Firstly, we present the accuracy results of linearly extrapolation unfiltered head position data on the pitch and yaw axes with increasing latency values (Fig. 3). Secondly, we present the accuracy of both linear and second degree Lagrange polynomial extrapolation with unfiltered head tracking data with a latency of 13 ms (Fig. 4). Finally, the accuracy of linearly extrapolated data with a latency of 13 ms when using different filtering techniques is presented (Fig. 5). All values are presented in average absolute error in arc degrees, and again summarized in Table 1.

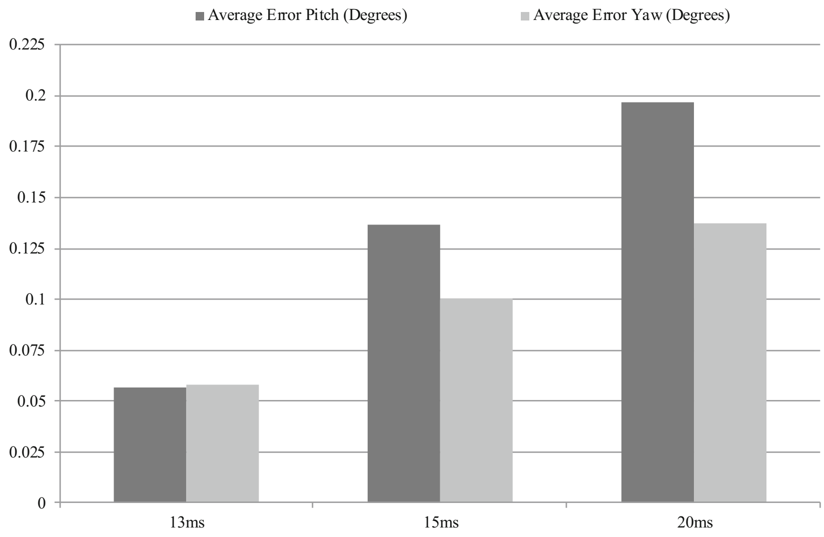

Fig. 3. Evaluation results for increasing timespans of 13, 15 and 20 ms in the pitch and yaw axes. Average absolute error of all values.

According to our results, the best accuracy is obtained when using linear extrapolation and a Savitzky-Golay filter (average absolute error, 0.04 arc degrees), although using other filtering methods (Local regression or moving average) also provides similar results.

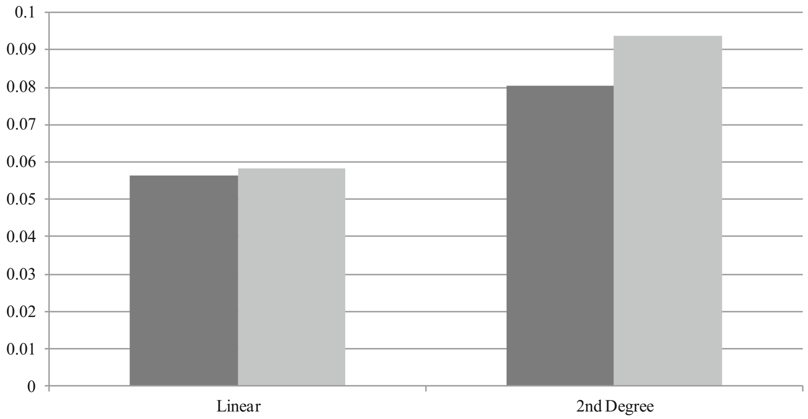

Fig. 4. Evaluation results linear and Lagrange polynomial extrapolation in the pitch and yaw axes with a latency of 13 ms. Average absolute error of all values.

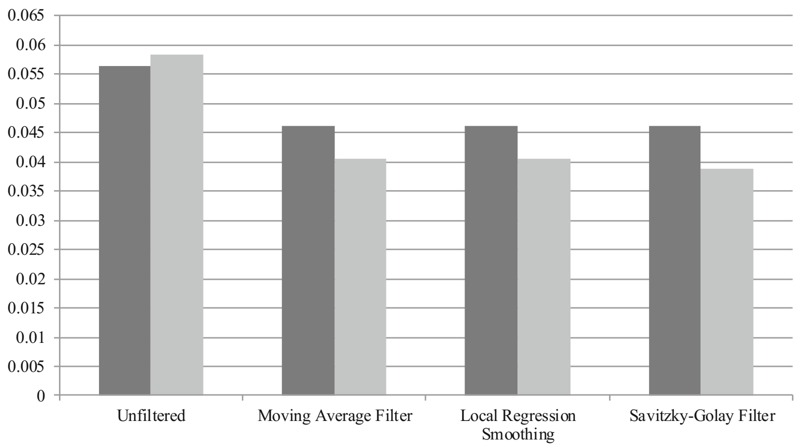

Fig. 5. Evaluation results of filtered head tracking data in the pitch and yaw axes with linear extrapolation and a latency of 13 ms. Average absolute error of all values.

5 Discussion

As it can be expected, prediction error increases with extrapolation time (Fig. 3). We noticed that, in general, the absolute error values are surprisingly low with some approaches, since the first result we obtained by simply using unfiltered linear extrapolation with a 13 ms timeframe was slightly lower than 0.06 arc degrees. This error value indeed increases with time and it does so linearly, although this increase is not equal for the pitch and yaw axes. We noticed that, in our evaluation, the angular acceleration in the pitch axis was normally higher than in the yaw axis, which might explain this difference.

Regarding the extrapolation methods, it would seem that linear extrapolation is more accurate than polynomial extrapolation for both axes, and in turn, both methods are vastly superior to other extrapolation techniques (3^{rd} degree polynomial, French curve and conical). We hypothesize that these extrapolation methods do not resemble the trajectory followed by head movements, explaining this drastic increase in prediction error. Nevertheless, the difference of using either method is reduced compared to the impact of decreasing prediction time.

Results also show that the best method is obtained by combining linear extrapolation with a Savitzky-Golay filter. By using this method, the head position can be extrapolated for 13 ms with an expected average absolute error of 0.04 arc degrees. Again, it is clear that there is an improvement on prediction error by using a filter, but the difference among filters is rather small.

Given the value of this error, and taking into consideration that current technology still cannot provide the processing power required to permit reducing latency to a sufficiently low value where no cybersickness is present, it would seem that extrapolating head movements can provide a reasonably low-cost solution with an acceptable prediction error.

Nevertheless, we are aware of several limitations in this study, which we will aim to improve in our future work. Firstly, due to the nature of first person shooters, our scenario did not require users to perform sufficiently numerous and continuous movements in the roll axis in order to analyze extrapolation accuracy in this direction as well. This could be improved by including a second scenario where roll head rotations may be more frequent, for example a first person perspective flight simulator. Secondly, the number of participants in future studies should be increased in order to determine whether our accuracy results are consistent on a larger user base. Finally, the use of different tracking approaches, for example the IR-based Lighthouse tracking system used in the HTC Vive, should also be taken into consideration.

Therefore, in a future publication, we plan to increase the number users and scenarios and ensure results remain consistent with the ones in this publication, particularly in HMD systems that include bodily movement, such as the HTC Vive, with head movement patterns derived from different typical game environments.

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Geodata Classification for Automatic Content Creation in Location-Based Games

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Abstract. The ubiquity of smartphones with integrated positioning systems made it possible to develop location-based games playable by most people without requiring additional equipment. Popular location-based games like Ingress or Pokémon Go have demonstrated the public interest in this genre and studies indicate that playing such games has a positive health influence related to the players' increased movement.

A big development challenge for these games is the content creation. Manually selecting points of interest (PoIs) of the real world for a game is time-consuming, expensive and often results in heterogeneous distributed PoIs with a low concentration in rural areas.

In this paper we present a system that uses georeferenced data from open available sources to generate a collection of PoIs usable for location-based games of free definable target groups with the goal of providing a comparable game experience everywhere. The content creation algorithm in our approach is fully parametrized allowing for individual configuration for desired PoI criteria. Our evaluation shows that our system can be used to automatically select well distributed relevant PoIs for densely populated areas as well as for rural areas.

Keywords: Geodata · Procedural content generation · Location-based games · Points of interest

1 Introduction

Location-based games have moved into the center of society with the launch of Pokémon Go when it became a global phenomenon. It was released on July 6th, 2016 and quickly built a user base of up to 45 million users worldwide (The Guardian 2016).

One problematic factor for these types of games is content creation. Because players use their current geographical position as their main input for the game, a player's game experience is dependent from the content in his surroundings. For game developers there are three options of content creation: (i) (semi-)random, (ii) crowd-sourced/user-generated content, (iii) manually created by content creators.

In Pokémon Go's precursor Ingress a crowd-sourcing approach with manual verification was chosen which allowed players to suggest PoIs. This system was

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suspended in September 2015 (Niantic, Inc.) after having processed 15 million submissions with 24 million submissions in the backlog. For small development teams often present for serious games this amount of work is infeasible. Semi-random location-based content creation has the major downside that content may pose a risk for the player, the surrounding people or the environment by providing content which induces players to trespass on private property or leading players to places which may pose a risk to their health.

Thereby for catering globally available game content a system is required that is based on existing geodata systems, which extracts and transforms the data into location-based game elements, while trying to verify their reachability. In this paper we propose the concept for such a system that can be used to automatically select PoIs from available geodata services based on their relevance. Relevant PoIs can for example be identified through metadata they are assigned with within the system. Using such an approach gives even small game development studios with limited budget the possibility to develop location-based games that can be played all around the world.

The remainder of this paper is organized as follows: Sect. 2 contains some in-formation about work that was relevant for the creation of our system. In Sects. 3 and 4 the system itself and its implementation is described in detail. Section 5 highlights the results of the evaluation were the concept was tested for 24 positions in 16 different countries and is followed by the conclusion in Sect. 6.

2 Related Work

Due to the ubiquity of smartphones and their incorporation of location sensors the latest location-based games are developed for and run on smart devices. Using a GNSS (Global Navigation Satellite System) like the Global Positioning System (GPS) users can be located with an accuracy of 7.8 m in a confidence interval of 95% using only the service provided for civilians (Grimes 2008).

For location-based games this accuracy is relevant as the reachability of PoIs is an important factor. During the time span of Ingress's crowd-sourcing approach the developer Niantic handed out a guideline for high quality location criteria (Niantic, Inc.):

Possible well-suited location candidates are:

- A location with a cool story, a place in history or educational value
- A cool piece of art or unique architecture
- A hidden Gem or hyper-local spot
- Public libraries
- Public places of worship

Excluding locations with one of the follow aspects:

- No safe pedestrian access
- Private residential property
- Candidates that may interfere with the operations of fire stations, police stations and hospitals.

Because this game depends on the player input and the submissions of potential PoIs the actual game elements within the game world are distributed heterogeneously. Especially in suburban and rural areas players report a worse game experience due to the lack of sufficient game content both in quantity and in diversity (Hargarten 2016), which the developer has reacted on (Hoffer 2016). However there still exist major differences between urban, suburban and rural areas.

Incorporating game content creation and open available geodata has been researched extensively with the focus on providing geographically accurate content elements in combination with the best practices in procedural content generation.

3 Concept

The goal of our concept is to provide a system based upon an open available geodata system that examines and processes the available data to extract a georeferenced set of PoIs, which suffice given quality criteria.

3.1 Data Analysis and Data Availability

We choose OpenStreetMap (OSM) as geodata source system because of the access options to the underlying map data. Data completeness and correctness is an additional factor which OSM tries to manage with its high user base.

Regarding quantity and correctness of OSM data, studies have shown that investigated map providers are comparable in the given aspects. Heterogeneous data distribution has been a problem for all map providers with less data available for rural areas (Ciepłuch et al. 2010) (Neis and Zielstra 2014). Due to the at least linear increase in active users and tagged locations OSM tries to reach an improved coverage (OpenStreetMap).

In an exemplary analysis we checked the data availability for multiple tag groups in OSM according to the previously described acceptance criteria for well-suited PoI candidates. Tags for historic relevant locations and places of worship appeared to be especially suitable due to their frequent occurrence and worldwide distribution.

For the tags which describe places of worship, over 806.000 locations have been tagged with a distribution depicted in Fig. 1. These places are especially valuable for PoI usage, as buildings of religious groups exist in most countries and represent a cultural and often architectural interesting location fulfilling multiple of the previously described acceptance criteria.

3.2 Classifier Creation

As described in Sect. 2 the discrepancy between urban, suburban and rural area in current location-based games is clearly perceivable and influences the player experience.

In order to create an ideally balanced distribution of PoIs and thereby meaningful gameplay locations, we selected specific tags or group of tags that are well-known to be available in urban, suburban and rural areas like town halls or educational

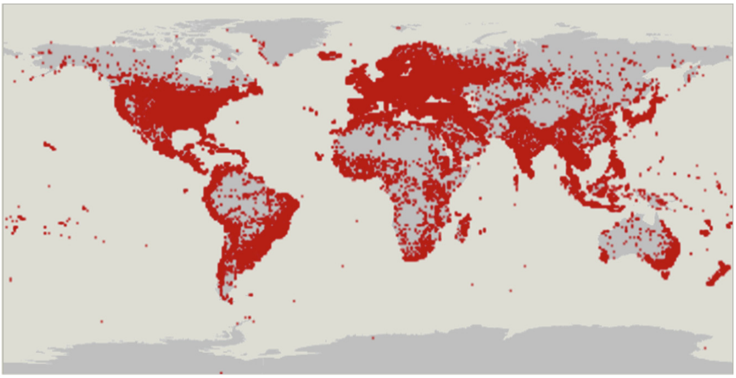

Fig. 1. Data distribution using OSM for places of worship.

establishments. Subsequently, we analyzed the tag distributions for candidate tags in order to verify their applicability. Each tag or group of tags, which we henceforth call classifiers, is assigned a numerical value representing its estimated relevance or representativeness for the surrounding area. This was driven by the assumption that e.g. town halls might be more expected to be a PoI in a game, than the public benches located in front of them.

As the frequency of possible PoIs in urban areas is relatively high most of our developed classifiers try to increase the coverage in more rural areas. Nonetheless, tags that are likely to be found in all types of areas are chosen with high priority like bus stop or stations for public transport in general. However we do not claim completeness for the chosen classifiers as they can be extended and modified in order to cover missing areas or corner cases we did not consider yet.

Thereby the classifier table shown in Table 1 is a first prototypical list of classifiers that aim to cover as much area types as possible, while respected corner cases like parks, which have a special characteristic in urban areas. The linear order is chosen to have a first approach for direct comparison. The classifiers and their priority values however can be modified according to the type of location-based game they are used in.

3.3 Position Handling to Increase Persistency

In location-based games the player's actual position is his main input and control option. According to the player's current position PoIs for the surrounding area could be extracted and processed into game elements. Due to the high amount of data available in certain areas, only a subset of candidate PoIs can be used as game relevant locations, as an oversupply leads to smaller spatial distances and thereby less actual movement between locations.

A first approach would be to define a radius around the player and to filter all available PoIs according to their priority and e.g. choose the two best ones as seen in Fig. 2. Due to the non-static approach of PoI extraction and its filtering a player might see a PoI disappear when approaching, regardless of the used viewing frustum size. As seen in the given example the PoI with the number five might disappear when

Table 1. The selected classifiers with their priority order and tags.

Classifiers	Priority	Tags
Historic places	21	Historic = *
Places of worship	20	Amenity = place_of_worship
Places of the categories arts, culture and tourism	19	Tourism = information | attraction | viewpoint | museum | artwork | theme_park | zoo | gallery Amenity = arts_centre | cinema | community_centre | fountain | planetarium | studio | theatre Man_made = windmill Leisure = water_park
Town halls	18	Amenity = townhall
Libraries and public bookcases	17	Amenity = library | public_bookcase
Places for picnic or barbecue	16	Amenity = bbq | picnic_table Tourism = picnic_site Leisure = picnic_table Shelter_type = picnic_shelter
Huts and other shelters	15	Amenity = hunting_stand | shelter Leisure = bird_hide Building = hut Tourism = alpine_hut
Mountain peaks	14	Natural = peak
Playgrounds	13	Leisure = playground
Educational establishments	12	Amenity = college | school | university | dancing_school | music_school | language_school building = college | school | university
Places for doing sport	11	Sport = *
Places for food or drinks	10	Amenity = cafe | drinking_water | fast_food | food_court | ice_cream | restaurant
Product shops and services	9	Shop = * Craft = * Amenity = pharmacy | bank
Stations and stops for public transport	8	Amenity = bus_station Railway = station | halt | tram_stop Public_transport = stop_position Highway = bus_stop
Parks	7	Leisure = park
Pedestrian walkways	6	Highway = pedestrian
Benches	5	Amenity = bench
Public communication	4	Amenity = post_box | telephone
Waste disposal	3	Amenity = waste_disposal | waste_basket | recycling
Wells, towers, survey points	2	Man_made = survey_point | tower | communications_tower | water_tower | water_well
Trees, stones, springs	1	Natural = tree | stone | rock | spring

movement is respected and the PoI with number nine, with an even higher priority comes within range. This behavior could be circumvented by not allowing PoIs to disappear during movement, which however leads to a higher amount of PoIs than

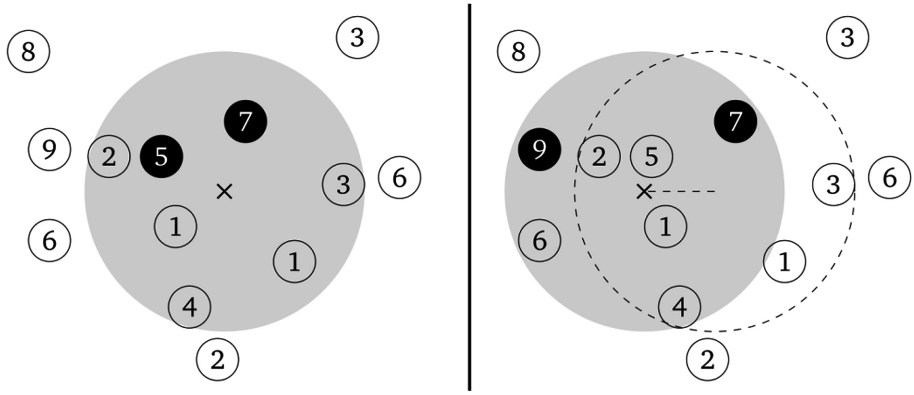

Fig. 2. PoI selection example during a horizontal movement.

intended and does not solve the problem of game world consistency, as players with different starting positions might encounter a different game world.

Our approach to encounter that problem is using a representation that divides the earth in non-overlapping contiguous polygons of similar size henceforth called cells. Thereby depending on the player's position the cell he is positioned in can be used for content generation. For all eight adjacent cells of similar size this is done accordingly, which leads to a consistent selection of game elements as illustrated in Fig. 3. This approach results in a consistent game world for all players since the PoIs are selected deterministically without being dependent on a player's current position.

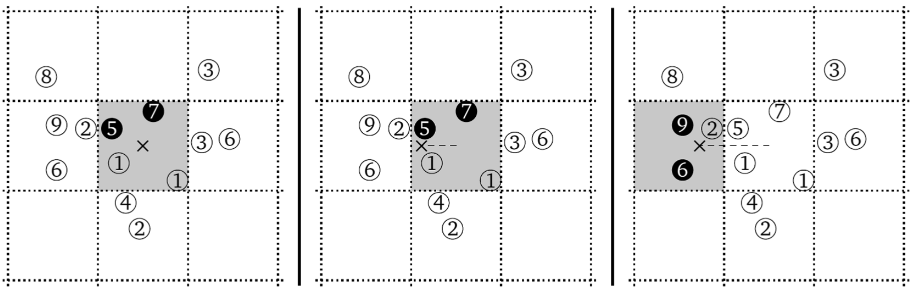

Fig. 3. Our approach for the selection of PoIs during player movements.

3.4 PoI Clustering

Depending on the chosen cell size (which depends on the specific game), areas can still have sizes of multiple square kilometres, which may lead to a bad distribution within the given cell. This is further enforced by cells that render the transition between different types of areas.

Another problem is the spatial clustering of candidate PoIs like at a university campus. When using a high priority classifier filtering for education-related buildings a high number of PoIs in close proximity would be extracted.

We aim to provide a close to equal distribution of PoIs over all different areas, in order to reduce the discrepancy between area types. In addition, spatial clustering of PoIs leads to central hubs, players may feel obliged to travel to and stay at rather than using the whole content diversity.

For that reason we use a clustering mechanism that finds a given amount of clusters and extract their most relevant representative. That way we eliminate spatially close candidate PoIs to be chosen.

To further increase spatial diversity we separate the given geographic cell into two levels of subcells as seen in Fig. 4 and use them as starting positions for the respective clusters. For the final PoI selection we enforce a distribution over the given subcells which we further describe in Sect. 4.3.

0	3	4	5
1	2	7	6
14	13	8	9
15	12	11	10

Fig. 4. Subcells of a cell. The numbers are assigned according to a Hilbert-Curve (Hilbert 1891).

3.5 Metric Development

In order to distinguish the quality of the candidate PoIs during the selection process and to compare multiple PoI sets we developed multiple metrics, which can be freely combined and integrated into a weighted sum:

1. Number of PoIs: For our approach it is desirable to be able to control the number of PoIs per cell, in order to present the "right" amount of game content to the player for the respective game. As discussed in Sect. 2 this choice defines the possible playstyles and dictates the pace of the game.
2. Equal distribution of PoIs: Besides the number of PoIs their distribution in the game area is important as discussed in Sect. 3.4. An unequal distribution might lead to players being able to easily reach a limited number of PoIs before having to travel long distances for more content. The challenge here lies within the data availability as there might be no relevant candidate PoI for a given area due to sparsity.
3. PoI priority focus: During the PoI selection process this metric controls the weight the classifier's priority has. Enforcing a priority focused approach leads to a result with more meaningful PoIs that can be identified and recognized by players.
4. PoI diversity focus: In order to increase the diversity of selected PoI a metric tries to maximize the number of PoIs resulting from different classifiers. When using this metric alone in the selection process high classifier diversity can be reached, however resulting into many low priority candidates being chosen.

4 Implementation

In order to test and evaluate our concept we implemented both a desktop version for data analysis and a mobile version for smartphones for live location handling. Both versions are based upon the same basic module.

4.1 S2 Geometry

As described in Sect. 3.3 a cell based approach is chosen in order to support persistency between multiple application cases. Because the targeted cell size may vary depending on the actual application, we chose a hierarchical model. Thereby the cell size can be adapted to the application's needs.

In our implementation we use the S2 Geometry Library because it provides an efficient approach to identify the relatedness between cells and their subcells due to their similar ID-prefix (Procopiuc).

4.2 Overpass Query Creation and Limitations to Avoid Trespassing

OSM offers the Overpass-API for custom queries, which enable the selection of specific tags and the specification of a target area using bounding boxes. The Overpass queries used in our implementation search for all OSM data in the nine current S2 cells which are specified by the player's current position. The returned result of the query consists of all PoIs which contain tags of the used classifiers as we listed them in Table 1. The data is specified using the keywords node, way and relation.

While nodes can be directly translated into candidate PoIs by their respective coordinate, ways need specific handling. A way can either represent a real way with a start- and end-point or an area enclosed by the given polygon. For these ways the Overpass-API defines the area type, which can be used to obtain information about e.g. the area's center. For our implementation an area is treated as a PoI because further investigation would be needed to calculate the reachability of the area's center like for e.g. lakes or non-public buildings.

In order to exclude PoIs that are located in area that are either dangerous or private property we apply a filter that uses tags indicating the land-use for military or private matters, as trespassing can become a serious problem for location-based games.

4.3 Specifying the Classifiers

To further reduce the amount of data sent for the mobile implementation we implemented a dynamic reloading approach that widens the range of classifiers from rare to common for areas or subareas that contain an insufficient amount of PoIs. The classifiers' placement into each rarity category has been done according to their assigned priority.

Additionally each classifier can assign a subpriority to their individual tags to e.g. indicate the higher priority of cathedrals over chapels for all places of worship.

The developed metrics are all incorporated into the PoI selection process. Hereby the number of PoIs (1) is used as an input value for the clustering algorithm leading to the desired outcome. By using subcells of each cell the equal distribution (2) is tackled, by enforcing the coverage of these subcells. Regarding metrics (3) and (4) a weighted approach was implemented that aims to maximize the weighted sum score of both approaches. Due to the wide range of possible application scenarios these weights are mapped onto the main configuration UI.

5 Evaluation

To evaluate the implementation of our concept we have applied it to 24 positions in 16 different countries and examined the results in regard of the metrics introduces in Sect. 3.5. The places were grouped into three categories:

1. places with more than 100,000 residents
2. places with 5,000–20,000 residents
3. places with less than 2,000 residents

Comparing the results of the categories showed that the average number of PoIs determined in an area is much greater in places with many residents. Figure 5 shows the amount of elements detected by the classifiers for the different places. After applying the clustering algorithm the amount of PoIs was as depicted in Fig. 6.

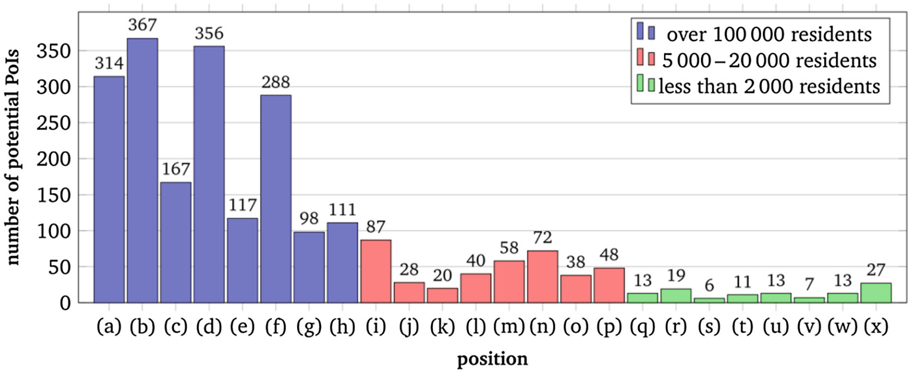

Fig. 5. The amount of potential PoIs for the examined places.

The amount of PoIs can easily be customized by increasing the amount of clusters and of simultaneously used classifiers. Figure 7 shows an example of such an increase for the center of Darmstadt. While the left side shows the result for the standard values with 32 clusters, the right side demonstrates the result when 256 clusters are used and all classifiers are applied at once.

To examine the distribution of the PoIs we constructed a minimal spanning tree for each cell with the PoIs being the nodes. By doing this we could estimate how far players would approximately walk to get from one PoI to the next one. The cells have a size of between 3.31 km^2 and 6.38 km^2. As depicted in Fig. 8 the distance becomes

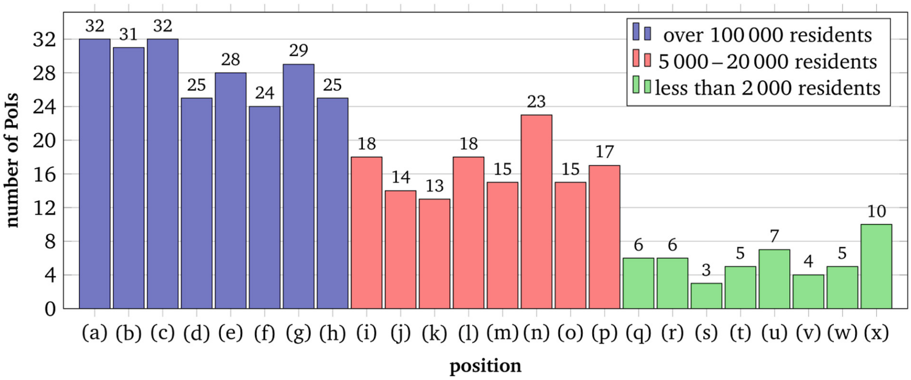

Fig. 6. The amount of PoIs for the examined places after the clustering was applied.

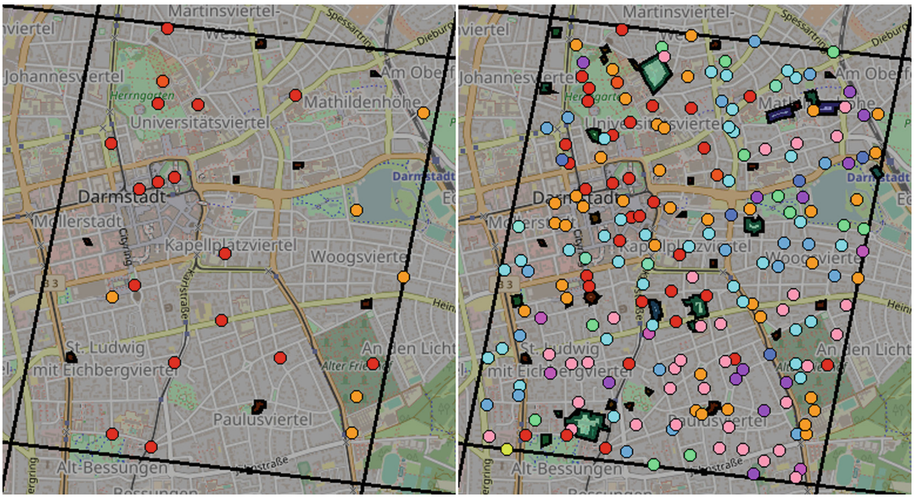

Fig. 7. PoIs in Darmstadt before and after the increase of the amount of clusters.

larger for places with fewer residents. For places with less than 2,000 residents when examining the standard deviation the PoI distance is within the [213 m, 862 m] interval. For cities with 5,000–20,000 residents the interval changes for the upper limit to [194 m, 538 m] and for cities with over 100,000 residents to [215 m and 444 m]. Thereby the results are stable for the minimum distance, which is the result of our clustering and selection approach. For the upper limit the distance decrease with higher PoI availability, hence more PoIs are available in larger cities.

In the next step we investigated the PoIs' priority values for each of the places. PoIs in places of the first category had an average value of 20.52, PoIs in the second category an average value of 14.61 and PoIs in the third category an average value of 17.12. The high last value can be explained by the fact that some of the classifiers with

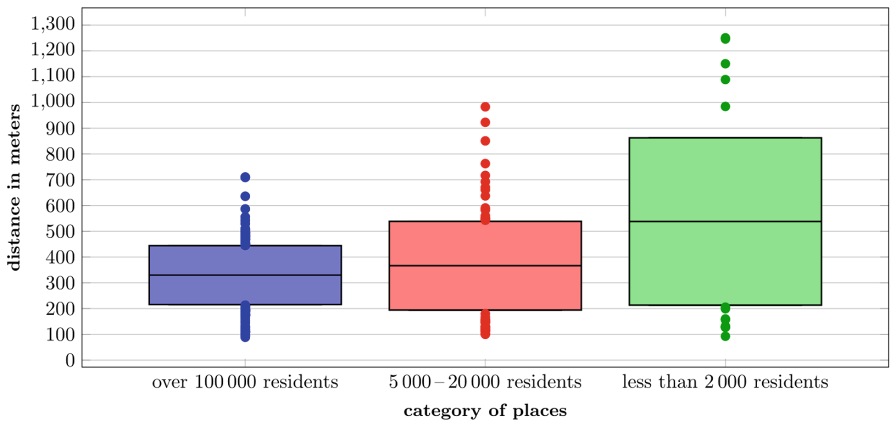

Fig. 8. Distances between PoIs in the minimal spanning tree, as well as the standard deviation from the mean value.

high priority values are also effective for rural areas, resulting e.g. in PoIs for touristic places or churches.

Finally we examined the amount of used classifiers. On average places of the category 1 used 6.25 classifiers, places of the category 2 used 8.25 and places of the category 3 used 3.88. The reason for the first value being lower than the second is that in cells of category 1 most of the times fewer queries are needed to get enough data to fill the cell, so that fewer classifiers are applied to such cells.

6 Conclusion

In this paper we presented a concept for automatically determining relevant PoIs for location-based games. Publicly available geodata has been analyzed using a set of developed tag groups. The 21 tag groups have been designed to value the usefulness and interestingness among the PoIs and to reach high area coverage among heterogeneous areas. A clustering algorithm is applied to the respective data, selecting the highest priority PoIs as the representative location within the cluster. These clusters are then to be used in location-based games of different scopes of application.

Our evaluation showed the concept's applicability for various cities and towns in different countries as well as the customization options regarding the amount of desired PoIs. The applied classifiers resulted in a reasonable amount of well distributed PoIs, while the PoI selection for rural areas still remains the main challenge regarding equality of available PoIs in comparison to urban areas.

Further research will focus on optimizing the list of classifiers to find more PoIs in very sparsely populated areas and modifying the classifier hierarchy accordingly. Classifiers based upon meta-data for fallback scenarios can prove to be useful in areas without enough available data or for aspects not actively tagged within the data like street crossings.

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Reflection Continuum Model for Supporting Reflection and Game-Based Learning at the Workplace

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Abstract. Game-based learning provides experiences where the learner has the opportunity of learning by doing. Existing theoretical models of learning describe the role of reflection and its importance in the consolidation and internalization of knowledge. However, reflection is often neglected in the game development process, where the emphasis is on balancing the didactical design of what is required to be taught with the game design to facilitate high engagement that leads to high motivation and flow. The Reflection Continuum Model brings together different theories of reflection into three levels: micro, macro and meta. The paper presents the analysis of three game-based learning experiences in corporate training according to the model.

Keywords: Reflection Continuum Model · Workplace learning · Game-based learning · Thoughtful action · Tacit knowledge

1 Introduction

Learning in the workplace is often situated learning [7] and involves learning by doing along with observing peers and experts at work. Adults learn best when they are actively engaged in the process and they participate and have engaging experiences. This type of learning is best described by Kolb's experiential learning cycle containing four related parts: concrete experience, reflective observation, abstract conceptualization, and active experimentation [5]. Experiential learning is also described as four phases: planning for action, carrying out action, reflection on action, and relating what happens back to theory [1] and as thinking about the experience, identifying learning needs that would improve future practice in the area, planning what learning to undertake, and applying the new learning in practice [2]. The EU project MIRROR, focused on reflection and learning at the workplace, builds upon experiential learning and considers the return to an experience to reflect and make changes in the work [6]. One of the key concepts in experiential learning appears to be reflection on an activity or an event.

Game-based learning provides an engaging learning experience, an ideal environment for learning cognitive skills and an interactive decision making context [3]. Simulation games are a virtual arena for people to experience and practice a variety of situations at the workplace. Reflection triggers are often designed as a part of the game;

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e.g. prompts about the knowledge to be learned [9], or through more subtle ways such as an icon or a visualization or the scores of other players [4]. Designing good support for reflection is not trivial for several reasons; firstly, Csikszentmihalyi's flow theory describes a state when the player is so engaged in the play that there may be little or no room for reflection [11]. This requires careful balance between flow and reflection for optimal benefit from the game. Secondly, not all players may be able to perceive the meaning of subtle or indirect reflection tools within a game [4]. Therefore, there is a need to build effective reflection tools in the game that help players achieve the desired learning. This paper presents the Reflection Continuum Model (Sect. 2) as a means of designing effective reflection support in serious games along with the analysis of three serious games to illustrate the model: Sect. 3 describes accelerating learning in the process industry (ALTT); Sect. 4 describes on-board learning solutions in the maritime industry (TOOLS); Sect. 5 describes LifeCycle Assessment in sustainable manufacturing (LCA) and Sect. 6 provides conclusions.

2 Reflection Continuum Model

The cognitive processes, such as diagnosis, analysis, judgment and choices of actions, in a workplace, need to be taken into account when designing learning solutions such as simulation games for competence development in the industry. Support for reflection is a major contributing factor for successful learning. The Reflection Continuum Model [12], shown in Fig. 1, illustrates the different levels of reflection support that can be designed into games and learning solutions.

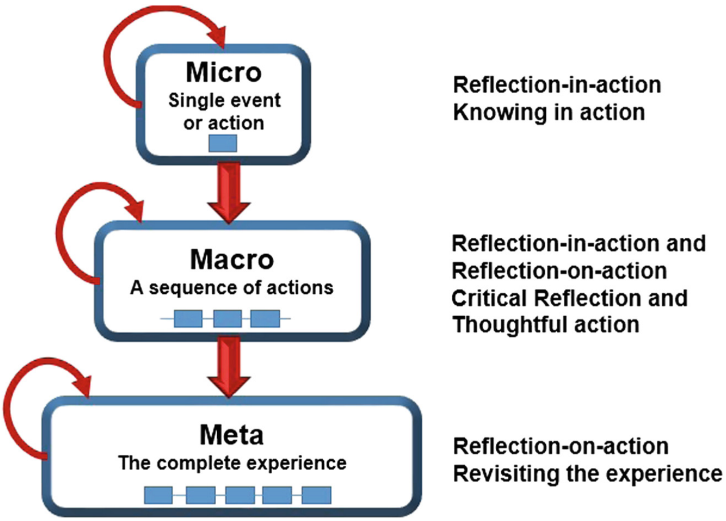

Fig. 1. Reflection Continuum Model

As with any experience, the learning experience comprises of a number of activities, where each activity can be considered as a micro activity. These micro activities are not isolated and have a degree of salience that makes a sequence of these activities, a relevant part of the learning experience. This is the macro level of the learning experience. The macro level emphasizes the evolution of the experience rather than a subset of activities that belong together. As most often explored in games, the entire experience seen as a whole provides a meta learning experience. The micro, macro and meta levels of learning experiences can be related to the relevant theories on reflection and learning; the micro level is reflection-in-action and knowing-in action and the meta level is reflection-on-action and revisiting an experience for improving one's understanding and future actions [12]. The macro level brings the other two levels together to provide support for critical reflection and thoughtful action [10], stimulating the reflective practice and encouraging the operators to reflect continuously about their actions and act intentionally. The three levels of reflection are necessary to support understanding, to encourage reflective action and to raise awareness of the consequences of their actions.

3 Accelerating Learning Through Technology in the Process Industry

The Norwegian company, Hydro, is keen to enhance the knowledge of their operators in the aluminium plants so that they will be able to make better and efficient decisions in the workplace. Today, the operators learn about heat balance, one of the critical processes in aluminium production, by observing and following instructions from their more experienced peers. They learn to follow procedures and recognize patterns without a deep understanding of the chemical process of aluminium extraction. Hydro is keen to accelerate the learning process and support operators acquire a level of understanding and experience that is closer to that of experts in a shorter time. Thus, the Norwegian project ALTT (Accelerate Learning Through Technology) project is funded by the Norwegian Research Council, bringing together the domain expertise and users from Hydro, a game developer (Attensi), the knowledge in the dynamic process models and process simulation experts (Cybernetica) and researchers and designers of Technology Enhanced Learning (TEL) solutions (SINTEF).

3.1 ALTT Game Concept

The ALTT Heat Balance game was designed to support operators learn about heat balance in the aluminium production cells. One of the main challenges in understanding this process is posed by the slow reaction times, which makes it harder for operators to see the consequences of their actions on the cell. The selection of which action to take is a complex cognitive decision making process, which involves establishing the current status of the cell and how it got there. The main game screen for the ALTT Heat Balance game is shown in Fig. 2.

The gameplay is based on rounds, each corresponding to a 24-h time period. The 9-cell matrix (top right) is the board game to indicate the current status w.r.t. to the

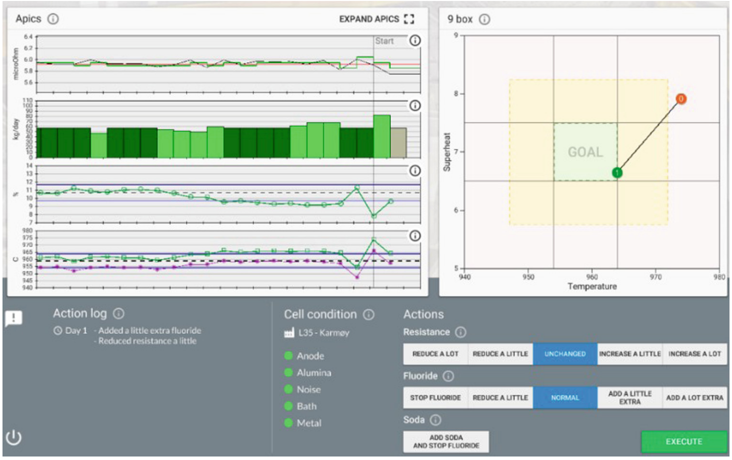

Fig. 2. ALTT heat balance game

temperature in the cell and the graphs to the left of the screen shows the recent history with values for several parameters including the temperature and acidity. The buttons to the bottom right of the screen show the actions in the game, which can be translated as parameter values for the dynamic process model. The available actions are adjusting the resistance and the amount of fluoride (acidity) in the cell, wait without taking any action or add soda to the cell. Once an action is taken, the graphs and the 9-box matrix are updated with the new state of the cell, calculated using the dynamic process model.

3.2 Reflection and Learning in ALTT

The learning needs in the ALTT project highlight the complex cognitive demands posed by the domain and the need to go beyond a single reflection model or theory [12]. Reflection in the ALTT Heat Balance game is designed to encourage operators to think carefully of each action they take, by studying the current state of the cell, detecting how it got there by looking at historical information and anticipating consequences of their action. The reflection tools incorporated in the game are shown in Fig. 3.

The micro level of reflection aims at drawing the operator's attention to each action they take to encourage knowledgeable and thoughtful action, based on the information available to them in the game. This is supported in each round of the game using knowledge questions, by asking the operator to anticipate how the behaviour of three important parameters of the cell (temperature, acidity and superheat) will change, which are also the focus of the learning goal. This is done by asking the operator to select one of the three possible behaviours of the parameters (increase, decrease or stable); Fig. 3(a). The feedback for this is provided as the actual consequences of the actions.

The macro level of reflection aims to draw attention to the dynamic nature of the process and to emphasize that each action (or round in the game) is not an isolated

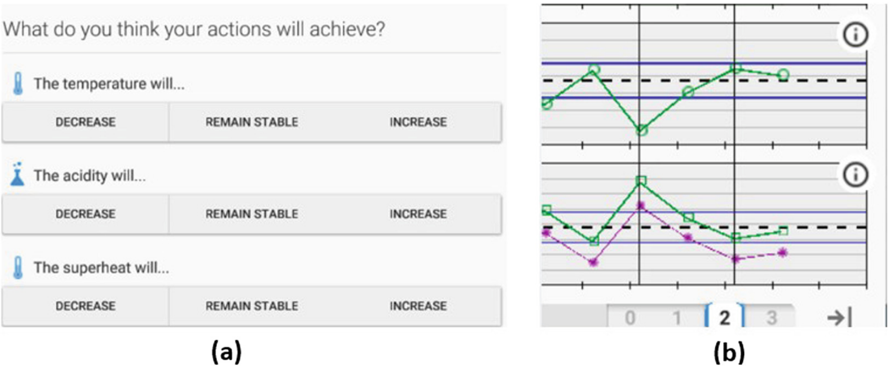

Fig. 3. Reflection support in ALTT

action and a consequence. It is designed to encourage operators to take thoughtful actions by dwelling upon past actions and anticipating the consequences of actions and to promote critical reflection. The reflection tool at the macro level is a slider, which allows the operator to revisit each point in the game when the operator took an action (or each round), see the status of the cell, and to reflect on how her actions at that point in time affected the cell and contributed to the current state of the cell. This functionality is shown in Fig. 3(b), where the operator has played three rounds and has moved the slider to show the cell status at round two. In addition to displaying the cell status at any round on graphs, the cell status at the round is also highlighted on the game board, the 9-box model; see Fig. 2.

The meta level of reflection is aimed at revisiting the whole experience after each game scenario and to encourage the operator to reflect upon their actions and how they had affected the whole performance. The intention is also to encourage the operator to think why they had either won or lost and to detect when or which actions may have been critical to the outcome of the game. This will serve as a stimulus to think strategically about how to adjust their choice of actions next time they play. This level is also supported by the slider functionality, enabling the operator to revisit.

Several novices and expert operators and engineers have played the game. The responses have been very enthusiastic and the operators appeared motivated and engaged. The novices found the knowledge questions at the micro level of reflection very helpful and said that they helped them understand the concepts and the cell dynamics. The experts, however, found it annoying that they had to anticipate the consequences of their actions at every round. They said that to think ahead is what they do already, and therefore, they did not see any benefits of the functionality. Nevertheless, they appreciated the value of the functionality; they would just like to be able to switch off the functionality when they desired. The slider functionality was not used by any of the operators during the evaluations. When the functionality was demonstrated to them afterwards, they liked it and said that it will be a great help, specially for the less experienced operators. Valuable feedback was received to improve the GUI for the slider. This is perhaps an example of a reflection trigger that was not perceived by users as it is meant to, thus reducing the envisioned effects on the learning process.

4 Tomorrow's Onboard Learning Systems in the Maritime Industry

Experience in the maritime industry, which upheld by research, indicates that there is a gap between so-called intended and actual work practice among the officers on board [8]. While officers seem to be familiar with the correct or preferred work routines given in steering documentation, training manuals, engine manuals and company policy, they sometimes use alternative work practices in their daily work on board. In a survey to the seafarers (deck officers) it was discovered that more than a third of the officers reported breaking company procedures regulating use of auxiliary engine (several instances) and other safety and environmental issues to a lesser degree [8]. This was the acknowledged breach of procedures which was admitted in a survey, and the possibility of underreporting such breaches was of course quite large. The TOOLS game-based learning solution was developed to research a novel approach that addressed specifically the registered gap.

4.1 TOOLS Game Concept

The TOOLS serious game provides a rich experiential learning experience where a seafarer assumes the role of 2nd engineer on a vessel that departs from Rotterdam on the way to Houston. The game consists of two distinct episodes:

- **Emission Control Area (ECA)**. The learning of the outcome of the episode is to have the seafarer to determine the crucial point in time when to switch from high sulfur fuel to low sulfur fuel to reduce the impact of emissions when entering a ECA, aligned with what regulations permit. The decision needs to take into account the fuel in the engine and the rate of consumption, thus calculating how long it takes to switch effectively the fuel.
- **Fuel Efficiency**. The intended learning outcome of the episode is to achieve the optimal fuel efficiency whilst in port. A seafarer needs to determine how many auxiliary engines to have in operation taking into account the necessary power consumption depending on the activities taking place.

The diagram in Fig. 4 reflects the different contexts that support the TOOLS learning experience. The start of the game (step 1) corresponds to a briefing of the HR resource manager providing the seafarer with their assignment. Thereafter, the seafarer engages in dialogue (step 2) with multiple characters, from higher and lower ranking officers. The higher ranking officers provide orders, which essentially corresponds to guiding the seafarer in what goals to achieve in a step-wise manner. However, the use of lower ranking officers facilitated the abstraction to the particulars of a shipping vessel since evidence demonstrated a significant absence of layout and design standardization. Consequently, the seafarer would decide what action to take and instruct their team mate to carry it out. The dialogue was carefully crafted to encourage particular behaviours, such as to always ask instead of making assumptions, to demonstrate principles of leadership by communicating well and building rapport with the remainder crew members, and ensure that lower ranking officers understand and

Fig. 4. TOOLS learning content

commit to the given orders. Due to the prominence of Filipinos in the seafarer population, the dialogue was carefully created to eliminate potential cultural stereotypes.

The seafarer is confined to the engine room (step 3), which gives them access to the instrumentation providing information on fuel, engine load, distance, etc. The seafarer also has access to the engine room log book (step 4), specifications of the vessel (step 6) and the company procedures. The acquisition of information to make informed decisions is a key behaviour that shaped the design of the TOOLS game since traditionally seafarers seldom practice consultation. Finally, in step 5, the seafarer is given the chance of controlling how time is governed thus allowing real-time for decision making whilst permitting to advance time to verify the outcomes of particular decisions.

Once the seafarer finishes the game session, they are given an in-game debriefing of the course (step 7). Although the seafarer is given a detailed post-action review, it is important to include in-game debriefing where the human resource manager can provide relevant feedback to the seafarer.

4.2 Reflection and Learning in TOOLS

In TOOLS, there is only a meta level of reflection, which consists of the in-game debrief and a rich-detailed feedback (Fig. 5) of their experience. The former provides overall recommendations for the seafarer to improve their performance in their next session whilst the latter provides feedback using a time-based continuum so the seafarer may reflect on the impact of the decisions made. The reflection support consists of three main areas, all governed by the timeline:

- **Competence Performance Measurement**. This provides feedback on the performance of particular skills, some are continuous over time (e.g.: building of trust with your team) and others are discrete in time (e.g.: decision made to change the fuel).

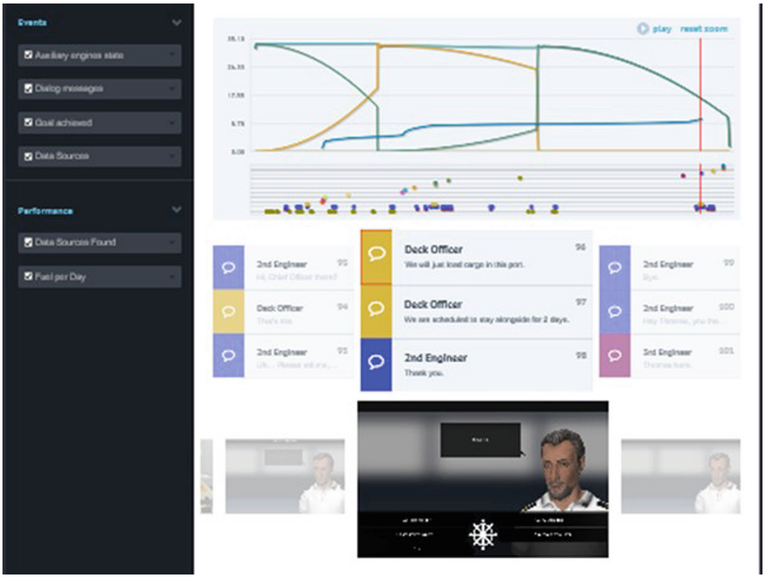

Fig. 5. Reflection support in TOOLS

- **Events and Dialogue**. This captures all the relevant events of the game, including dialogue, thus enabling the seafarer to know the precise context at each particular instance along with the build up until that moment.
- **Context**. Although the events provide insight into what happened, it is not sufficient for a seafarer to recall precisely the context. Consequently, this area consists of a timeline of images derived from snapshots taken at regular intervals.

5 Life Cycle Assessment in Manufacturing

Life Cycle Assessment (LCA) is a complete, structured and standardized method for environmental impacts evaluation. The innovative approach of LCA allows to avoid the shifting of a potential environmental burden between life cycle stages or individual processes, through the evaluation of resources consumption, from raw material extraction and acquisition, through energy and material production and manufacturing, to use and end of life treatment and final disposal. The increasing of awareness of environmental implication has allowed the development of LCA training in many courses (e.g. university, master, professional training). However, these courses focus mostly on the theory, supported with practical work, thus failing to convey the complexities for implementing a LCA in a real context. In particular, the discovering of information needed for the Life Cycle Inventory, into the complexity of Business Company. The development of a full LCA, can require an important amount in terms of costs, people and time, and one of the most important reason of time consuming is the gathering of information between the company, databases and statistical data.

5.1 LCA Game Concept

The student is given the role of a sustainability manager working for a manufacturing company of coffee machines. The CEO of the company wants to optimize the production process with the following specific goals:

- Reduction of energy by 15%
- Zero emission of ozone-layer destroying substances
- Reduction of solid waste by 10%.

For the LCA inventory, the student needs to interact with several stakeholders within the manufacturing company, being aware of their biases when answering requests for information. In addition to the social interactions, the student needs to access different sources of information from databases, production cells on the shopfloor and documentation. However, the student must apply critical analysis to resolve the perceived contradictions and avoid pitfalls of erroneous (and outdated) data (Fig. 6).

Fig. 6. The screenshot on the left is the default view of the user with the icon on the lower portion of the screen to activate the screenshot of the right where the user has all the functions of the LCA reporting process

The session is completed when the user submits the LCA report to the CEO via the LCA tool.

5.2 Reflection and Learning in LCA

With regards to the reflection continuum, the LCA serious game supports both the macro and meta levels of reflection. The meta level is facilitated by a rich in-depth feedback based on a time continuum similar to the TOOLS serious game, with three level of information: competence performance, events/dialogue, and context based on visual snapshots.

The initial studies demonstrated that whilst useful, the meta level of reflection was not sufficient for students to develop their understanding on the decisions made concerning LCA since the game focus on the creating the LCA report. Consequently, the game design was refined to embed in the game a macro level of reflection where the student is required to make recommendations to the CEO to accompany the LCA report. This level of reflection requires the student to understand the output of the LCA simulation and interpret the results within the business context and strategy outlined by the CEO.

6 Conclusions

An analysis of the three serious games according the reflection levels of the Reflection Continuum Model the analysis is summarily captured in Table 1. This analysis based on concrete examples provides a clearer understanding of the Reflection Continuum Model. Most serious games support the meta level of reflection, with a final debrief of the learning experience with different levels of richness and details. The TOOLS serious game only support the meta level of reflection and the reason is rooted on the procedural nature of TOOLS, since seafarers are required to follow Standard Operating Procedures as determined by the shipping companies. Although TOOLS could be enhanced to support additional reflection levels, it would not be necessary considering the didactical aims driving the game design.

Table 1. Comparison of the levels of reflection of the three serious games based on the Reflection Continuum Model

Serious game	Micro	Macro	Meta
ALTT	Yes	Yes	Yes
TOOLS	No	No	Yes
LCA	No	Yes	Yes

The LCA serious game supports both Macro and Meta levels of reflection due to the requirement of students reflecting in-game, between the phases of data collation and providing recommendations to the CEO.

The most comprehensive serious game is ALTT, which is to be expected considering that the strong focus on the development of the cognitive ability of operators to make the correct decisions concerning the heat balancing with regards to aluminium production.

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Experimental Serious Games: Short Form Narrative in Augmented Reality Dioramas

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Abstract. This paper describes on-going research to explore design strategies, grammars and languages to articulate, manipulate and drive narrative in digital media - games, simulations, virtual reality, augmented reality, and mixed reality. One of the main objectives of this work is to create synergy and to reconcile designed narrative with interactive narrative. In previous work we focused on tablet and touch screen devices and immersive virtual reality experiences, and in particular on the exploration of pace and slow interaction and gameplay to create opportunities for contemplation on the purpose. Continuing the purpose and theme, to raise awareness on issues and human activities disrupting and effecting the Great Barrier Reef, current work described herein focuses on augmented reality dioramas (miniature 3D digital model) and explores participant-driven narrative, to manipulate short form narrative, and encourage deeper involvement and contemplation with the serious purpose. To provide creative inspiration for our novel approaches, described herein is a framework to inform and guide design of experimental games and experimental serious games.

Keywords: Narrative · Interactive narrative · Short form · Long form · Scenario · Story · Experience · Design · Design strategies · Grammars · Serious games · Virtual reality · Augmented reality · Mixed reality · Diorama · Purpose · Great Barrier Reef

1 Introduction

Serious games are games, simulations and experiential and experimental environments for purpose supported on an array of delivery platforms from desktop, tablet and smartphone, to virtual reality (VR), augmented reality (AR) and mixed reality (MR) [1]. There is an emerging variety of purposes that include but are not limited to learning, change, persuasion, societal impact, to raise consciousness and awareness, to provoke thought, for health, well-being and therapeutic uses, etc. Purpose is delivered to participants and players through interactions and gameplay and captured in mechanics, programming code and rules. For example, Brathwaite emphasises the significance of game mechanics in her works under the caption of "mechanic is the message" [2]. In contrast, Bogost points to the importance of arguments captured in rules of behaviour and "authored in code through the practice of programming" [3] (Bogost p. 29). Herein it is argued that whatever the mechanism or mechanic to deliver

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purpose, or provide a message or argument, these can arguably be considered as grammars and language to construct, articulate, manipulate and drive narrative.

Digital games, simulations, serious games, virtual and augmented reality provide narrative forms that are different to narrative that unfold in a linear manner as found for example in literature, film and theatre [4, 5]. These differences and complexities have been widely reported [6–10] and arise from participants' influence on narrative through gameplay and interactions. Just how much influence they have on narrative is a complex negotiation between, on the one hand, designed pre-scripted narrative moments and on the other, participants creating their own journey. Similarly, focusing specifically on time, [11] Benford and Giannachi refer to this as a creative balance between a canonical trajectory and participant trajectory. See also [12].

This paper is part of continuing work to explore interactive narrative in games, VR and digital media, and investigate design strategies and devices to articulate, manipulate and drive narrative. While narrative is typically associated with story, narrative can be many things in interactive digital media, including a great storytelling medium, but also, an adventure, for exploration, discovery, for play, opportunities for activities, and an experience, etc. [5]. Borrowing from film that identifies "long form" narrative for feature film and "short form" for shorter productions, I refer to "short form" to identify interactive digital media that has a short duration of play, interaction and narrative, and "long form" to refer to interactive digital media that has long play, interaction or narrative. The focus herein is on short form narrative with augmented reality diorama (3D virtual miniature representation/model). The purpose is the continuation of the theme to raise awareness on issues and harmful human activities disrupting and effecting the Great Barrier Reef. To deliver on and meet a variety of purposes, as serious games designers and developers much of what we create is through experimentation and this is especially fitting with new and emerging delivery platforms like VR and AR. The next section starts by describing a framework that has been devised to provide creative inspiration and inform and guide design of experimental games and serious games. This is followed by outlining previous work in the development of a serious game and VR. Finally, we describe augmented reality diorama utilizing proprioceptive sense and body movements to update narrative and story – in this way the participant is not only an audience member or spectator but drives the narrative forward with the aim of encouraging a deeper contemplation and engagement with the narrative and the serious purpose.

2 Framework for Experimental Serious Games

To ensure innovation and creativity in our designs, and to ensure we deliver on and meet an emerging variety of serious purposes, serious games designers, developers and practitioners, typically explore and experiment with gameplay, mechanics, interactions, narrative, grammars and languages. This is especially appropriate with new and emerging delivery platforms like VR and AR where conventions and best practice are still yet to be devised. An emerging genre of digital games that could provide inspiration for our designs is experimental games. But what are experimental games and how do we create them? Jenova Chen refers to his experimental game *Cloud* as a "whole new land of emotional content in games" [13]. The Experimental Games Workshop at the Games Development Conference (GDC) has been organising highly successful sessions for over a decade and describes them as "interesting approaches to interactivity that haven't been tried before" and adds an inexhaustible long list of what could be and what is not experimental gameplay [14]. These are accurate descriptions of experimental games, but they are typically vague and informal. Although there is a large body of literature on games and serious games, there is very little literature on guidelines or design strategies to provide inspiration to explore and experiment with the design, development and the creation of novel games and serious games. Therefore, to provide creative inspiration and guide design of experimental games and serious games a framework has been devised to inform:

- exploration of game designs *beyond traditional genres and conventions*
- creation of *innovative forms of gameplay, interactions and underlying mechanics*
- creation of games supported by either *traditional or novel/new technology*

The framework consists of four main categories to inspire the exploration of gameplay and interaction mechanics and narrative grammars and languages to inform and guide design of experimental games and experimental serious games and create novel ways to play, interact and experience. The four main categories of the experimental game framework are as follows:

- Interactivity, manipulating/subverting: (i) user control (influence over content); (ii) direction of communication (responsiveness and exchange) (iii) time/pace (speed of response/feedback)
- Experience, moods, feelings and emotions: from pleasant/fun to difficult and dark (e.g. shock, surprise, anger, frustrate)
- Arguments, messages, and issues: purpose, gamification, political, societal impact, activism
- Technology: new technology, new ways to interact, play and display games

In addition to these four categories, as we are pushing the boundaries it is recommended that designers and developers consider the ethical and social considerations and implications in their creations. The framework has been used successfully for several years to inform students' interactive digital game projects on the Experimental Games Design course (3130GFS undergraduate, 7130GFS postgraduate) at Griffith Film School, Griffith University [15]. Using the categories, in 12 weeks students have designed and developed experiential digital games to create new experiences, devised novel forms of interactivity and play, and in short have, created new grammars and languages between the designers and the players/participants. Some examples of students' experimental games that have a serious purpose and so can be considered as experimental serious games are:

- experiencing what it's like to be a stray dog
- suicide prevention
- game to learn about cinema censorship
- experiencing the monotony of someone's "day in the life"

In the following sections, we describe our on-going research to create novel experimental serious games that were inspired, informed and guided by this framework.

3 Previous Work: Narrative in Serious Games and VR

In previous work we explored interactions and gameplay, grammars and language of narrative in games [5, 16, 17] and with immersive virtual reality experiences [18, 19] to raise awareness on issues and human activities disrupting and effecting the Great Barrier Reef. The focus was on the articulation and manipulation of space (CG virtual environment, movement through, for activities) and time (past, current and future, and pace) to stimulate thought and for the shaping of experience between positive and negative experience [20], as described below.

3.1 The Reef Game has three main levels or scenes as shown in Fig. 1. Developed for tablet and touch screen devices [16, 17, 20]. Each scene and transition between them is designed to provide an unfolding narrative from pristine and healthy reef teaming with marine life through to destroyed reef. In the first scene participant's movement through the ocean is slow and is intended to focus and sharpen concentration so they experience and reflect on the beauty and tranquillity of the coral reef and marine life. The objective of the second scene is to "play" with, and slow down/stop the issues and human activities effecting the reef. "Play" becomes progressively faster to the point where the destruction of the reef is inevitable.

Fig. 1. The Reef Game: three interactive scenes (l-to-r) (i) swim through the tranquil and healthy reef (ii) mini game to slow down and "play" with human activities that damage the reef (iii) the reef's inevitable death and destruction

The last scene is again performed by slow interaction and exploration in the ocean in order for participants/players to reflect, but this time on the disruption and destruction from the effect of gameplay in the second scene. The experience from the last scene is shocking and disturbing, as reported by participants during its showcase at JCSG 2015 [17, 20] and this is intended to provoke thought and linger, resonate or bleed out from the game [20–22]. Experimental design features are the slow pace and movement in the first and third scenes, and the shocking experience in the third scene. To emphasise the unhealthy, destroyed and bleached corals, and dead marine life and fish, participants are free to explore the third scene for as long as they desire and so narrative and experience is potentially continuous.

3.2 VR Slow Reef Experience shown in Fig. 2 allows participants to learn about and experience the beauty and wonder of corals, marine life and ecosystems in Australia's Great Barrier Reef [18, 19]. Using Oculus Rift, exploration in the virtual Great Barrier Reef is through slow movement intended to focus and sharpen concentration so participants experience and reflect on the beauty and tranquillity of the coral reef and the abundant marine life. Movements through the environment are in a leisurely, gentle and unhurried manner. In an attempt to enhance experience real sounds of the reef, ocean and fish are gently heard through headphones.

Fig. 2. VR Slow Reef Experience: display showing point-of-view through VR headset

Different types of fish and marine life are identified in text by moving towards them and activated through a prolonged stare (Fig. 3a). When this occurs the background image surrounding the marine life becomes blurred and out of focus while the marine life and text remains in focus. Journey through the ocean and amongst reefs, corals and marine life can be for as long as the participant desires.

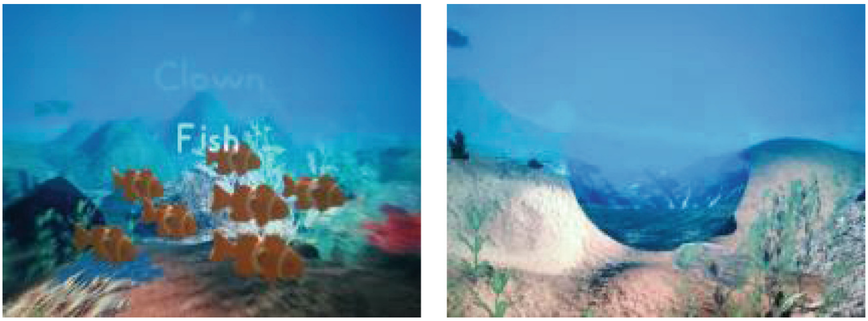

Fig. 3. (a) Different types of fish and marine life are identified in text. (b) Lens-like sphere provides transition or portal to "flashforward" taking the narrative forward in time

During a journey, sprinklings of evidence of human activity that is harmful and disruptive to the reef (e.g. pollution, litter, contamination) are seen. These devices are subtle reminders intended to stick in the participant's mind and provoke thought and questioning that may linger, resonate, and together with the design strategy described next, bleed out from the game [21, 22]. In addition, we incorporate a novel flashforward transition in the form of a lens-like sphere that is a boundary and portal to witness the same ocean area at a future point in time where the reef is unhealthy and destroyed, the coral is bleached, and the marine life and fish are gone (Fig. 3b). Participants' movements through the destroyed reef is again in a slow, gentle and unhurried manner, intended to open opportunities for reflective thought and contemplation on the damaged and destroyed reef. At any point participants are free to transition back to the healthy reef. Experimental design features are the slow pace and movement, and the disturbing experience following observing the destroyed reef. As participants are free to explore the VR reef for as long as they desire the interactive narrative and experience is potentially never-ending. Finally, the lens-like transition and portal provides a novel device to articulate and manipulate time.

4 The Augmented Reality Reef Diorama

The Augmented Reality Reef Diorama is a three-dimensional virtual representation of Australia's Great Barrier Reef in miniature (Figs. 4 and 5). Research is focused on exploring novel means through which narrative can be progressively revealed, paying particular attention to the role of participant interaction in virtual and augmented reality spaces.

This work seeks to depict the gradual degradation of the Great Barrier Reef's flora and fauna over the last century. The diorama is viewed via an augmented reality interface (tablet, smartphone) and appears superimposed onto a real-world surface. Upon initial viewing, the participant is presented with a virtual diorama of a healthy and pristine Great Barrier Reef. The real-world marker image disappears entirely, and the space it occupies is replaced with a window through which the virtual scene can be viewed. This work is intended to be viewed with the image marker placed on a flat surface, so that when it is activated the participant is able to look down 'into' the diorama scene. The now-transparent surface of the image marker acts much like the floor of a glass-bottom boat. Looking down through the window, the participant can see several meters of ocean and a segment of the pristine Great Barrier Reef, teeming with corals and marine life, along with a dynamic shoal of AI-controlled angelfish driven by a modified version of Craig Reynold's 'Boids' flocking algorithm [23].

Attached to the window's edge is a virtual button labelled 'tap to begin'. Prior to pressing this button, the participant is able to view the pristine reef diorama unimpeded, supporting our intended aim of allowing narrative reveal to take place at a rate determined by the participant. Once the button is pressed, it snaps from its original position to the point on the window's edge closest to the participant's viewpoint, and when they move the device the button moves with them. This is the first indication that the diorama reacts to the participant's view angle.

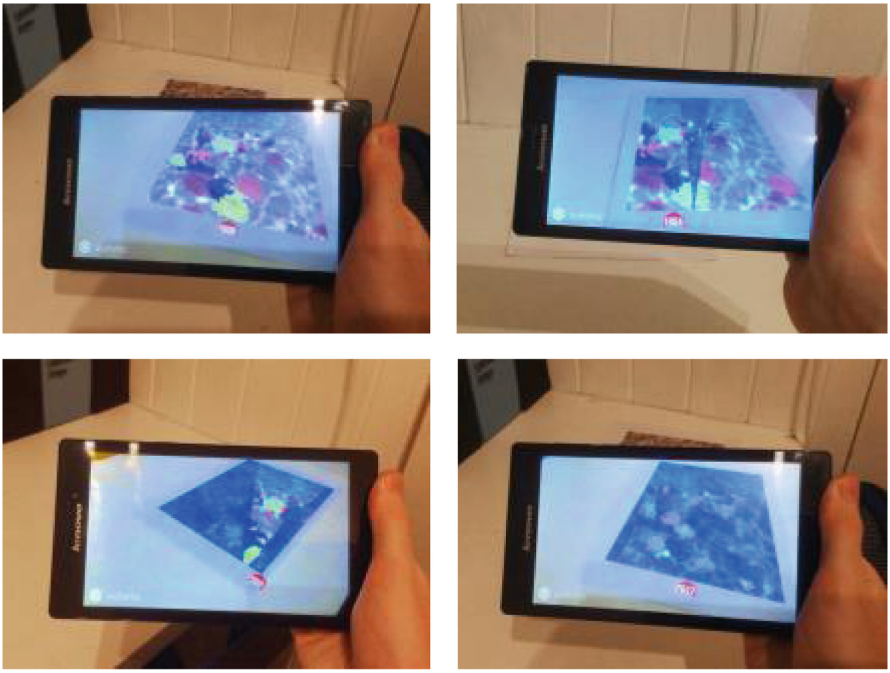

Fig. 4. Augmented Reality Reef Diorama: three-dimensional virtual representation of Australia's Great Barrier Reef viewed through a tablet device showing several metres of ocean and progressive narrative unfolding from pristine and healthy reef (top l-r) to gradual degradation (bottom l-r)

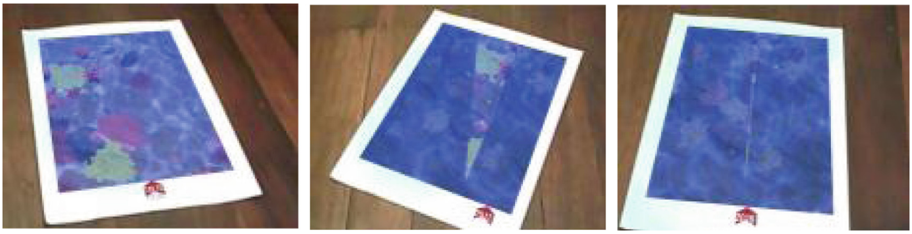

Fig. 5. Screenshots of the Augmented Reality Reef Diorama three-dimensional virtual representation of Australia's Great Barrier Reef superimposed on the AR marker showing progressive narrative unfolding from pristine and healthy reef (l-r) to gradual degradation

As the participant moves the tablet device a small sliver of the diorama opposite the participant turns a notably darker colour. Further movement reveals that the sliver's size is proportionate to the difference in angle from the participant's view and the page's upright direction. In order to reveal more of the hidden content, it is necessary to physically walk around the diorama. It rapidly becomes clear that the slice is from an entirely different diorama; as the participant walks around the diorama, the scene progressively updates and a larger portion of the healthy reef scene is replaced with the second, hidden scenario. The new diorama depicts the same area of reef in the near future. Eventually the unfolding diorama reaches a point in time where the reef is destroyed beyond repair; the coral is bleached or dying, the water is cloudy and polluted, and much of the marine life is gone. When a large portion of both dioramas are viewed simultaneously, the participant can see the fish shoal dart into the future diorama and instantly disappear, visible only as a faint glimmer until they reappear fully restored out the other side.

In this way the diorama can be conceptualised as a clock face where the participant acts as the second hand. By circling around the diorama a progressively greater ‘slice’ of the next scenario is revealed, allowing the participant to experience the changing environment at their own pace. When the participant begins to move the transition effect is subtle, but as they continue to move and a larger amount of the new scene is revealed, the transition becomes overt and impossible to ignore; an unfortunate parallel with the fate of the real-world Barrier Reef.

The Augmented Reality Reef Diorama achieves a successful negotiation between designed narrative, and participant-driven narrative; the two primary methods of narrative presentation. Utilizing participants’ body movements and proprioceptive sense provides an experimental approach to update and unfold narrative and story so they actively and physically drive the narrative forward. This is intended to encourage a deeper involvement and contemplation with the narrative and the work’s serious purpose, and stands in contrast with the role of an audience member or spectator of a film, animation or augmented reality scene where narrative unfolds without participant involvement.

5 Discussion and Conclusion

This paper presents on-going research carried out over several years to explore design strategies, grammars and languages to construct, articulate, manipulate and drive narrative in digital games, virtual, augmented and mixed reality. Described are approaches to create synergy between designed narrative with interactive narrative. The purpose and theme continued in the case study presented herein is to raise awareness on issues and human activities disrupting and effecting the Great Barrier Reef. In particular, the focus and new work presented in this paper is on augmented reality diorama (miniature 3D digital model) with participant-driven narrative. Through firstly, a standard interactive slider to manipulate the timeline and update narrative (not the focus of this paper), and secondly by utilizing a participants’ body movements and proprioceptive sense to update and unfold narrative and story, they actively and physically drive the narrative forward. These participant-driven design strategies are intended to encourage a deeper connection, involvement and contemplation with the narrative and the serious purpose. Described herein is a framework that has guided and provided inspiration for the design and development of experimental digital games and experimental serious games over the last few years and has provided inspiration and guidance for the novel designs presented herein.

In contrast to the Reef Game and VR Slow Immersive Reef Experience (Sect. 3), augmented reality diorama represents a narrative that is not only shorter in length but also smaller in size or miniature. So, it could be appropriately referred to as short form or micro-AR diorama to represent being both miniature in size and shorter in length. This is highly appropriate and consistent and connects on many levels with today's digital media use with mobile, social media, and YouTube, etc. where attention and use is short and brief. The short form allows participants to engage with and consider a topic in a short timeframe. Much like short news items on-line, through TV news updates or news ticker. Once participants are drawn in through curiosity, have their interest piqued, or desire to learn more, participants can choose to uncover greater detail and explore the serious purpose in more depth. The advantage that AR dioramas have is that they provide wonder, intrigue and a wow factor that heightens experience, is memorable, and so provides motivational drive to want to experience more AR dioramas on serious topics. In future work we aim to carry out an investigation and comparative study between our reef game, VR, and AR in order to reason about experience of use and experience from use (i.e. usability and player/UX) [24].

We envision that future developments in augmented reality dioramas not only facilitate an ideal platform for display of short form narrative, news, campaigns, vines, advertisements and promotions, but also for short dramas and stories. Furthermore, we envision that long form counterparts of these AR dioramas will inevitably emerge and lay the foundations towards AR cinema and theatre.

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Games for Mental and Moral Development of Youth: A Review of Empirical Studies

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Abstract. This study aims at critically reviewing recently published papers on the use of games for serious purposes to help young people's mental and moral development. The objective of this review is: (a) to present the empirical evidence of games for serious purposes as an effective vehicle to transfer moral value orientations and positive emotions; (b) to identify the explored area of the game impact and evaluate the effectiveness of a game impact from the previous studies; (c) to summarize different game assessments and study designs of the previous studies; (d) to define future research perspectives. After searching several influential databases, 26 relevant articles were included in the study. This review provided empirical evidences that games for serious purposes may improve young people's prosocial behaviour, empathy, emotion regulation, mental health and moral belief. Furthermore, these games can change people's attitude, affect people's behaviour and even influence people's psychological state. This review made a comprehensive summary of game assessment including in- and out off-game assessment and detailed analysis of study designs from the previous study. The current finding reveals that studies about prosocial games are of relatively good quality, and that there is great potential for the study of games regarding empathy and moral development. Besides, in accordance with Johnson and Hall's Job Demand-Control-Support (JDCS) model, a new and innovative way of classifying games is proposed: purpose-driven, action-driven, mode-driven and game context-driven.

Keywords: Serious games · Mental health · Moral development · Young people · Empathy · Video games

1 Introduction

Academic research about video games last for over two decades. The early research focused on the negative effects of the digital game play, particularly on the potential harm related to aggression, addiction, social isolation and depression. There has been a rising interest on the positive impact of game play for recent years. Figure 1 shows that the STEM was and still is the most commonly explored area in terms of serious game

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and Game-Based Learning (GBL), and suggests the surprising fact that the research interests have stayed almost the same over the past decade.

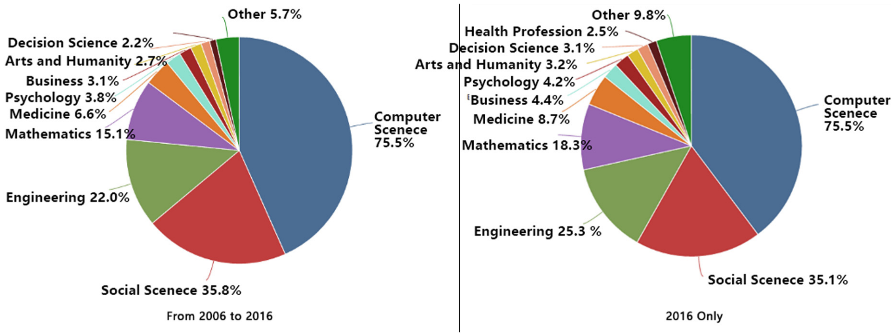

Fig. 1. Search results of term "serious game" and "game-based learning" given by Scopus database. Left image shows the result from 2006 to 2016. Right image shows the result of 2016 only.

According to the uses and gratifications theory developed by Katz, Gurevitch and Haas, mass media are supposed to satisfy 35 needs which can be put into five categories: cognitive needs, affective needs, personal integrative needs, social integrative needs, and tension release needs [1]. Games, one of the most popular and promising mass media, should have the potential for satisfying the above five needs. Several reviews are investigated to look into how the video or serious games fit the cognitive needs and affective needs (mainly motivation and engagement) [2–5]. However, there is no comprehensive review about game impact on mental health and moral development, focusing on young people's personal and social integrative needs, tension release needs and affective needs. In order to provide strong evidence and confidence to inspire more researchers to work on the largely unexplored mental health benefits and moral inculcating ability of gaming, the present research is devoted to summarize empirical evidence in research of games for serious purposes for positive youth's development in last decade.

2 Search Strategies for Literature and Games

Taking the games terms which are derived from a previous search carried out on the evaluation of computer games as a reference, the words and phrase are used in this study as follows: ("computer game "OR "video game" OR "digital game" OR "serious game" OR "games-based learning" OR "online game"). Terms for mental health or moral development are derived from consideration of terms used for affections and morality as well as specific impacts and outcomes such as, confidence, self-efficacy and empathy: ("emotion" OR "affection" OR "mental health" OR "moral" OR "moral belief" OR "social skills" OR "empathy" OR "altruism" OR "humanity" OR "confidence" OR "self-efficacy" OR "self-esteem" OR "ethical").

In this study, we focus on the large and accessible databases which are relevant with subjects of education, information technology and social science: Scopus, Science Direct, IEEE/CSDL and PLOS.

Several detailed criteria were refined to select appropriate papers for inclusion in the review as follows: (a) the paper should be published between January 2006 and Dec 2016; (b) the paper should include empirical evidence relating to the impacts and outcomes of playing games; (c) the involved participants' age should be between 7 and 30, which can meet the definition of young people; (d) the paper should contain positive conclusion related with mental health or moral belief and those papers; (e) the paper has an abstract.

The criteria for exclusion were as follows: (a) research only include on traditional games such as board games; (b) research only aim at unhealthy people and only include participants with mental health disorders; (c) research only focus on pleasure of engagement and motivation; (d) research only give prominence on knowledge acquisition, content understanding, perceptual, cognitive and motor skills.

We also searched serious games though the following four sources i.e. games included in selected papers, Google, YouTube and Steam. The keywords and phrases used in the searching engines are ("educational game" OR "serious game" OR "moral education game" OR "humanitarian game" OR "games for students"). For the games included in the paper, the author installed and played the game if the game or its installation could be found online. If a game was not available on the Internet, the author watched its gameplay on YouTube instead.

3 Data Analysis and Result

A total large number of papers (3820) were identified with the term indicating a huge growing interest in issues relevant to the mental health topic. However, only a few papers (26) meet with the inclusion criteria suggesting that there is still great potential in the video game researching area related to young people's mental and moral health development.

3.1 Research Methods Used in Previous Research

Four main research methods consisting of Randomised Controlled Trials (RCTs), quasi-experiment, correlation study and qualitative study are adopted in this academic domain. Because several papers contain more than one experiment and some papers select a mixed method (e.g. RCTs and qualitative study), the total number of experiments is 38. Figure 2 shows the experiment numbers for each four methods and the proportion of Serious-Game-Based (SGB) studies and Video-Game-Based (VGB) studies.

Connolly appealed to researchers for more RCT-based studies and high-quality qualitative studies [6]. After years, there is apparent ascent in RCTs, however, it's hard to define a non-game-based control for experiments in these RCTS because game can offer additional experience (e.g. leisure, audio-visual stimuli) which are hard to

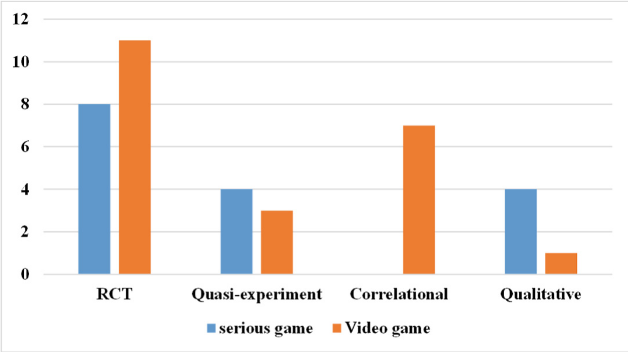

Fig. 2. Number of experiments of different types included in the relevant papers

simulate separately and offer to participants. In our findings, researches established three strategies to figure out the above issue as follows:

- Introduce a "neutral game" as the control condition
- Embed the "control condition" within the game design itself
- Offer the similar core information and experience by other media as the control condition.

The first strategy is widely used and accepted in VGB research, especially for the ones aiming at prosocial or violence topics. Many research studies use *Tetris* as the "neutral game". Gentile used pilot test to rate the selected games by young people themselves on its prosocial and anti-social aspects, and he used much more modern games (i.e. *Pure Pinball* or *Super Monkey Ball Deluxe*) validated by the pretest as the game for control condition [7]. The second strategy is perfect to align all the other influence in the control condition and treatment condition. One study splits participants (from western developed countries) into two groups (journalists and refugees) in a serious game named *Haiti Earthquake,* to experience different character perspectives and explore the impact of character identification on empathy [8]. Some studies use different game mode (i.e. competitive mode and cooperative mode) as the different conditions. The third strategy is also commonly used and normally infers more reliable conclusions as a control condition. In the research of sympathy for homeless people, reading a story based on a homeless character, which can offer similar information compared to the *Homeless* gameplay, is used as one of the control approaches [9]. A more creative control group example is asking participants to conduct internet research and create a PowerPoint presentation of a different country's life. In this case, by self-learning with the internet, participants can not only get similar information as the treatment group but also a similar experience due to this active learning process [10].

There is no correlation study of serious games at the moment. There may emerge some correlation studies in the future in order to have a better overview as the acceptance and quality of serious games improves.

3.2 Participants Involved in Previous Research

Participants are coded according to education levels. A large sample of participants (13694) are involved in these selected papers and Fig. 3 shows a wide range of young people covering primary, secondary, tertiary and higher education. Participants are also spread across many different countries. For example, in the study of international evidence of prosocial video games on prosocial behavior, participants from the United States, Japan and Singapore are picked [7]. This quantity and variety of participants contributes to the reliability of conclusions of these papers. It seems that academia lays more emphasis on the primary and middle school students, which cover more than 60% of the participants, however, the amount of high school participants, which is less than 500, is surprisingly low. This dearth of high school students suggests that more academic attention should be paid to these adolescents.

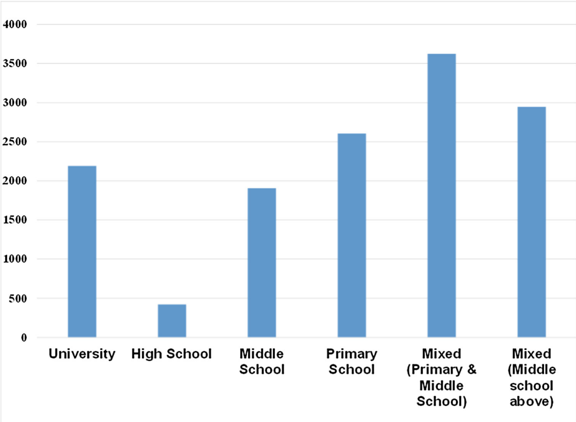

Fig. 3. Number of involved participants at different education phases

3.3 Genre of Games for Serious Purposes

The majority of classifications focus on the commercial video game [11], but it is not useful for analysis of games for serious purposes. Johnson and Hall's JDCS model is a good basis for an alternative taxonomy of game genre. The model operates with three main dimensions: job demands, job decision latitude and job social support. In a video game context, the three dimensions refer to purpose, actions and game mode. Purpose indicates the objective of a game or a segment of a game, for example, the objective of video game *Lemmings* is to guide as many Lemmings as possible from the entrance to the exit. Actions imply each step players need to take in order to achieve the task purpose, for example, the action of *Lemmings* is to assign different skills to different Lemmings to clear the obstacle or create a safe passage through the landscape. Game mode refer to whether it is a single- or multi-player game, in other words, the type of connections between players and how strong the connection is. Game context, which specifies the background story of a game or the storyline of a game, is another important dimension of serious games.

In conclusion, in order to reach a prosocial educational purpose, there are four approaches including purpose-driven, action-driven, mode-driven and context-driven according to the above analysis of four dimensions of a game. Table 1 shows 20 games we found by our searching strategies. If a game does not have clear objectives, the game is excluded from the purpose-driven approach, such as *Real Lives, Nintendogs, Killbox, Haiti Earthquake, The Sims, Gone home* etc. The aim of these games is to go through an experience instead of accomplishing certain goals. It should be noted that a game is more likely to be boring without an explicit purpose.

Table 1. Selected games classified by four driven mode

Game title	Purpose-driven	Action-driven	Mode-driven	Context-driven
Homeless: It's No Game	√			
MindLight		√		
Dojo		√		
ZooU		√		√
Lemmings	√	√		
Haiti Earthquake		√		√
Real Lives		√		√
Nintendogs		√		
FearNot!	√	√		√
Gone home				√
Agar.io			√	
Killbox				√
Wii Sports			√	
Don't Starve Together (multiplayer)			√	
The Sims		√		√
Inside	√	√		√
3rd World Farmer	√	√		√
Darfur is Dying	√			√
Stop Disasters!	√	√		√
O.Zen		√		
Total number	**7**	**13**	**3**	**11**

As to a well-designed action-driven game, the players are supposed to take a series of prosocial and purposive actions in order to complete the task. However, some game designs are over-simplified so that players can only take limited and straightforward actions. For example, in *Homeless: It's No Game*, the only action that players can take is to move the virtual character to collect food to keep alive in the street. These kind of games are excluded from the action-driven approach, because these actions cannot influence players' thinking and reflection on their behaviours or the game content.

There are only 3 games adopting mode-driven approach. *Agar.io* is a massively multiplayer online (MMO) game and it requires teamwork to gain as much mass as possible by swallowing smaller cells without being swallowed by bigger ones. *Don't Starve Together* also requires players to share collected resources and work together to get over the dark cold night.

A context-driven approach has three sub-types. The first type is to use stories as background information, with the game play not affecting the story at all, such as *3rd World Farmer*, *Killbox* and *Stop Disasters!*. The second type is to embed the story into the game and players can understand and alter the storytelling of the game during game play, e.g. *Haiti Earthquake, ZooU, Darfur is Dying, Real Lives, FearNot!*. The third type is to use narrative as a motivation for players to play, such as *Gone home, Inside, The Sims*.

In summary, many games which only take one approach actually could be better designed. Besides, pure entertainment game like *League of Legends* also experimented in curbing players' negative behaviour by introducing "Honor initiative" and "Tribunal system", which encourage players to commend the others for excellence in teamwork and mete out warnings and bans for negative player behaviour. As a result, negative chat saw a decrease by 32.7% and positive chat went up by 34.5% [12]. It is encouraging that big companies like Riots Games is paying attention and instituting strategies to players' mental health and moral development now, and it further support the idea that players' attitude, behaviour and psychological state could be effectively influenced by well-designed games.

3.4 Assessment in and Out of Game

Two types of assessment of serious games are discussed in this section: (1) in-game assessment that contains all the assessment embedded in the virtual game world, and (2) assessment out of the game, which includes assessments taking place in the real world.

With regard to real world assessment, there are 6 common approaches: (1) surveys, (2) pre- and post-questionnaires that are often validated with a decent Cronbach's α value, (3) pre- and post-questionnaires with a follow-up one (e.g. several weeks or months after the experience) to assess long-term lasting effects, (4) situational judgment tests referring to contextual tests and behavioural tests, e.g. completion task of word fragments list [13], sequential modified prisoner's dilemma game (PDG)[1], and helping tasks such as picking up intentionally spilled pens [14] or returning lost letter [15], etc., (5) interviews or participants' self-reporting, (6) mixed approaches.

In the identified papers, most research deployed the second approach of pre- and post-questionnaire which were less convincible. 5 SGB and 5 VGB research used the third approach. 7 VGB and only one SGB research further adopt the fourth approach.

[1] Participants are supposed to assign their partner certain tangram puzzles to complete. There are several puzzles of three different levels including easy, medium and hard. Participants could help their partner by assigning easy puzzles, or hurt their partner by assigning difficult puzzles. The evaluation of one's prosocial attitude can be assessed by their behaviour.

Another interesting finding is the “real-time” assessment used by three studies which collect the Heart Rate Variability (HRV) data [16, 17]. electroencephalogram (EEG) [18] and during the participants’ gameplay for analysis. Another in-game assessment strategy is a bi-feedback game design mechanism: according to participants’ decision or choice, the game can give a response by leading to different situation (e.g. different narrative branch, different character personality) and this response should also influence participants subsequently. Within the relevant papers, three games take the storyline branch design [8, 19, 20], and one game take the character personality design [21].

3.5 Categorization of the Game Impacts

Impacts of playing games are analysed in terms of the following two aspects.

Area of impact. The aim of this review is to find empirical evidence that support games can be an effective vehicle for inculcating moral values and improving mental health of young people. According to the selected papers, the most frequent research emphases are prosocial emotion and behavior (11) and empathy (6) followed by social moral (3), emotion regulation (3), bully prevention (2) and self-esteem (1).

Impact outcome effectiveness. Effectiveness is an important aspect of the empirical evidence. Three degrees of effectiveness are proposed for this paper: affective outcome, behavioural outcome and psychological outcome. By using experiments with questionnaires or survey, the conclusion can only be viewed as an attitude outcome. By using properly designed experiments containing situational judgment tests including high-cost contextual tests or behavioural tests, the findings can be regarded as a behavioural outcome. By using long-term well-designed experiments or short-term experiments with an additional follow-up questionnaire, the findings can indicate a lasting psychological outcome. In accordance with expectation, the most frequently outcome effectiveness is affective outcome (14), the easiest to prove, is more than the sum of behaviour (6) and psychology (6).

4 Discussion

4.1 Discussion of Assessment Design

Unlike knowledge acquisition, moral beliefs and affection is very hard to assess directly and people tend to hide their true thoughts when they fill a questionnaire. The approach of a simple questionnaire is not persuasive enough. As the data showed in Sect. 3, VGB research generally has more successful assessment design than SGB research, especially in respect of situational judgment tests which consist of contextual tests and behavioural tests. It should be noted that there are different levels of these tests ranged from low-cost to high-cost.

Picking up the spilled pens [22–24] is one of the lowest; returning the lost envelope [25] and offering help to be a volunteer for someone’s master thesis are higher [24]; the highest cost design is attempting to stop an aggressive intimidation of a male confederate, also found in Greitemeyer's study of prosocial behavior [24]. Greitemeyer made further contribution to the "spilled pens scenario" by introducing an independent experimenter who was not aware of the participant's experimental condition to spill the pencils, and the above modification avoid the potential influence of a dependent experimenter [24].

In contextual tests, completing an ambiguous story by listing possible actions of the main character [26], reactions after reading stories of actual persons or fictions [27], and completion task of many word fragments list in limited time [26] are lower cost, while behavior in a modified PDG and assigning partners tangram puzzles games of different difficulty to prevent them from getting reward are higher cost.

In a word, high-cost situational judgment tests are highly recommended as one of the assessment approach for the future research in this area. Besides, there is still a paucity in high-quality qualitative designs. The five papers (i.e. [9, 21, 28–30]) either use a qualitative approach (e.g. interview, report) as an adjunct of other research methods or are poorly organized with basic questions, flat analysis and absence of raw data from participants.

In addition, more emphasis should be put on real-time assessment. Though an overall meaningful interpretation of the physiological data is not provided and is unsolved [31], modern physiological measures are still promising and future measures of assessment (including facial electromyography (EMG) for measuring facial muscle activity through the detecting of generated electrical impulses [32], cardiovascular measures (e.g. interbeat interval, heart rate) [32], Galvanic Skin Response (GSR) for measuring the electrical conductance of the skin, Electroencephalography (EEG) for measuring the electrical activity along the scalp [33], and eye tracking for measuring either the point of gaze or the motion of an eye). Researchers should keep tracking the latest advances in this field and employ it. Physiological measurement is in particular effective when participants tend to hide their true feelings or reactions. For example, participants pretend to be fearless when they stand on clifftops in a virtual environment. In this case, it is difficult to judge only by a questionnaire or even observation, however, physiological data such as GSR can help researchers to reveal the truth.

In-game real-time assessment offers seamless experience for players and are more reliable. For example, in the game *MindLight*, by using an EEG headset that converts brain waves to the intensity of a head light of the avatar in the game, the more relaxed the players become, the brighter the "mindlight" shines, and the light is the only way that players can see in the dark haunted house [18]. Except physiological data like GSR, EEG or EMG, the movement of the body is also a possible input. Another design is to use players' decisions or actions as input, and the game reciprocates an "assessment" by altering narrative or character's personality. An excellent example is an interactive fantasy mystery adventure game named *The Wolf Among Us*. Players need to keep making decisions within the game, e.g. beating someone or persuading someone, each decision can not only lead to different storyline but also affect the main character's disposition to be gentler or more violent. The third possible design is to embed the survey, interview or self-report inside the game. The benefit of this design can offer a seamless experience and induce more authentic idea of the participants. For example, in the game *Haiti Earthquake* which offers two perspective (i.e. journalist and survivor role) to experience the aftermath of Haitians' earthquake [8], it could be a better instrument to plant the qualitative measure into the game itself by asking the player in the journalist's perspective to write daily news report and players in the survivor's perspective to write daily diary.

4.2 Discussion of Game Impact

As Sect. 3 revealed, games for serious purposes can have an impact on several areas including prosocial, empathy, emotion regulation, etc. It can also change player's attitudes and behavior and influence their psychological state.

Prosocial video game is the most investigated area. Several studies demonstrate that people tend to have more prosocial attitude and behaviors after playing a prosocial game even for a short time (8–25 min) [7, 22–24, 26, 34, 35]. One interesting finding is that five of the above seven studies adopt contextual tests or behavioural tests as assessment approach, and after a short-term prosocial video game play people incline to offer high-cost help to protect a girl from her ex-boyfriend [24]. Besides, the seven studies cover different prosocial games such as *Lemmings*, *Chibi Robo*, *Wii Sports*, *NBA Street* and a customized game. Study of *Lemmings*, which is a prosocial purpose-driven and prosocial action-driven game, reveals that the game play can reduce antisocial thoughts and encourage prosocial thoughts and positive feelings through assessment of ambiguous story stems and word fragments completion [26]; Study of *Wii Sports* and *NBA Streets*, which are cooperative mode-driven game, shows that cooperative game mode can motivate prosocial behavior [23]. Because the positive impact on prosocial reciprocity expectations, playing with a helpful teammate can further lead to an increased donation to strangers in the sequential assessment of prisoner's dilemma game [34]. The above studies provide strong evidence of positive effect from games with prosocial task purpose, actions and game mode. However, there is no study on impact of the context-driven prosocial game, for example the difference between a neutral game with and without a prosocial game context.

Three studies focused on the long-term effect of the prosocial game play by using questionnaire and survey on a large sample of people. One important finding of a study suggests that prosocial behavior tendencies and prosocial game playing are positively connected with each other and improve each other, and this study provides stronger evidence for a causal long-term relationship between prosocial game play and prosocial behavior. [7]. Another important finding of a long-term longitudinal study shows that both the prosocial- and the violent-game effects on prosocial behavior were mediated by changes in empathy and provides evidence that prosocial-media use can lead to long-term increases in trait empathy and helping [36].

Empathy also attracts great attention from researchers. Six studies about empathy are more diverse with a different research focus based on six different games. One study shows the great impact of game context by introducing the background story of Superman and The Joker to the participants before playing the video game *Mortal Combat vs. DC Universe*. The background stories, which make the participants have more empathy for Superman and The Joker, unexpectedly serve as an amplifier for already established attitudes and cognition widening the gap between "good" attitude and "evil" attitude [25]. *Lemmings* is also used to support the positive influence of prosocial games on empathy, and this study demonstrates that a prosocial-task-based game without any background story could also be helpful for empathic concern [27].

Several studies focus on game impact on moral education and bully prevention, but most of them use poorly-designed game. The only study based on a high-quality commercial serious game *ZooU* concluded mixed results. After 10-week intervention trial, children who participate in Zoo U showed significant improvements in impulse control, social initiation skills and cooperation, but also an increase on social withdrawal and anxiety level at the same time. Because social skills including moral and mental health development are particularly sophisticated and need long-term intervention, more qualitative study designs should be used and studies should focus on impact over 6 month or even a longer period.

It should be specially noted that researchers must carefully choose or design a game to investigate or support their research question and hypothesis. In order to prove the game is not poorly designed, the in-game experience including presence and flow should be checked. Compared to commercial games, serious games normally have much worse game experience and visual image and the poor experience could distort participants' feelings and result in a different research conclusion. For example, *Nintendogs* developed by Nintendo has vivid image and animation of a virtual 3D dog. A study based on this game concludes a computer-simulated virtual pet dog might be able to influence children's development of humane attitudes and empathy [21]. If the study based on a pixelate virtual pet dog (just as the virtual pet games in 1990s), the research result is probable to be different.

In summary, studies about prosocial are relatively high-quality, while studies about empathy, which examine the game impact for empathy by several different games with different assessment approaches, are also good. Because the poorly-designed games are used, studies about moral issues are relatively low-quality and the results are mixed. Furthermore, regarding to moral and mental health issues, there are great potential for a wider range of areas such as domestic violence and the current refugee problem.

The authors are currently working on a research project about history empathy in terms of Holocaust education for young people and developing a serious game for the National Holocaust Centre and Museum. The game features interactive storytelling about the Kindertransport programme that helped ten thousand children escape the Holocaust. The game utilizes the latest Augmented Reality (AR) equipment HoloLens. This AR technology has an amazing ability to mix virtual 3D characters into real world environments. According to findings of this paper, the game will be developed using the latest 3D game engine to guarantee a vivid image and animation so that players can have a good in-game experience. The game will be designed in a mixed way which combines purpose-driven, action-driven and context-driven approaches. To be specific it will set up a certain task purpose with a series of actions that players should take, and will use narrative as a motivation to encourage players to dig into the story, similar to the video game *Gone Home.* To ensure the reliability of the conclusion, contextual or behavioral testament would be adopted as the assessment approach. Besides, qualitative research methods including individual interview, observation and personal report will also be taken into account. This AR based study can contribute to the study of serious games' impact regarding empathy and understanding of the connotations of moral education based on serious games in a museum environment.

5 Conclusion

The current review provided empirical evidence to support the educational effectiveness of games in moral and mental development of young people. The four dimensional analysis of the game proposed in the current study has helped to provide an innovative new approach for classifying and analyzing games for serious purpose.

Studies about prosocial games are of relatively good quality, and the previous studies only covers parts of the area in terms of prosocial, social moral, bully prevention, empathy, emotion regulation etc. There is great potential for a wider range of areas regarding mental health and moral development. In order to avoid distorting the emotions of players and collect the reliable data from the players, it is essential to use or design a game with a good in-game presence and flow experience and it is important to employed well-designed game assessment including in- and out of- game assessment.

As most studies adopt quantitative study design such as RCT and quasi-experiment and there exist not enough studies which have been conducted over a long time span. There is a need for more high-quality qualitative study and more longitudinal studies to provide deeper understanding of the effectiveness and advantages of game-based education.

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None in Three: The Design and Development of a Low-Cost Violence Prevention Game for the Caribbean Region

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Abstract. Domestic violence is a persistent and universal problem occurring in every culture and social group, with lack of empathy identified as a contributing factor. On average, one in three women and girls in the Caribbean experience domestic violence in their lifetime. In this paper we demonstrate the techniques used during the creation of a low-cost, violence prevention game titled *None in Three*, targeted at enhancing empathy and awareness among young people in Barbados and Grenada. A research trip was undertaken to gather photographic reference and to meet with young people. Methods to measure the emotional state of players and awareness of characters in-game were explored. Cost-saving measures such as asset store purchases were evaluated. Custom tools were created in order to speed up production, including a bespoke event editor for multiple-choice dialogue sequences, and the use of motion capture libraries and auto-rigging tools to speed up character animation workflows.

Keywords: Game design · Young people · Serious games · Emotional Intelligence · Gender based violence · Violence prevention

1 Introduction

Video games have been used as a medium through which to educate children for decades, with a large number of teachers using them in the classroom. A 2013 survey found that 74% of K-8 teachers reported using digital games for instruction [1]. There are lots of games designed to educate children that focus on the development of hard skills directly related to the curriculum, such as *Starfall* [2], a game aimed at enhancing children's reading and arithmetic skills.

Recently, educational games have attempted to teach soft skills as well. In order to achieve this, these games have attempted to provide a role-playing experience, through which players can explore scenarios and perspectives they may not have experienced in their own lives. Through such role play, players can develop interpersonal empathy towards real-life situations and interactions [3].

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These games present more challenges in design and technical implementation than their hard skill counterparts, due to the range of character expression and possibility that role playing intends to offer. Increased technical challenges typically require larger teams, more time and as a result larger budgets to overcome.

Although abstraction of the themes and visual elements can reduce the time required to develop detailed content, this can limit how closely a player can relate to the situations on screen. Are there design techniques that can be used to make the most of small teams? What technologies can be used to reduce the workload when designing games featuring 3D characters, animation and branching dialogue?

This paper reveals the design considerations made during the creation of a low-cost Domestic Violence (DV) prevention game, created for children and young people in the Caribbean as part of the None in Three project. *None in Three* is a European Union funded project, aiming to preventing domestic and sexual violence in the Caribbean. The project targets not only victims and perpetrators, but children, young people, adults and agencies across wider society. As part of this project, a serious gaming intervention has been developed, aimed at facilitating behavioural change.

2 Serious Games for Raising Awareness of Sensitive Issues

There are numerous different approaches to games for wellbeing. Some games are designed to be provocative, and encourage the player to think about issues that may not directly involve them. The designers of these games may go about addressing these issues in subtle ways, so as to appeal to a larger audience. *Papo & Yo* [4] is a game in which the player must solve puzzles alongside their monster companion, who becomes violent if he is exposed to poisoned frogs. This behaviour change upon exposure to a substance is an allegory for the alcoholism of the player-character's abusive father, and this is revealed in the closing moments of the game, as the imagery used in the game switches with that of the player-character's reality [5].

Other games can be more upfront with their themes, presenting them through gameplay systems. *Papers, Please* [6] is a game about border control. Assuming the role of an immigration inspector, players must identify the correct documentation, letting only those legally allowed to enter the fictional Arstotzka past the checkpoint. However, players can choose to sympathise with the situations of individual characters and let them through at the risk of their own family's safety. Due to the nature of these gameplay systems, the game raises awareness of how borders can separate families, and presents players with a moral dilemma.

Bespoke games built to deal with social problems are very rare. In particular, games dealing with sensitive topics, such as child neglect and unhealthy relationship behaviour do not often reach a large audience. *Rosie 2* [7] is a 2D child protection simulation created by the University of Kent, designed to assist health visitors and social workers with recognising the signs of child neglect. *Rosie 2* is structured into multiple scenes, with players engaging in conversations with the family members and children concerned. Players can choose to ask specific questions to build up a more complete picture of the situation. Players can flag objects in the background of scenes as cause for concern, and the player is told which of these they were correct to flag, providing constructive feedback on the player's own choices.

In order to analyse emotional responses to the simulation, the development team used a face tracking monitor to determine the facial expressions used by players. With this data they could analyse which in-game events were causing changes in a player's emotional state. Such technology can be expensive and difficult to implement, and so unlikely to be beneficial in resource-limited countries such as those for which the *None in Three* game is intended.

Honeymoon is a 2D visual novel created for a competition by the Jennifer Ann's Group [8], designed to raise awareness of unhealthy relationship aspects, such as controlling behaviour. The game features multiple conversation choices and decisions on how to present yourself in the game. Through dialogue, it is apparent that the player's character is becoming a victim of controlling behaviour of their new relationship partner. The other characters in the game provide different perspectives on the situation, allowing the player to understand not just how the unhealthy relationship behaviours affect the player, but everyone around them as well.

Honeymoon also promotes self-reflection between different scenes, by asking rhetorical questions about the behaviour of its characters. This is a way of implementing formative feedback, which can be defined as 'information communicated to the learner that is intended to modify the learner's thinking or behaviour for the purpose of improving learning' [9]. By asking questions directly related to the themes of the experience, *Honeymoon* encourages players to think critically about these issues.

3 Design and Development of *None in Three*

None in Three is a point-and-click role-playing game in which players assume the role of multiple characters related to a family who are experiencing and perpetrating domestic abuse. The game is designed to positively affect player behaviour, intending to raise public awareness of the impact violence can have on everyone involved. The game will be piloted in schools across Barbados and Grenada before being made widely available across the region. Described next are the approaches taken to designing a violence prevention game.

3.1 Behaviour Analysis Methods

As the game is intended to lead to attitude and behaviour change, a method was required to measure the impact on players. Daniel Goleman's Model of Emotional Intelligence [10] provides a framework through which various factors of Emotional Intelligence in game players can be identified. These are split into four categories, two of which are personal competencies and two of which are social competencies. The first category is Self-awareness, which refers to how aware a person is of their emotional state. There are multiple ways to measure a player's emotional state. One of the most common methods is to request players to reflect upon their experiences after playing a game. Due to the subjective nature of emotional experience, data gathering of this sort is often of a qualitative nature, and is accomplished through surveys, focus groups or interviews. The disadvantage is that players may not be able to recall how they felt at the time. In order to avoid this problem, the game will attempt to measure a player's emotional state during gameplay.

Measuring a player's physiological responses can determine how their body is responding to the situations in the game. Cardiovascular signals can be measured with heart rate monitors to determine patterns mapped to emotional profiles [11]. Electrodermal activity can be measured by applying a low-constant voltage to the skin. As a participant's skin secretes sweat, the skin conductance causes a change in electrical activity, which can be used to identify stressful situations [12]. Physiological measurements remove the need for a subjective report from the participant, avoiding bias they may have with regards to awareness of their own emotional state.

Although many physiological response measurements are non-invasive [13], gathering data in this manner is a challenge due to the requirements of additional sensors and hardware. Given that the intended audience of this game is young people in schools in the Caribbean, it would be impractical to send sensors on a large scale to the region, potentially further disrupting the curriculum by spending time setting up these systems of measurement. Furthermore, the conditions of measuring this data can themselves have an impact on a player's emotional state [11]. Because of this, non-physiological methods of measurement during gameplay will be utilised.

Players can use real-time self-reporting systems built into games to identify their emotions. This technique can be used for measuring empathetic response, by requesting players evaluate the emotional state of the characters in a game. A systematic review of literature on self-reporting interfaces by Fuentes et al. [14] discovered 26 different named self-reporting interfaces between them. Of particular note is a self-reporting interface called AffectButton [15], which allows users to select a facial expression using a single mouse click. The resulting output is a three-dimensional value representing the player's pleasure, arousal and dominance. These values can then reveal the emotion the player was attempting to express. The *None in Three* game will feature a single-click self-reporting system based around the traits of AffectButton.

The second Emotional Intelligence category is Self-management [10]. This refers to how much control a person has over their own emotions, and how they then react. It also refers to how adaptable a person can be to changing situations. In the None in Three game players will encounter an abusive character with little self-control, who believes he is losing control over the changes in his life. Throughout the course of the game this character will be presented with better ways of dealing with his anger, including going to an anger management class.

The remaining two categories are social competencies, which revolve around recognising and managing the emotions of others [10]. Social Awareness identifies empathy as a key skill. To this end, the *None in Three* game provides many different perspectives on how its characters might be feeling by using the other characters as emotional lenses.

The final category is Relationship management. Of particular relevance to the *None in Three* game is the key skill Conflict management. In order to teach this to players, characters in the game will explain that certain interactions are not found in a healthy relationship, and suggest better approaches to dealing with conflict.

3.2 Prosocial Game Elements and Benefits

Although recent educational games have focused solely on prosocial gameplay, these elements are also found in mass-market games. Many video games include elements of teamwork and cooperative play, which are required to make progress. In *Portal 2* [16], players must work together in order to solve puzzles. Some of these puzzles require specific timing of each player's actions, which requires players to communicate effectively with each other. Other games allow multiple players to work together to reduce the difficulty of a game's challenges. In *Left 4 Dead* [17], players can use their own medical supplies to heal other characters, and rescue them if they collapse to the floor. Although the survival of the entire team is not required to complete a level, keeping more characters alive makes the game easier.

A significant number of video games provide opportunities for the player to help characters within them. Often this is through helping quest-givers with their troubles by accepting and completing their quests. Some games take the theme of helping characters and embed it further into the gameplay. *BioShock* [18] features defenceless characters known as 'little sisters'. If the player encounters one, they have the choice to rescue or harvest them. Harvesting kills the little sister, but provides greater rewards for the player. In offering this choice, *BioShock* asks a moral question – does the player kill an innocent character to become more powerful and wealthy, or do they rescue them for lesser rewards?

Another method through which games can encourage prosocial play is by defining consequences for player behaviour. *The Walking Dead* [19] does this by providing each game character with a memory of the player's actions. This is then intended to provide long-lasting consequences, which can cause players to be more considerate with their actions than they might be in other games.

The common thread throughout most prosocial elements in entertainment games, is that they provide players with further advantages if players use their systems with positive intent. This can lead to players taking prosocial actions in order to fulfil selfish strategies. Although players may be undertaking prosocial actions for personal gain, the positive feedback provided by prosocial elements can affect the attitudes of players. Gentile et al. [20] revealed that change in video-game use from violent to prosocial significantly affected change in helping, and that this relationship was mediated by change in empathy. This is in essence a reversal of the relationship between games that provide positive feedback to violent behaviour and a player's aggression levels.

3.3 Gameplay

The *None in Three* game features a number of gameplay systems that have been designed to allow the player to role-play as a variety of characters in various scenarios. These were drawn from qualitative research on domestic violence carried out by the project team with 109 adults (female = 49; male = 60) in Barbados and Grenada in 2016 [21]. Semi structured interviews and focus groups were recorded, transcribed and analysed thematically using a-priori themes drawn from a narrative review of the literature and the primary research questions. Key themes used to develop the case study, characters, and storyline were applied on a level-by-level basis.

The game features a multiple-choice conversation system, allowing players to question other characters to learn more about the themes that are presented to them. Being multiple-choice, replaying the game's content is encouraged, with the intended outcome being students discussing the options they chose with each other.

The game uses a point-and-click interface, with players clicking to walk to places and interact with objects. This was designed to be simple and fully controllable with a mouse by any player capable of using a computer, ensuring even children unfamiliar with computer games will be able to use it. To provide players with an interesting way to interact with the world, a drag interaction system was developed. This is used to build up tension in the first level, where players can open the door to the parent's bedroom slowly to overhear an argument the perpetrator of violence is having with his victim.

Given the game's audience ranging from children aged 10, to young adults aged 18, and the variety of skill difference among them, it is important to ensure that those who have less experience can continue to make progress. To facilitate this, a quest system was implemented to provide hints as to what actions to take. The game is designed so that players must undertake certain actions in order to complete a level. Due to the short amount of time players will have with the game, this ensures that players will complete each level, and experience more of the themes presented.

3.4 Game Structure

The *None in Three* game is based on a case study derived from original research conducted by the team and includes a variety of characters and themes. An important aspect of the game's development has been socio-cultural sensitisation to Caribbean context, through consultation with groups of young people in Barbados and Grenada and continuous input from Caribbean experts. This included a research trip to gather photographic reference and learn about the experiences of young people there. This has ensured that the game's environment, language, ambience and characters are based on Caribbean realities rather than being imported from elsewhere. To further this, the character dialogue has been recorded with voice actors local to Barbados and Grenada, who volunteered their time to speak the parts.

Each level is grounded in a Caribbean context, in terms of the environment and the activities undertaken. For example, in Level 4, players visit a Pool Hall, a popular Barbadian pastime. In Level 5, a roadside standpipe is visited, which is still a common sight for many in Grenada. The national dishes of both Barbados and Grenada are mentioned. Colloquial sayings are included, such as "*coconut don' grow 'pon pumpkin vine*" – meaning a child is not very different from their parent.

The game's content is split into 5 levels. Each level takes place in a different environment, with the player taking control of a new character related to the story each time. By allowing players to experience the themes from the perspective of different characters, they will discover the ways domestic violence affects more than just the primary victim (Fig. 1).

As a tool for use in education settings, breaking the game up into smaller sections allows for flexibility in the curriculum. Each level can have a lesson dedicated to its theme, and allowing a break between levels provides time for discussion.

Fig. 1. The 5 level structure of the game, with each level's primary theme

Level 1 is an introduction to the main characters involved, and begins on a typical evening. The main player character, Jesse, is a young schoolboy. In this level, players are introduced to the conversation system. The victim, Jesse's mother (Diana), is introduced along with the perpetrator, Diana's partner (Rondell). Players get the opportunity to explore the house and interact with objects while learning the movement system. Later, Rondell attacks Diana and players must help Jesse locate the ambulance number, which is the real-world number for their country. Including real-world information provides the game with an additional element of educational content. The level also references Rondell's drinking, which has been determined as a contributing factor to violence [21] (Fig. 2).

Fig. 2. Left - screenshot of Level 1, in which players must find the number to call an ambulance for his injured mother after she is attacked by her partner. Right – photograph of a bedroom in Barbados featuring similar wood, tiles and decoration.

Level 2 takes place in hospital the next day. Players control a nurse who is tasked with looking after Diana. The situation is complicated by the fact that Diana is pregnant, thus introducing another victim of Rondell's violence into the mix. Diana's fear of Rondell is revealed, when she lies about how she received her injuries. Players will learn how to reassure a victim, what the impact of violence on an unborn child can be and how to provide the victim with the information they need to escape from the situation. This level is based around the preliminary research that revealed how Domestic Violence does not always stop during pregnancy, and an abuser's behaviour can actually worsen during this period [21].

Level 3 takes place in Jesse's school. As Jesse's teacher (George), players must ask Jesse questions and attempt to discover why Jesse's behaviour and grades are suffering. Players will use a board game in order to get Jesse to engage with George's questions. This level is designed around the actionable outcome of getting victims and secondary victims to open up about what is happening in the home [21]. Levels 2 and 3 may also be used to provide training for professionals such as healthcare providers, nurses, social workers and teachers (Fig. 3).

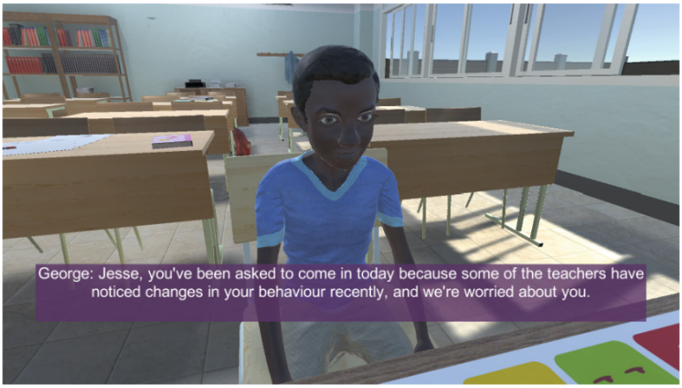

Fig. 3. Screenshot of Level 3, in which players must question Jesse through the means of a board game.

Level 4 features Rondell's best friend (Hayden), who goes to a pool hall to play pool with Rondell. Players can try to learn about Rondell's behaviour through questions between pool shots. This level draws from the research outcome that Men should be activists against DV - challenging negative gender attitudes and violent behaviours by other men. It is also revealed during this level that Rondell's father was violent towards Rondell's mother. This addresses research identifying DV as an inter-generational issue, with violence being perpetuated from parents to children [21].

Level 5 follows Rondell as he listens to advice. Players (playing as Diana) are given a choice to determine the outcome of the story, based upon the information and perspectives they have gathered from the characters in previous levels. The level explores how victims of DV can be conflicted in their emotions, both loving and hating the 'harmer', and also prepares players to handle conflict in relationships [21].

3.5 Low-Cost Game Development Techniques

Due to the scale of the project and the small development team, it was necessary to explore a number of cost-saving techniques, including the automation of some processes to save on staffing costs. The first decision that had to be made was which game engine technology to use. The two primary choices were *Unity* [22] and *Unreal Engine 4* [23]. Information about computer infrastructure in schools suggested computer hardware was variable and in many cases, would not meet the requirements for *Unreal Engine*. It was decided to create the game with *Unity* for this reason.

A significant amount of development time is required to manually create 3D game characters before they are ready to be animated, with rigging and skinning being time-consuming tasks. Fortunately, there have been several breakthroughs in the automation of these processes. *Adobe Fuse* [24] is a piece of character generation software that allows users to modify template characters, pulling sliders and adjusting parameters until they have characters that fit their specifications. *Fuse* also contains a library of motion capture ready to apply, covering a large number of the animations players would expect to see in a humanoid game. This meant that time could be spent creating bespoke animations unique to the game.

For bespoke animations where characters interacted with objects in the game environment, *Maya* was used for keyframed animation. For standalone, more natural motions, animations were created using motion capture. This was accomplished using a Noitom *Perception Neuron* suit [25], a magnetic motion capture suit. This allowed for animation retargeting using *Maya* to match the Fuse skeleton (Fig. 4).

Fig. 4. Left and Middle – volunteer voice actors local to the region. Right – motion capture suit.

Mixamo also generates facial blend shapes, allowing deformation of a characters face. This is used to further demonstrate how a character is feeling beyond their dialogue and motion. A plugin for *Unity* called Mixamo *Face Plus* was tested, which allows the user to make facial expressions into a webcam that are mapped onto a character using image recognition. The plugin provided inaccurate results, because of poor lighting and a lack of depth sensor information to support the webcam. Instead, manual creation of facial expressions was explored by creating blend shape poses as animation clips. This approach to facial animation differs from other low-cost techniques, which often rely on static avatars or animated texture maps to move a mouth.

As conversations in the game can have multiple paths and prompts, an event editor called Actus was created to visualise each piece of dialogue (Fig. 5).

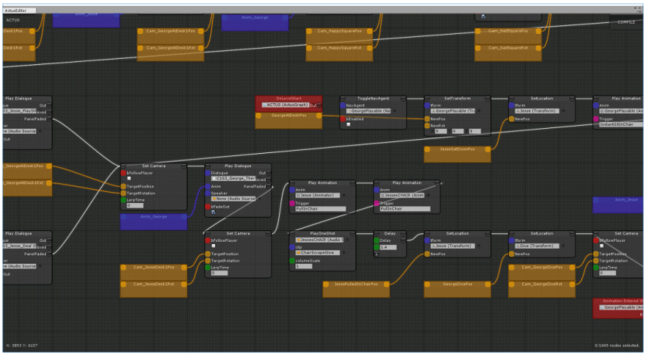

Fig. 5. The custom-built Actus Event editor, used to create branching dialogue and bespoke events for each gameplay interaction.

Actus contains variable support, multiple graphs and event handling. Function nodes are generated using reflection at editor time. Given that optimised run time performance is a project focus due to the low-specification computers in the Caribbean, the graphs created in the Actus editor are then compiled back down to C# functions and variables for speed of execution.

3.6 Game Analysis Process

In order to measure the impact the game will have, the *None in Three* team have designed an initial survey to generate a psychosocial profile of young people in Barbados and Grenada. This survey is used to ensure that the themes tackled in the game are issues that the profile reveals students being at risk of perpetrating. In addition to this, the team will create a pre-intervention and post-intervention survey instrument, which will be used to measure attitude and behaviour change in players of the game in comparison with a control group.

In order to support this, logging systems will be implemented in the game to gather player data. An Emotional Intelligence (EI) Indicator will appear after moments where a character's emotions in game have changed, and players will be tasked with describing how they believe this character is feeling by selecting from a choice of emoticons. The specific emotions used on the indicator are based on the 6 basic emotions put forward by Ekman [26]. The EI Indicator was prototyped initially to request that the player report on their own emotional state. However, Goleman's model [10] refers to both self-awareness and social awareness. As a result, the indicator is designed to provide a way for the player to guess the emotional state of others.

4 Conclusion and Future Work

In this article, we have demonstrated techniques that can be used to develop low-cost, violence prevention games. Methods used to gather data on a player's emotions were covered, including self-reporting of a player's emotional state. A number of cost-saving techniques were utilized including the use of *Adobe Fuse* and Mixamo's motion capture store allowing for the creation of a large number of characters and a. Creating younger characters was more of a challenge, with the templates not providing as much flexibility. The creation of animated sequences and varied level events was considered a large bottleneck if tackled through traditional programming techniques. As a result, an event editor called Actus was developed, which also allowed for a multiple-choice dialogue system to communicate with the rest of a level's functionality, saving implementation time connecting object types together.

During the piloting of the game, a study will be carried out to assess player's experiences, and determine if the intervention has had any impact on player's perceptions of violence and their emotional intelligence, particularly levels of awareness and empathy.

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Sliced Serious Games: Conceptual Approach Towards Environment-Friendly Mobility Behavior

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Abstract. This paper introduces the concept of Sliced Serious Games aiming to improve environment-friendly mobility behavior. The conceptual approach is motivated by two aspects: First, it is proven that Serious Games can help to learn or to change behavior in educational settings or games for health. Second, referring to climate and pollution, there is a strong need for environment-friendly mobility behavior.

The basic idea is to combine both aspects and to provide a playful environment to support environment-friendly mobility behavior. Technically, the key challenge tackles the characteristics of intermodal mobility chains when people are moving from A to B with modality changes and short time frames to play. For that, the concept of Sliced Serious Games considers activity recognition to figure out which modalities are used, and makes use of gamification principles to motivate users to change their mobility behavior and to use environment-friendly modalities.

Section 1 describes the intention of the approach and characterizes the overall research question, i.e. how to use serious games within intermodal mobility chains with changes among modalities and short time frames to play in a train, in a bus, tram, on a bicycle or during a walk. This leads to the concept of Sliced Serious Games being introduced in Sect. 2, considering related work and best practice examples. Section 3 describes two prototypes for Sliced Serious Games, 'Smog' and 'Fred'. The main results are summarized in Sect. 4, also providing an outlook for future research.

Keywords: Sliced Serious Games · Gamification · Activity recognition · Intermodal mobility chains · Environment-friendly mobility behavior

1 Introduction

1.1 Motivation

The research presented in this paper is motivated by two facts: On the one side, the ongoing climate change requires appropriate mechanisms to reduce CO_2 emission. This

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implies the strong need to create public awareness for this societal relevant topic and mechanisms to change the mobility behavior [1], especially the switch from car use towards more environment-friendly modalities [2]. Hereby, an ongoing trend is noticeable – primarily in the younger audience – to consider intermodal mobility solutions (e.g. pedelecs) away from the car – as 'one and only' vehicle and status symbol in former times [3].

On the other side, smartphones and wearables nowadays are widespread in society (according to a survey from Statista, worldwide 1.4 billion smartphones and about 207 billion tablets have been sold in 2015) and video games and are very popular – mobile games are the most popular category of mobile applications[1]. Young people as digital natives [4] grow up with digital media, smartphones and wearables. But also 'mid-ager' (as digital immigrants) and elderly people (as 'silver generation') use that technology and play video games. As stated by the German game publisher association BIU, in 2015 around 42% of the population in Germany (47% female) regularly played games; the average was 35 years[2]. Studies of Serious Games – as games with a characterizing goal [5] – prove the benefit of that kind of games for serious purposes apart from entertainment, e.g. towards an intended learning effect in the field of education [6, 7] or towards an intended behavior change in the field of health (therapy) and nutrition [8, 9]. Gamification principles [10, 11] are widespread both in the private sector (e.g. for location based games or fitness apps, cf. Quantified Self initiative [12]) and in industry (e.g. to enforce knowledge share in a company).

Goal. Based on that situation the goal of this research is to combine both sides and to elaborate a conceptual approach for sliced serious games enforcing environment-friendly mobility behavior. This implies the overall goal is to reduce CO_2 emission in order to hinder the ongoing negative climate change. Hereby, serious games [5] and gamification principles [10] are used as motivational instrument to consider the approach by users, to enter the system and to continuously use it.

1.2 Problem Definition

The overall question is how to encourage people to use environment-friendly modalities and to change their mobility behavior. More detailed, the following research questions arise, whereby the focus of this paper is set on the introduction of the overall framework and first conceptual approaches to tackle RQ1 to RQ4:

- How to structure a playful environment in form of a mobile game considering short time frames to play (research question RQ1)?
- Which game-based principles are appropriate for specific situations and modalities within a route from A to B (RQ2)
- How to figure out the context and modality of a user on a trip from A to B (RQ3)?
- Which scoring mechanisms are appropriate to motivate users and reflect their mobility behavior reasonable (RQ4)?

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[1] PocketGamer.biz. Ranking of the top 20 categories in the app store, http://de.statista.com.

[2] https://www.biu-online.de/marktdaten/deutscher-markt-fuer-digitale-spiele-2015/.

2 Concept for Sliced Serious Games

Figure 1 introduces the concept of Sliced Serious Games (SSG) and illustrates the working principle and scenarios how to use SSG. The overall aim of the approach is to support (motivate for) environment-friendly mobility behavior. Analogue, this serious aspect is the characterizing goal of the sliced serious game and determines the functionality of intermodal mobility assistants (which modalities should be considered, in which priority) and provides the basic conceptual information for the design of the game world. On a global, societal perspective, the game (approach) is successful when (the effects are proven that) many individuals change their mobility behavior and switch away from car use – resulting on a reduction of CO_2 emission.

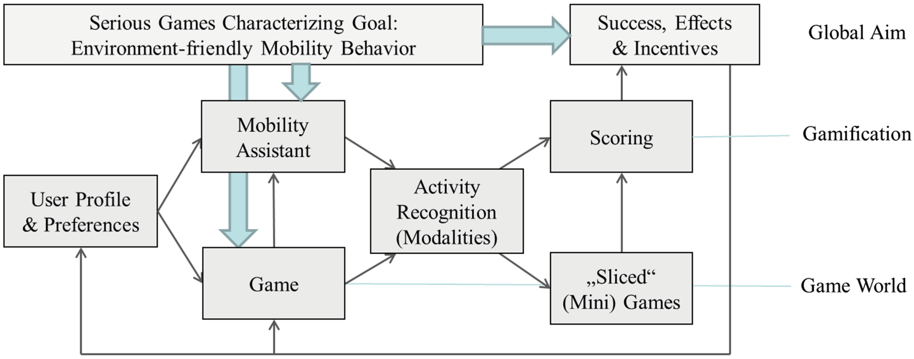

Fig. 1. Conceptual framework for sliced serious games.

Hereby, in principle it is not necessary to play games. Users might use a mobility assistant to select environment-friendly routes from a geographic location ‘A’ (departure) to a destination ‘B’, the system recognizes the activities (as basis to prove the effects) and provides good scores as rewards for choosing environment-friendly modalities. This scenario might be interpreted as ‘gamification version’, c.f. the upper layer in Fig. 1.

Contrary, a second scenario focuses on the use of games and sliced mini games, resulting in a real ‘game version’. Here, users optionally also use a mobility assistant, but the difference is that they start with a game and always come back to the game world during their intermodal mobility trips. As incentive, they get an additional score for the game activities – in addition to the score for intermodal mobility activities – enabling new functionality or further content (i.e. up-leveling) in the game world.

In both scenarios, further non-gaming incentives such as reduced price models for public transport might be considered by mobility service providers respectively are already discussed in townships (e.g. Darmstadt) as regulatory instance for public transport (systems).

In the following, individual components and major aspects of the framework for sliced serious games addressing the research questions are briefly described.

2.1 Components a Sliced Serious Games Framework

User profile and preferences. This component serves as administration and configuration component for the framework. User profile information includes personal information such as age and gender, but also gaming information and preferences on mobility behavior. Gaming information describes (i) the experience in gaming, attributed with categories such as 'casual/regular/hardcore gamer' (ii) preferences on game genres, e.g. 'strategy/adventure/action games' and (iii) player type information according to player models from Bartle [13] or Houlette [14]. Referring to preferences on mobility behavior, basic information includes the motivation and purpose/necessity for mobility resulting in categories of user groups such as pupils (going to school), commuters (students or employees on their way to work) or seniors (e.g. visiting a doctor, shopping or visiting a cultural event). User preferences are composed by classical factors like costs and time, but also psychological factors such as autonomy, arousal, status and privacy as well socio-demographic factors like income or size of a household [1]. The user profile information and preferences are used both for the configuration of the mobility assistant (modus and style: visual appearance and degree of provided information/information load) and the game world (game genre, gameplay, content and, again, user interface design).

Mobility assistance. Recently, more and more mobility assistants came up, not only traditional portals about the routes and schedules of public transport, but also in the form of mobility apps [15] both for individual mobility services such as car sharing or rent a bike and integrated services covering the offer of different mobility services, e.g. viel-mobil.de (for the Rhein-Main region around Frankfurt in Germany) or the intermodal mobility assistant (IMA) [16]. The goal of IMA is to provide an open platform, where mobility service provides can integrate their offer/service in a standardized way. The working principle of integrated mobility services/platforms such as IMA is divided into three steps (see also Fig. 2): The user (optionally) provides individual mobility preferences and (mandatory) defines a route with a starting point and destination plus date/time (1), the system figures out possible connections in a route search phase (2) and presents a list of possible routes/intermodal mobility chains – considering user preferences as basis for the ranking/listing of possible routes. Based on this list, the user selects one route (3). During travel, adaptations might be necessary according to traffic jam, delays of public transport, etc. These changes are automatically considered by the system (using real-time information of mobility service providers) and presented to the user.

Activity recognition. This component aims to figure out which activities a user performs respectively which movement modalities are used by the users (cf. RQ3). For that, activity sensors are necessary. The main challenge is to distinguish modalities such as 'in a bus', 'in a car' or 'in a tram'. Some libraries such as Google's Fence API[3], as part of Google's Awareness API developed for Android in 2016, offers an open interface for activity recognition. This API delivers information about the geographic location of a user, headphone states, modality types and the weather. Referring to the

[3] https://developers.google.com/awareness/android-api/fence-api-overview.

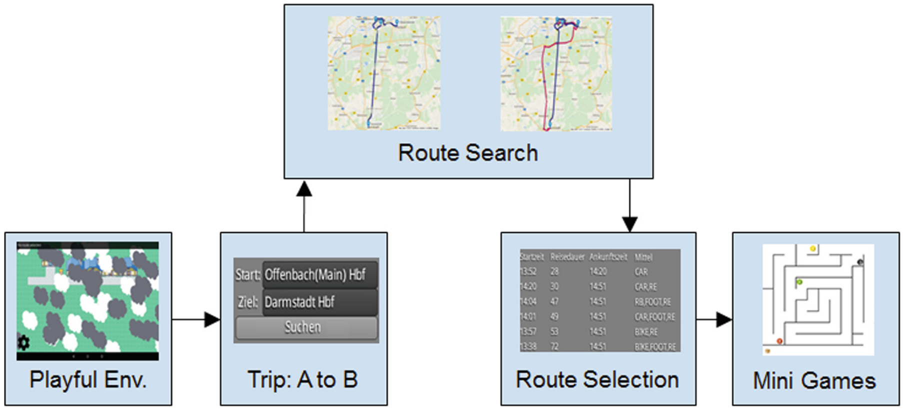

Fig. 2. Working principle of the sliced serious game 'smog'.

movement modalities, the states 'IN_VEHICLE', 'ON_BIKE', 'ON_FOOT' (as aggregation of walking and running), 'WALKING', 'RUNNING', 'STILL' and 'TILTING' (is set when the smartphone orientation changes significantly) are recognized. If it is not clear, 'UNKNOWN' is set. The API works very well for modality changes, but the accuracy rate of the recognition is only $\sim$70% and could be improved.

Scoring. Referring to RQ4 appropriate scoring mechanisms need to be elaborated providing a 'fair' rewarding system for the use of (more or less) environment-friendly mobility behavior. Apart from the movement modality, the duration of an activity is considered for the score per 'slice' of an intermodal mobility chain. Further, playing the games is also rewarded with points – whereby the activity points should have more weight compared to the game points. This implies that a user who uses environment-friendly movement modalities, but is not playing at all, gets a higher score compared to a user who is playing, but does not show an environment-friendly mobility behavior. Though, a user doing both – environment-friendly mobility behavior and playing a game (when possible) – has the best chances to become no. 1 in a leaderboard for environment-friendly mobility behavior.

Effects. The application prototype of 'ViaggaRovereto' [17] might serve as best-practice example validating the concepts of a gamified framework for environment-friendly mobility behavior. Within an experimental study over five weeks, users have been invited to use a mobility app: In the first week the users became familiar with the app and information about the mobility behavior of individuals (as baseline) has been collected on system side. In the following two weeks intermodal mobility chains have been suggested including movement modalities via car, train, bike sharing, bicycling and moving on foot. The suggested mobility chains (routes) have been ranked and presented to the user according to ecological guidelines. In the last two weeks the game 'Green Game con ViaggiaRovereto' has been introduced. The game includes 'Green Points' for environment-friendly intermodal mobility chains, 'Health Points' for passed distances by foot or by bicycle and 'Park & Ride' points when those services have been selected. Further, gamification elements such as awards in the form of badges, trophies and leaderboards are integrated. At the end of the experimental study, all participants received a certificate listing all received points and rewards. Additionally, as incentive the three most successful participants received a voucher for one-month free service provided by a bike sharing provider. The experimental study has shown two outcomes: First, the mobility app has been used much more frequently during the gaming phase. Second, the experiment has proven a positive mobility behavior change with the game: Whereas in the first week 49% of the users used the car, the amount significantly decreased to 21% in the gaming phase in the last two weeks.

2.2 Game Structure – 'Sliced' Approach

According to RQ1 the question is how to structure a (mobile) game world and particular 'sliced' mini games considering the nature of intermodal mobility chains and short time frames to play.

Most mobile games are used as casual games with a typical play time of 5–10 min [18]. During this time a complete mobile gaming experience for a user with a concrete task (goal of a game) is envisioned. Scolastici and Nolte suggest that this time should be even shorter, i.e. three minutes max [19]. Hereby, due to the short time span, the creation of immersion and 'flow' [20] is difficult respectively it is not possible to realize. Hence, mobile games should be flexible, easy to access ('dip-in-dip-out' principle with an easy start and ending a game) and easy to play (gameplay, game mechanics). Referring to the narrative aspect, Flintham et al. suggest to structure the underlying story of mobile games into episodes [21]. Popular games following that episodic structure represent the facebook game 'CastleVille' provided by Zynga. The episodic structure has the advantage that the game is not limited to a fixed story, but is extensible in the form of additional episodes with new content which not only extends the time of play, but also motivates a user to revisit the game (again and again) and to explore the new content. Lee also suggests to subdivide stories for mobile games into small parts, so-called 'thinly slices'. In the same context, Buchanan introduced the concept of byte sized storytelling [22], also following the 'dip-in-dip-out' principle. Practically, story/game episodes in the form of game slices might be interpreted as game modules which can be arranged in any order. For the orchestration of game slices (mini games) within intermodal mobility chains, the (external) time constraints of route sections (and movement modalities) as well as the appropriateness of mini games (and its gameplay and game control) for particular movement modalities need to be considered. The question is which episode/mini game fits best for a modality in a specific moment and which next episode/game module should be selected? In that context, Göbel et al. provided an algorithm considering external and internal constraints in their paper about Story Pacing [23].

3 Prototypical Implementation and Validation

Within a practical course on Serious Games (primarily for computer scientists) at TU Darmstadt, two student teams tackled the new field of Sliced Serious Games and developed prototypes considering the theoretic concepts described above.

3.1 Sliced Serious Game 'Smog'

Game principle. The basic idea of 'Smog' is to provide a game world following the principles of city-building strategy games, cf. 'SimCity' or 'Cities: Skylines'. The game aims to support environment-friendly mobility behavior and to create awareness about environmental, ecological issues. Smog starts with a very cloudy urban environment (of a fictive town) with many clouds and only a few buildings. As soon as points have been collected by environment-friendly mobility behavior, it is possible to build and place more buildings and further mini games are unlocked. The more points are collected (and not being used to build something), the less clouds/smog appears above the town.

Mobility assistance. For route finding and route selection, the open transport API from Opendata[4] has been used. This mobility assistant provides routes for public transport (based on stations/stops of public transport), basically for Switzerland, but also offers connections in Germany. In a first step, the user specifies a starting point and a destination of a route. For the case that these points do not match a stop/station of public transport, the next stations are determined using the location API from Opendata (with the geographic location/coordinates of the start and destination as input parameter). Then, in a second step, routes between the starting point and the destination are searched, using the connections API. Then, the idea is to replace (short) route sections of public transport by the movement modalities 'car', 'foot' and 'bike'. For that, the OSRM service[5] providing a table with connections and required time (per modality) from A to B is used; and the user selects one of the listed routes.

Scoring. The scoring mechanism used in 'Smog' is based on statistical data (based on an regularly updated environment mobility check from DB Regio and further info from DB Umwelt and the Deutsche Bahn) and basically is built by a linear dependency of the movement modality from the CO_2 emission per (passed) kilometer.

Mini games. A set of mini games has been developed – combining game mechanics and content (ecological topics): In the game 'Maze Labyrinth' (see Fig. 2, right part), the user needs to lead waste through a labyrinth and to throw it into the correct garbage can. For correctness, the database of a public service called 'FES-Abfall ABC'[6] (engl.: garbage ABC) is used. For the gameplay and game control, the smartphone serves as a spoon and – like in the child game 'chicken run' – the user needs an unhasty hand to control an egg, whereby in the case of Maze Labyrinth game objects such as a marble are used instead of an egg. Further, different difficulty levels are provided with a different speed of the game objects, i.e. it becomes much harder to control the game when using dedicated movement modalities, e.g. going by bus on streets with potholes. In 'Oilrun' the goal is to bring oil to a destination. Each lost drip reduces the points. Similar to the maze game, an unhasty hand is required. Hereby, apart from gravity as

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4 https://transport.opendata.ch.

5 http://router.project-osrm.org/, https://github.com/Project-OSRM/osrm-backend.

6 https://www.fes-frankfurt.de/buerger/entsorgung/abfall-abc.

kinetic energy, also the G-forces resulting from curves, acceleration, braking or uneven ground are reflected in the physical behavior of the gameplay.

For the selection of mini games two aspects have been considered: The play time (required/min, intended average, max) and the appropriateness of sensor technology for different mobility modalities (e.g. display, audio/headphones, vibration, speech or gyroscope and GPS).

3.2 Sliced Serious Game ‘Fred’

In contrast to ‘Smog’, ‘Fred’ is used without the support of mobility assistants, i.e. users such as commuters are moving around and mini games are offered purely on the basis of activity recognition respectively the recognition of modality changes. For the activity recognition, basically the Fence API (see Sect. 2.1) is used (Fig. 3).

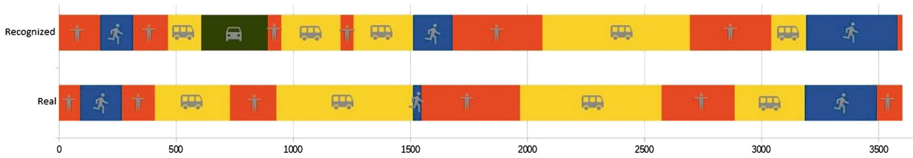

Fig. 3. Activity recognition using Google’s Fence API – real movement (lower layer) and recognized modality changes in the upper part, with latency and recognition errors of modalities.

Due to the fact that the accuracy recognition rate of the API is only $\sim 70\%$ and there is enormous latency up to a minute before a modality change is recognized, an additional component in form of a so-called ‘Speed Supervisor’ (see Fig. 4) has been conceptionalized and prototypically implemented. The idea is to combine the results from the Fence API with GPS data in order to verify and improve the quality of the activity recognition.

System overview. Fred is realized as mobile game running on Android smartphones. The entry point for a user is the main menu. The player can start or stop routes, configure options, start games according to a current modality, view the modality history, the highscores or the manual. The modality history allows the player to take a look at the latest detected modalities in combination with a timestamp when a modality was detected. The highscore view displays a list with routes the player finished and the points the player achieved. He/she can look at the starting and end point of the route – which is produced using a map view provided by mapbox[7] – and compare the score to other players who used the same route. Mini games are integrated in the framework by an interface which encapsulates the game logic from the main program. The advantage of this design is that any game can be integrated into the application, as long as it supports instant switching to another game when another modality is detected.

[7] Mapbox. An open source mapping platform for custom design maps, see www.mapbox.com.

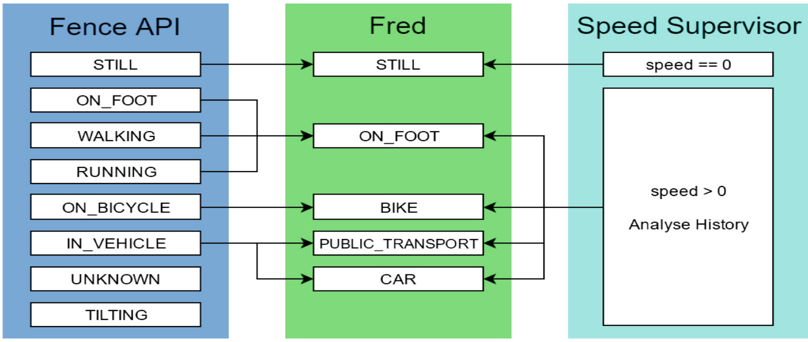

Fig. 4. Fred's Speed Supervisor component – combining the results from the Fence API with GPS data in order to verify and improve the quality of the activity recognition.

Mini games. Technically speaking, mini games in 'Fred' (see Fig. 5) can be registered for a specific modality. Switching between the games is handled automatically by the Fred system. Every modality has exactly one mini game, but one mini game can be assigned to different modalities. For example, a particular game might be assigned to the modalities 'in tram', 'in bus' and 'in car' (as co-driver). Whereas the bubble game has been drafted for the movement modalities standing ('STILL') and walking (with sporadic game play during a walk), the side-scroller is foreseen primarily for public transport (sitting in a bus, tram or train) and cars (as co-driver or sitting in the back). Within the side-scroller, the player controls a fish "Fred" which tries to swim around obstacles as long as possible. Fred is also able to collect bubbles to fill up his

Fig. 5. Fred's mini games 'bubbles' (left) and a side-scroller (middle and right).

ammunition and to destroy barriers. During public transport, the setting of the side-scroller is rather friendly as Fred swims in water and fires bubbles. When using a car instead, the game gets faster, harder and darker. Fred now uses a motorized board and drives on a road, dodging traffic cones and brick walls instead of fish nets and tree trunks. The game mechanic stays the same, but the visual appearance is more unfriendly, caused by the intention to indicate that a car use is not the best movement modality in terms of environment-friendly mobility behavior.

Scoring. A bicycle is regarded as the most environment-friendly mode of travel, followed by the movement on foot and the public transport. A car is considered the worst. For that, a so-called environment factor is introduced and values are assigned to the particular movement modalities: BIKE – 1.0, ON_FOOT – 0.8, PUBLIC (transport) – 0.6, STILL – 0.4 and CAR – 0.2. The app enables the player to collect points that result from two components. First, players are awarded with points for the used movement modality. In addition, users can collect points during the route via the sliced (mini) games. The maximum value for the activity points is determined by the distance between the starting point and the destination; accordingly for route sections the value is determined by the relative duration of a route section in relation to the overall duration of the complete tour. Similar to the activity side, a game factor is introduced for the gaming side. This factor is calculated by the division of collected game points divided by the expected points per minute (over the time of play). The overall score for a route is built by the sum of activity and game points.

Validation. The elaborated concepts of the SSG Fred have been validated in a technical feasibility study enhanced by two smaller qualitative evaluation studies. In a first step, the activity recognition and the scoring mechanism have been tested within a concrete application scenario, i.e. a selected geographic area with a set of routes from a fix starting point A (design school in Offenbach) to a fixed destination B (TU Darmstadt, campus ‘Lichtwiese’). The beeline between the two locations is 27.8 km resulting in a maximum score of 2780 points to be achieved by players. The connection data for possible public transport routes was generated by the website of the main service provider for public transport in the region, the Rhein-Main-Verkehrsverbund.

Station	Duration	Modality	Evironment points	Game factor	Points
OF Marktplatz					
	8	PUBLIC TRANSPORT	180	0.8 (= 96P)	276
FRA Ostendstraße	10	STILL	150	0.0 (= 0P)	150
	31	PUBLIC TRANSPORT	699	0.9 (= 419P)	1118
DA Hauptbahnhof	7	STILL	105	0.7 (= 110P)	215
	17	BIKE	639	0.0 (= 0P)	639
DA TU Lichtwiese					
	73		1773	625 P	2398

Fig. 6. Scoring mechanisms in Fred – test scenario for a route from Offenbach to Darmstadt.

As expected, the maximum score is achieved by bike (cf. Fig. 6, lower part). Also if the user only travels short distances by bike, the amount of points increases significantly compared to a movement without. This scenario occurs for example if the user uses a bike on ‘the last mile’ of the route.

For the evaluation of the usability two qualitative tests have been performed during the (five month lasting) iterative development period with a small number of persons (n = 10). The tests included free testing on a smartphone and filling a questionnaire. The results confirmed that the overall system (prototype) works fine and is usable (user interface, menu; activity recognition and scoring), whereby the accuracy rate of the activity recognition respectively the ($\sim$20%) missed or wrong interpreted modality changes have been received as frustrating. Further, the participants (>64%) indicated that they enjoyed the ‘environment-friendly’ mini games more than others (i.e. the side-scroller version for cars), which is in alignment with the intension of the game developers. A few participants also asked to extend the time of the exploration for using the application in their everyday live, which is a nice compliment and promising indicator to continue the work with this prototype and SSG in general.

4 Conclusion and Outlook

In this paper the concept of Sliced Serious Games is introduced. The basic idea is to provide game-based concepts to encourage people to positively change their mobility behavior and to use environment-friendly movement modalities. The main RTD challenges tackle the nature of intermodal mobility chains with modality changes along the route from a starting point to a destination and short time frames to play. For that, first game concepts in the form of sliced serious games with a game world and game slices (mini games) have been elaborated. The technical basis for scoring mechanisms builds the activity recognition of movement modalities. Within the two prototypes ‘Smog’ and ‘Fred’ the basic concepts for sliced serious games have been implemented and concrete game scenarios including a set of mini games and scoring mechanisms are suggested. First validation tests are promising and inspire to continue the applied research in this societal relevant topic of environment-friendly mobility.

In the next step, the different concepts and prototypical results need to be further developed and tested in comprehensive studies, i.e. a field test with numerous participants. Also, business development and technical integration is necessary on the side of system providers (for public transport, car and bike sharing, etc.) in order to provide integrated mobility services. On the serious games and gamification side, sophisticated game worlds and convincing mini games (with gameplay appropriate for the movement modalities) as well as ingenious scoring and incentive mechanism are required for the acceptance and success of sliced serious games.

Acknowledgements. The concept of Sliced Serious Games has been originated at the Serious Games group at the Multimedia Communications Lab – KOM at TU Darmstadt in 2016 and tackled within research and teaching activities. Major parts of this paper result from the analytic outcomes of two seminars (Isabel Maschik and Jan Schröder) and the practical results achieved by two project teams (Denis Krcmar, Fabian Bauer and Nicolas Vogt; Jannis Weil, Hendrik Würz and Maja Nöll), all supervised by Stefan Göbel.

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Conceptual Approach Towards Recursive Hardware Abstraction Layers

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Abstract. Cross-platform publishing is a must have in game development. Sophisticated game engines such as Unreal or Unity provide cross-platform publishing capability. Therefore, many developers use these game engines. On the other hand, several game developers also provide their own technology and do not want to become fully dependent on external technology. Based on that situation efficient mechanisms are required to combine both sides: Usage of custom in-house technology enhanced with multi-platform capabilities. This paper introduces a new concept for hardware abstraction layers tackling this issue. Sections 1 and 2 motivate the use of multiple hardware abstraction layers and provide a brief overview of related work. Section 3 describes the Kha and Kore frameworks as basic game technology for custom in-house game engines. In the main part of this paper, a conceptual approach of hardware abstraction layers, is introduced in Sect. 4 and Sect. 5 discusses its practical use for the integration in Unreal and Unity. Finally, Sect. 6 provides an overview and best practice examples of how to use Kha and Kore for Serious Games.

Keywords: Kha · Kore · Hardware abstraction layer · OpenGL · Unreal · Unity

1 Introduction

In recent years developing video games became considerably easier than it used to be due to the broad use of off the shelf game engines [1]. The leading game engines provide a big collection of different tools and technical components, from level editors to the low level components which make applications work on a plethora of target platforms. The market is dominated by just two engines - Unreal and Unity - and a difficult hardware situation (large diversity of Android devices, technical challenges in developing for video game consoles,...) makes it hard for new engines to catch on and dangerous to use in-house technology solutions. Like with any kind of monoculture this comes not without problems. It is a hindrance for innovations like new rendering technologies or support for unusual

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hardware. This situation is especially tragic for Serious Games which can benefit greatly from innovations and often have to be tailored for very specific hardware environments (old school-computers, integration with exercise hardware,...).

Custom game engines could be made viable again if it would be possible to run them inside of one of the market leading engines. Depending on the capabilities and the distribution models of a game engine (open- or closed-source) it can be possible to do exactly that - to avoid all higher level functionality of an engine and target its underlying portability layer more or less directly. This so called hardware abstraction layer (HAL) is the lowest level component in a typical game engine architecture. To abstract the underlying hardware a HAL provides an interface which is functionally equivalent to the common set of features of the targeted hardware devices. As the functionality is dictated by current hardware specifications, different HALs are very similar in the feature sets they provide. Therefore it is feasible to modify a HAL of one game engine to target the HAL of a completely different game engine. If sufficient underlying functionality of a target game engine is accessible, one game engine can consequently be made to run on top of another game engine, inheriting additional cross-platform functionality in the process.

2 Related Work

Targeting a game engine is conceptually similar to the implementation of a multi-platform game engine. Instead of targeting system APIs directly, the HAL of a game engine (if it can be accessed) is targeted and HALs tend to be similar to the APIs they abstract. Functionally complete hardware abstraction layers are relatively rare however. Most openly accessible game engines and game libraries do not implement an abstraction for the graphics APIs and instead solely rely on OpenGL for multi-platform graphics support. Notable exceptions are Oryol[1] and Unreal Engine 4[2]. A second type of applications which implement similar functionality are web browsers. When running on Windows operating systems web browsers do not use OpenGL to provide the closely related WebGL API but instead rely on Microsoft's competing Direct3D APIs for better compatibility. Google's Chrome and Mozilla's Firefox in particular use the ANGLE library[3] for this purpose.

Graphics APIs are by far the most complex system APIs used by game engines and as such multi-platform graphics APIs like OpenGL [2] and Vulkan [3] are relevant as are libraries which purely aim to abstract graphics APIs like bgfx[4] and gfx-rs[5].

For running code written for one game engine on top of another game engine it can be necessary to cross-compile source code from one programming language

1 https://github.com/floooh/oryol.
2 https://www.unrealengine.com.
3 http://angleproject.org.
4 https://github.com/bkaradzic/bgfx.
5 http://gfx-rs.github.io.

to another. The Haxe[6] compiler can compile the Haxe programming language to multiple different target languages, among them are most programming languages which are popular in the games industry like C++, JavaScript, C# and Lua. The emscripten[7] compiler in combination with the LLVM[8] compiler suite translates C and C++ code into an especially efficient subset of JavaScript. SPIRV-Cross[9] compiles SPIR-V bytecode into different GPU programming languages like GLSL, HLSL and the Metal Shading Language.

3 Kha and Kore

Kha[10] and Kore[11] are frameworks for cross-platform multimedia application development. They are especially well suited for games as they tend to be the most complex type of multimedia applications but instead of providing a complete game engine they concentrate purely on providing very complete hardware abstraction layers, including a cross-platform build system, asset management and shader cross-compilation.

Kha and Kore are functionally very similar, the primary difference being that the former is implemented in the aforementioned Haxe programming language, which can be cross-compiled to other programming languages, therefore boosting its cross-platform capabilities and the latter being implemented in C++, providing lower level access and a potential for higher performance.

Compared to conventional game engine packages the usage of Kha and Kore requires a much deeper understanding of the technological foundations of video games. This is an explicit design goal for both of these frameworks. Kha was originally created in an educational context and Kore is currently used to teach a Game Technology course at the Technische Universität Darmstadt.

4 Conceptual Hardware Abstraction Requirements

In the following a minimal viable feature set for a hardware abstraction layer is defined based on theoretical observations as well as practical experience based on the implementation of the Kha and Kore frameworks.

On the most basic level a computer consists of different input and output devices as well as internal units for computation. The computation devices in most modern computers are CPUs and GPUs (often residing on the same chip). Output is restricted to visuals and audio on most systems and common input devices are keyboards, mice, gamepads, touch surfaces and accelerometer data. Additionally computers include networking hardware and storage devices.

[6] http://haxe.org.
[7] https://github.com/kripken/emscripten.
[8] http://llvm.org.
[9] https://github.com/KhronosGroup/SPIRV-Cross.
[10] https://github.com/Kode/Kha.
[11] https://github.com/Kode/Kore.

4.1 Computation on CPUs and GPUs

In theory access to a turing-complete programming language is sufficient to provide all necessary functionality [4] but especially in the context of video games execution speed has to be considered. Game engines are often split in part in an engine-implementation language (typically C++) and a game-logic language (often Lua). When only the latter is accessible to a developer, performance might be unacceptable for running an additional game engine inside of it.

GPUs are programmed using so-called Shaders which are programs which execute in parallel on the GPU's many execution units. Shader programming is generally not turing-complete, disallowing recursive function calls, but provides access to many special graphics hardware features. Proving the equivalence of different shading languages is therefore difficult but the actual current situation is less complex as game engines tend to use just one of two established shader programming languages: GLSL or HLSL. Cross-compilation from GLSL to HLSL and from HLSL to GLSL is widely used in practice, for example in Unreal Engine and Unity [5] as well as in any modern web browser running on the Windows operating system. Therefore support for either GLSL or HLSL shaders by a game engine makes it a viable target regarding computations on the GPU.

4.2 Graphics Output

Visual output is internally represented by a dedicated memory area for which the content is replicated on a monitor - the so called framebuffer [6,7]. On modern systems however the framebuffer can not be directly accessed by an application. Instead GPU APIs are used to write to the framebuffer indirectly using shader programs in combination with several blocks of configurable graphics functionality.

Although GPU feature sets are constantly advancing a reasonable minimum configuration can be defined based on OpenGL ES 2 which is designed to run on the majority of today's hardware and as of now nearly 40% of all Android devices still support only OpenGL ES 2 [8].

Apart from the shading language GLSL the OpenGL ES 2.0 specification [9] contains the following functional blocks:

Draw calls. Fundamentally GPUs rasterize triangles and the OpenGL API resolves around this. So called draw calls are the actual commands which initialize geometry drawing processes.
OpenGL ES 2's draw calls support rendering of points, lines and triangles based on vertex buffers and optional index buffers, the former defining the points of the geometry and the latter defining which points make up each geometrical primitive. Points and lines however are not mathematical lines of zero size or thickness - actual mathematical points and lines are invisible and therefore not useful for displaying graphics. A line with a thickness is in mathematical terms a rectangle as is a point of a certain size and rectangles can be triangulated trivially and therefore it is sufficient to only support triangles.

When no index buffer is provided, OpenGL works as if it uses an implicit index buffer containing the numbers from 0 up to the size of the index buffer minus one. This index buffer could also be provided explicitly thus eliminating the need to make index buffers optional. Considering these simplifications only a single kind of draw call is necessary, supporting indexed vertices to draw triangles.

Screen clearing. OpenGL provides an explicit screen clearing call which can be simulated by drawing two triangles. The clear call can be optimized in hardware and therefore be faster but it is not strictly necessary.

Backface culling. The front and back-face of a triangle are defined by its winding order [10]. Culling of back facing triangles is an optimization technique but is also important for rendering semi-transparent objects - without backface culling the innards of a semi-transparent object would be visible which is generally not intended. Backface culling is therefore a necessary feature.

Textures. Texture mapping is the process of mapping image data to geometry [11] and it is fundamental to modern realtime 3D graphics. OpenGL ES 2 supports texturing including mip mapping and cube maps. Mip maps improve scaling quality. Optimal scaling quality requires reading all pixels of an image to produce what can be a single pixel on screen which is highly inefficient and not supported by GPUs. Mip maps are arrays of pre-scaled images and depending on the necessary scaling the most fitting mip layer is used to read actual pixel data [12].

Cube-maps are arrays of six images which represent the inner six sides of a cube [13]. Cube-maps are used to pre-calculate lighting environments. As cube maps consist of six regular textures sampling a cube map can be simulated by implementing the texture coord calculations in a shader but care has to be taken when sampling at the edges of a single texture. Emulating cube-maps degrades performance and, depending on the implementation, image quality. Texturing support itself is essential while mip maps and cube maps are not strictly necessary.

Frame- and Renderbuffers. More complex rendering techniques and any kind of post-processing require access to data from previously executed render passes. OpenGL supports this by provide functionality for rendering into a texture instead of the framebuffer. These textures can then be used as normal. This functionality can not be achieved otherwise and is therefore necessary.

Write Masks. Depth and stencil channels as well as individual color channels can be masked. This is useful for some rendering tricks like writing special data to the alpha channel of an image. This functionality can not be trivially replicated by a shader because it has no read access to its own render target and can not write to only a component of a color by itself. Multiple render targets can be used alternatively at great performance costs but as write masks are not widely used this compromise would be acceptable for most applications.

Stencil operations. The stencil buffer is a special drawing buffer which can be used in combination with predefined comparison functions. Stencil buffers are best known for the stencil shadows algorithm [14]. Stencil operations are useful in special cases but not used much if at all in modern engines. Stencil shadows in particular have been replaced by shadow mapping and therefore do not seem to be absolutely necessary.

Blending. On most hardware shader programs do not have read access to the current render target to increase parallelization efficiency. Blending colors is therefore not programmable and instead achieved using predefined blending modes.

Blending modes have historically become more and more complex but most commonly colors are either mixed directly based on the alpha values ($newcolor * alpha + oldcolor * (1 - alpha)$) or use additive blending which is typically used in combination with premultiplied alpha images [15,16].

Blending could be emulated using render targets but performance would likely be unacceptable, making support for at least the most basic blending modes necessary.

Scissoring. Scissor support can be used to mask rectangular screen regions which is especially important for components of graphical user interfaces e.g. for scroll-views. Scissoring can trivially be emulated using render-targets but with severe performance implications. Alternatively triangles can be clipped beforehand, resulting in potentially large CPU overhead. Due to performance considerations and the omnipresent usage of graphical user interfaces scissoring is highly important.

Viewports. Viewports define rectangular regions to which a scene is mapped. This is important for rendering different views of a scene at the same time. This feature can be emulated using render targets with reasonable performance.

Reading back pixels. OpenGL allows reading pixel data from the framebuffer but this is a very slow operation because the GPU has to finish drawing and then transfer data back to CPU memory and is therefore avoided in modern game engines. Apart from features like screenshots or image analysis on the CPU reading back pixels is not necessary.

Monitor Synchronization. For fluid animations applications have to be synced with the monitor refresh rate. Many game engines provide callback mechanisms which are triggered when a new frame can be rendered. This is not strictly an OpenGL feature as it is commonly provided by the operating system in a platform-specific way - nonetheless it is a necessary feature.

Graphics Intricacies. Apart from the listed feature sets graphics APIs include several definitions about how they work and how data is structured which eventually have to be adapted: Images data can start at the top or bottom of an image. Matrices can be row or column major. Clip space - the final rendering coordinate system - can be defined differently. All of these situations can be handled in the shader cross-compilation step when the definitions are clear.

4.3 Remaining Hardware

Audio. Current operating systems represent audio output by a small ring buffer which is written to by software and read by the audio hardware. As with the visual output modern systems do not allow direct access to the global audio ring buffer but the same concept is in use - applications are provided with their own audio buffers which are then mixed into the global buffer by the underlying system software. A hardware abstraction layer can use this concept of an audio ring buffer directly to provide all audio features easily and every more advanced audio can be built on top.

Input. Common input devices are conceptually very simple, only consisting of buttons and two-dimensional movements. Touch input can be represented as an array of 2D positions. All of this can typically be mapped trivially between different game engines.

Networking. UDP is the most basic networking protocol supported in the world's networking infrastructure, adding only a target port to an IP package. All other networking functionality can be built on top and UDP support is therefore sufficient.

Storage Devices. Some method to read and write data, preferably based on files and directories, is of course required.

5 Feasibility Analysis for Targeting Game Engines Using a Hardware Abstraction Layer

5.1 Unreal Engine 4

Unreal Engine 4 is distributed including the full C++ source code and it is possible to directly access Unreal's own hardware abstraction layer inside of a regular Unreal project. Consequently apart from some small complications all required functionality can be accessed:

Computation on CPUs and GPUs. Unreal projects are implemented in C++ making it an ideal target for other game engines in this regard.

Shaders for Unreal are written in HLSL but Unreal has no direct support for per project shader files and all new shader files have to be copied into Unreal's own directory tree, which is usually global per system. This is an unfortunate situation but can be handled satisfactorily using name mangling. Shaders also can only be loaded during Unreal's PostConfigInit phase which itself only works inside of a plugin. Unreal plugins can be components of regular Unreal projects but the project structure becomes more complicated.

Graphics Output. Unreal's RHI package represents the graphics hardware abstraction layer. It is used similarly to a graphics API like OpenGL and actually provides more advanced features than Open GL ES 2 with an API that more closely resembles newer APIs like Metal using concepts like pipeline states and command buffers but retaining a relatively simple interface for setting shader parameters unlike Vulkan and Direct3D 12. This is to be expected as the current iteration of Unreal Engine (version 4.x) is relatively new, being first released to the public in 2014 and requires relatively recent graphics hardware. Monitor synchronization can be achieved by overriding the Tick method of the AActor class. To then run the code on the render thread one of the ENQUEUE_UNIQUE_RENDER_COMMAND macros can be used.

Remaining Hardware. Unreal's USoundWaveProcedural API provides access to an audio ring buffer which is all that is required for full audio support. The UInputComponent class can be used for all input functionality, which is provided in the SetupPlayerInputComponent method of the APawn class which is a subclass of AActor. Unreal provides network access via a UDP socket API using the FSocket, FUdpSocketBuilder and FUdpSocketReceiver classes. For further functionality Unreal contains a source package which is called HAL and does indeed contain the hardware abstraction layer - excluding however any graphics or audio functionality but including file access.

5.2 Unity

Unity is fundamentally a closed source platform and source licenses are expensive (actual prices are not disclosed publicly) making it a potentially problematic target.

Computation on CPUs and GPUs. Unity applications are developed on top of a .NET runtime, the actual C++ engine is inaccessible. The .NET code is either executed using the Mono runtime or a custom .NET to C++ cross-compilation based solution. Performance is not as fast as running compiled C++ code but fast enough to run at least lower end game engines on top of it.

Shaders for Unity are written in HLSL but fragment and vertex shaders reside in a single file next to some additional data and use special HLSL input semantics. A shader cross-compiler requires small adjustments to target HLSL for Unity.

Graphics Output. Unity supports draw calls via the Graphics.DrawMeshNow method which draws triangles based on vertices and indices but does not support subranges of indices which is a surprising omission which can result in performance problems.

All other required functionality is supported but some of it like blending and culling is not controlled by a programming API but instead defined in the shader files.

Whether image data starts at the top or bottom of an image is not abstracted and applications have to read the UNITY_UV_STARTS_AT_TOP define and handle the situation themselves.

Monitor synchronization is achieved using the OnPostRender callback.

Remaining Hardware. Generating audio programatically is supported using OnAudioFilterRead. The input API is called Input and provides methods to access keyboards, mice, gamepads, touch and accelerometer state. Being based on .NET Unity supports the System.Net.Sockets API which includes support for UDP sockets. Files have to be added to the Unity project structure. Directly supported file types can be loaded using Unity's Resources.Load calls. For binary access filenames have to end with a ".bytes" extension. Bytes files can then be cast to the TextAsset class which provides a bytes member.

5.3 Prototypical Implementations in Kha and Kore

Two prototypical implementations have been implemented to verify the presented concepts.

Kore provides a prototypical implementation of an Unreal backend which is not yet fully automated but all basic functionality could be verified to work. C++ code can be directly linked into an Unreal project and direct access to the HAL - which is provided trivially for all regular Unreal projects - provides all necessary features in a direct way. Kore applications can optionally run inside of any Unreal texture which can be used freely within a 3D scene. Not being able to add shader files directly to a project sadly complicates project export and in combination with Unreal's shader caching and loading behavior proved to be the most challenging aspect of targeting Unreal.

Kha provides a fully working Unity backend. Kha's Haxe code is cross-compiled to C# with no special adjustments. Kha's GLSL based shaders are cross-compiled to Unity's special form of HLSL shaders but the differing concepts of how shaders are used in Kha and Unity proved problematic - Kha uses separate vertex and fragment shader files and sets all rendering state via APIs while Unity combines vertex and fragment shaders together with some rendering state in single files. To fully support Khas feature set all possible shader and render-state combinations have to be create beforehand resulting in a large number of shader files and currently the functionality is compromised to reduce that number. API mapping showed no further problems apart from the slightly restricted draw call API.

6 Development of Serious Games with Kha and Kore

A focus on understandable low level technology sports a number of additional advantages beyond educational aspects. Common game engines suffer from technological drawbacks because they tend to be optimized for the mass market hardware situation only although it can make a lot of sense for Serious Games to target hardware which does not fulfill these criteria. Unity recently stopped supporting Direct3D 9 [17] which is required for proper Windows XP support. Nonetheless many schools around the world continue to use very old hardware. The Raspberry Pi is a very popular platform for building custom hardware solutions (for example an ergometer containing integrated exercise games) but is neither supported by Unreal nor Unity. Arguably the most successful serious game - Dr. Kawashima's Brain Training - was only ever released on Nintendo DS. The most recent sequel - Dr. Kawashima's Devilish Brain Training - was released exclusively for Nintendo 3DS which is not supported by Unreal or Unity. Even a popular software platform proves problematic: Web browser support is not ideal due to the typical RAM requirements of large, cross-compiled C++ game engines (a non-standardized http extension is supported by Firefox for that reason [18]).

Kha and Kore - in contrast to Unreal and Unity - do not dictate a specific workflow and embedding into other applications is easy - Armory3D and StoryTec are two examples which demonstrate this approach.

6.1 Armory3D

Armory3D embeds a Kha-based realtime 3D graphics engine in Blender. With Blender being a full 3D modeling suite such a combination offers features beyond what Unreal and Unity can provide and demonstrates the feasibility of implementing high end realtime rendering pipelines (see Fig. 1) in Kha.

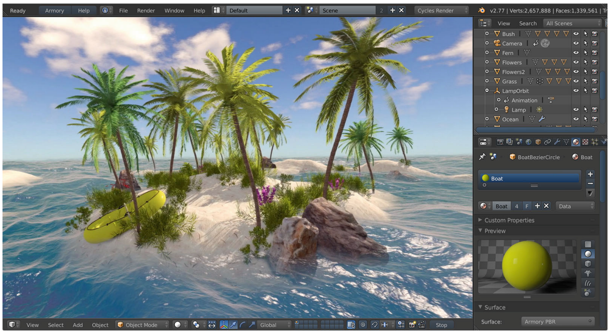

Fig. 1. Armory3D

It is aimed specifically at artists, creating a more efficient workflow for 3D asset creation by utilizing technology and algorithms originating from the game development community. It also provides options to add interactivity using a graphical programming system, empowering artists to target new application domains.

6.2 StoryTec

StoryTec is an authoring environment for Serious Games with a focus on narrative design. It provides an integrated environment including editors for the overall structure of a game, the creations of game scenes and for graphical interaction programming. It is aimed at users with very little or no programming experience, making it possible for a teacher to implement game-based e-learning courses or for a curator in a museum to create a virtual tour guide.

StoryTec exists in two different versions. One is a complex application developed for offline usage in C# and WPF. The other is a simplified online version running entirely in HTML5. Both versions of StoryTec make use of Kha. StoryTec uses it for broad multiplatform export support and to create a runtime component which can be used independently (on all target platforms) as well as integrated in a scientific analysis application. The integration in the web version of StoryTec goes even deeper. The editor itself uses an integrated Kha runtime, executing the same code which is also used to run the stories (see Fig. 2).

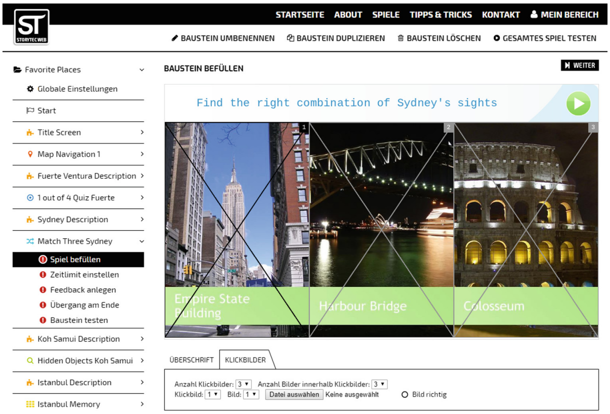

Fig. 2. StoryTec

Many serious games have already been developed and released using StoryTec, some examples are NeuroCare[12], Der Chaos-Flush[13] and the IUNO-Serious Game[14].

7 Conclusion

This paper provides a conceptual approach for Hardware Abstraction Layers as basic game technology to support cross-platform publishing of games and serious games using in-house game technology combined with sophisticated game engines. Running two game engines on top of one another is a development strategy which works in theory and practice but the benefit of better hardware compatibility has to be weighted against the disadvantages of additional complexity. Nonetheless a game engine HAL backend is a useful fall-back plan for compatibility challenges like the very diverse market of Android devices or for hardware which is hard to access for smaller development teams - for example Nintendo for a time only supported Unity based development for small teams on its Wii U games console. The initial implementation of a HAL backend for a game engine can take a lot of effort because this use-case is typically not considered in the accompanying documentation, which proved to be true for Unreal and Unity, but the current implementations in Kha and Kore are useful starting points which can speed up this process immensely.

[12] https://neurocare-aal.de.

[13] http://darmstadt-marketing.de/fileadmin/spiel/.

[14] https://www.iuno-projekt.de/veranstaltungen/termine/eventdetail/44/-/hessentag.html.

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Bridging Educational and Working Environments Through Pervasive Approaches

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Abstract. In the education of mechanical engineers alternative learning methods like serious games, simulations etc. have been used in past decades to better the learning outcomes. However, a main concern is still the amount of resources used on adapting and modding games as well as the challenges related to the implementation in the class room setting. Typically a positive learning experience does not only rely on the game as such, but how good the facilitator or teacher is to change game mechanics and the narratives so that players with different learning curves, past experience and cognitive abilities all stay in flow and feel immersed. Physical simulation games played in a workshop setting often have this ability, whereas this still seems to be a challenge in digitalized games. The main purpose of this article is to identify mechanics that need to be adapted differently for different user groups in order to keep them in flow, motivated and engaged in order to have a high learning experience and how we can take advantage of technologies like VR to reduce the costs and the resources.

1 Introduction

The European economy gets more and more knowledge-driven and the global competition gets harder. In addition, for many companies, it is difficult to find engineers with the right skills. Consequently, the universities need to respond to the need and teach in such a way that the students develop the required competences. Within engineering education and training, experiential learning approaches like game based learning and simulations have been used for decades and proven to be efficient to enable the learners to cope with real problems and authentic situations that are close to reality [1, 2], but their proper insertion in meaningful curricula are still quite low [3]. There are different reasons for this: designing games with a good game-play and immerse game players with different backgrounds and needs in a realistic setting while also encouraging

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replay-ability is challenging [4]. Consequently, both the customisation at design level as well as the implementation in an educational setting is a challenge [5, 6].

The focus of this article is two-fold: based on a long experience of adapting physical simulation based games to different, often inhomogeneous groups of participants, we have identified a set of mechanics that can be used to adapt the games while planning. Based on the results, we can conclude that this increases the players' immersiveness, but increases the workload of the facilitator while facilitating, the preparation time as well as reduces the reusability of the whole setting. Thus, the second part focus on how such games can take advantage of being transferred to a VR environment as well as the disadvantage this might have. This VR transition is currently at the beginning of the process.

2 Problem Statement and Research Questions

Though serious games (SG) have been used in engineering and management education their deployment rate remains low [6]. As mentioned above the two main reasons are in the game design as well as embedding the game to user group and curricula. Key barriers for deploying SGs in an educational environment can be summarized as a two-fold approach [7, 8]:

a. Even if a flexible curricular design would exist to allow modding a SG to fit different learning goals and target groups, the time and the knowledge to do so often makes a purposeful adoption difficult.
b. The time consumed on the technical aspects of the game can be a significant obstacle. The successful integration of SGs in classrooms imply overcoming various challenges across an extensive process that reunite the learning objectives, teacher's gaming experience, the students' gaming experience, choosing the right game to meet the learning objectives, technical issues, etc.

The two main research questions derived from the problem statement are:

1. How to increase the elasticity of the mechanics in order to react promptly to different competence level while playing, so that the players stay in flow and get immersed with the game play.
2. How to reduce the preparation and set-up time by replacing or extending physical simulation based games with VR.

3 Methodology

The reported games have been used for several years, and have been continuously adapted and improved. However, the main topic of this article is related to our observation, feedback from participants and analysis of learning results and based on that the improved design concept. For that we have used an action based research approach.

4 Didactical and Pedagogical Background

The games we have used as basis for our analysis are used in a workshop setting. Several pedagogical theories and learning models are the have been employed to inspire SG design and to assess validity of SGs. Among the knowledge models, we highlight the Nonaka SECI model [9] which is mentioned as a theoretical basis for the use of SG-based workshops, at least in the fields of business, management and manufacturing [10], and Kirkpatrick's "The Four Levels of Learning Evaluation" that is a popular learning impact assessment model, involving the following levels: reaction, learning, behaviour, results [11] and evaluation. A fifth level of evaluation has been added in new versions of the model by [12], considering also return on investment and impact on clients and society, respectively. In our work we have focused in particular on describing SGs through two models that we consider complementary, simple and particularly useful to analyse SGs: the Revised Bloom Taxonomy for the cognitive learning, which is the most popular cognitive approach to SG evaluation [13]; and the Kolb's Experiential Learning model, which systemizes the work rooted on Piaget's cognitive developmental genetic epistemology [14], on Dewey's philosophical pragmatism [15]. The games presented in the next section are designed according to an experimental learning model. This is typically for this type of simulation games.

5 Case Studies

This section describes the games analysed, as well as how they are normally used. The overall number of participants for both games is around 1000. The games have been played in a workshop setting for more than 15 years in different contexts.

Use Case 1: Pedal car
The game is developed by a Japanese consultancy and Saab I Trollhättan and further developed in a co-operation between a large Swedish truck manufacturer and the Royal Institute for Technology (KTH). At KTH, around 250–300 players have played the game with the same instructors. It is a multi-user simulation game, simulating the production and the assembly processes within the manufacturing site. The final product can be seen in Fig. 1.

Fig. 1. KTH case pedal car

The game consists of seven stations – four assembly stations, one quality check station and two disassembly stations. The circular arrangement of the stations allows the reuse of disassembled parts in the assembly stations. A job description including safety measures and ergonomic topics is available. A key point for the game play is that the player follows this instruction in order to guarantee the quality of the finished product. Production and customer orders are floated into the game play during game play. The production is based on a modular strategy and therefore, there are two different kinds of production orders: customer specific (MTO) and orders for make-to-stock (MTS). Only a few parts are customisable. The customer specification is attached to the chassis through the whole assembly line. Table 1 shows the different tasks at each station.

Table 1. Task per station at the pedal car

Station	Task
1	Add a front end, pedal and fenders to chassis
2	Add two steering column, seat and rear reflexes
3	Steering wheel and steering links connected to the car
4	Wheels and hub caps added, product finished
5	Quality check according to ……
A	Dissembling steering wheels and links, wheels and hub caps
B	Dissembling front end, pedals, fenders, steering column, seat and rear reflexes

The set-up is flexible, but the most used one comprises 7–14 players (i.e. 1–2 per station) and partly depending on their past experience. Normal play time is 3.5–4 h, but depending on the objectives it is also possible to have a set-up designed for 3 days.

The game is very flexible regarding how it can be integrated in a curriculum or Vocational training (VET) context. The objectives for the game vary: it ranges from simple hands on experience to actually rebalancing the stations in order to smoothen the production flow. Additional, in order to respond better to inhomogeneous learning groups and to different competence levels, it is possible to insert specific tasks like setting up a new design for material supply in each station either for a specific player or a whole group. Depending on the learning goals, different key performance indicators are measured: Almost accidents, dropping tools and parts etc. These are measured both for quality and waste aspects as well as for safety and security aspects, but also KPIs more related to logistics like lead time, quality of delivery, etc.

As described above, the game is embedded in different types of workshops with different user groups (to some extent inhomogeneous), so consequently, there is no typical player, but we categorise them in some user groups, according to how the game normally need to be facilitated and adapted. The game is integrated in the 2. Year curricula for the undergraduate students in mechanical engineering, after having studying the basic LEAN theory in first year. For the logistics postgraduate students, the game is a part of the 4. Year, so the game is played at a more advanced level. In addition, this group of postgraduates is inhomogeneous, with several students having years of working experience from production and logistics. Thus, their understanding of the production processes is often better. In addition to these students groups, the game is regularly played by employees (both managers and blue/white colour workers). In order to understand basic concepts of LEAN the game is also used as a common platform to build discussions and mutual experience exchange on. These debriefing sessions can often be identified as the most rewarding and stimulating – which is indicated in the game assessments every player is encouraged to fill in at the end of the game. The next section is analysing how the game supports the different cognitive levels using Blooms revised taxonomy (Table 2).

Table 2. Bloom's cognitive learning goals covered by the Pedal car

Learning goal	Modality/mechanics
Remembering	The game supports that the player re-use previous theoretical and practical knowledge in the field of LEAN and players regular work as a base for discussion
Understanding	Cycle time, concept, learning progression curve
Applying	Standardized way of work. This is realized through exact workplace and task descriptions as well as through the measurement of the KPIs related to the execution of the tasks
Analysing	Quality vs production time as a base for improvements
Evaluating	The game requires that the player evaluate the present set up of the production line in order to look for better solutions
Creating	Continuous improvements in work

The game is designed according to the principles of constructivism. The setting in which it is embedded is designed according to Kolb's learning cycle. The units always comprises a debriefing session, which is a key factor the learning outcome. Table 3 describes how the game supports the learning cycle.

Table 3. Support for Kolb's learning cycle

Learning stage	Modality/mechanics
Concrete experience (feeling)	Hands on experience in assembling a physical item
Reflective observation (watching)	Experience difficulties in understanding assembly instructions, finding unbalances and reasons for uneven quality
Abstract conceptualization (thinking)	Suggest possible ways of evening out production flow, and suggest ways of reducing unbalances
Active experimentation (doing)	Implement rebalancing and investigate the outcome

Use Case 2: Glotrain

The original game Glotrain, consists of 3 modules, which enable students to learn, gain experiences and reflect on the characteristics of a distributed manufacturing system.

The current version has been further developed at the University of Bremen and BIBA in Germany to fit the educational need in a master course. It is a facilitated multi-player (16–23) physical game. So far 700–800 participants have played the game, with different facilitators and in diverse editions. The collected feedback has been used to improve the game play for different user groups. Furthermore, due to the technology development, this aspect of the training has been continuously changed. Learning goals are to analyse the effect of re-organisation as well as to experience how the introduction of new technologies requires changes in the processes.

The product to be constructed is a lifting ramp and the players are organised in three different companies. Each player has a detailed job description, which he or she has to follow. The companies are separated in space, so that all material and all orders have to be transported from one company to the other (with in the BIBA building). In level one, there is no communication means involved, i.e. information change is only possible through physical meetings. Here, the main focus is on organisational aspects, lead times, throughput times etc. Figure 2 left shows the set-up of one of the three companies, whereas to the right you see the final product.

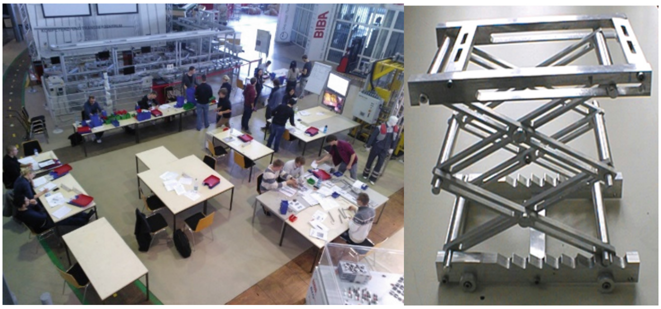

Fig. 2. Set-up Joga company Glotrain game and the product produced

The game is designed in such away, that the students will run out of time at level 1. In addition, we regularly observe lack in quality, which is one of the main concerns in the debriefing sessions between level 1 and 2. The Average play time is 7 h (full day including specific working sessions-simulating meeting between companies/departments) for improving identified problems in the supply chain. The players will also learn about different collaboration forms in a supply chain.

Depending on if the game is played with bachelor and master students or with managers, we use different set-ups and different additional tasks (Table 4).

The use of *Glotrain* uses an extension of Kolb's learning cycle: it uses the BIG (beyond the information given) BIG constructivism. Following the BIG approach, a facilitator directly introduces the concepts, provides examples to the students with concrete experience in activities that challenge them to apply, generalise and refine their initial understanding in multiple activities. This approach presents information to the learners but stresses the need to go beyond the information given (Table 5).

Table 4. Bloom's cognitive learning goals covered by Glotrain

Learning goal	Modality/mechanics
Remembering	The game does not really support this level
Understanding	The game allows the players to understand the assembly, the order management and the production process
Applying	In order to increase the quality, reduce the throughput time as well as to optimize the information and goods flow, the players apply different QM methods
Analysing	The game provides sufficient KPIs for a detailed analysis of all processes
Evaluating	Main target of level 1, where the players evaluate how well they met the goal according to the KPIs
Creating	Level 2 and 3 support this, since the players re-organise and experience the differences depending on their decision

Table 5. Support of Kolb's learning cycle due to the BIG approach

Learning stage	Modality/mechanics
Concrete experience (feeling)	At the beginning, the students do not have enough information to make their decisions based upon what is happening in the game, but rather of what they think may happen
Reflective observation (watching)	The student can observe both how their own processes evolves depending on his/her own decisions but also how the decisions affect the collaboration with the other players
Abstract conceptualization (thinking)	During game play: can draw his conclusion based on how his indicators (financial, stock level, use of material, material flow etc.) emerge
Active experimentation (doing)	Based upon the outcome of the previous phase, the player changes the processes according to the analysis. This needs to be carried out as a collaborative task

The next session will discuss lessons learned for both games both related to how we have to adapt the games for different user groups, and what we have observed related to how pervasive the players found the gaming environment.

6 Lessons Learned

The experience shows that in both cases, it is important to carefully align gaming goals with course goals and course assessment (i.e. constructive alignment). A main concern is often how to change the learning mechanics–game mechanics interaction. [16] can provide guidance.

In addition, it has to be taken into consideration that in these physical games, user engagement is dependent on the quality of facilitation, fitness of the SG to the subject, the content and context of use, combinatorial effects of learner types and user groups, interactivity and learning curve [17]. An experienced teacher has often acquired a quite a precise understanding on how the game-play needs to be changed for different groups both in order to be engaging, to deliver the learning outcome as well to make sure that the player stay in flow and feel immersed. The following section describes this experience and answers research question 1- the elasticity usage of mechanics.

The experience with using Pedal car game and Glotrain with different user groups as well with inhomogeneous user groups shows clearly user group specific learning outcomes, which is both dependent participants' previous knowledge and experience. Whereas undergraduate students benefit most from hands on, post graduates experience a more holistic picture of the production line enabling them to apply system perspective on the business allowing them to create new concepts and solutions, i.e. the learning outcomes is in three highest levels of Blooms revised taxonomy. The main learning achievements for undergraduates is however more related to understanding and awareness- through their experience within pedal cars they increase the understanding for concepts like cycle time, standardised ways of work, the predicted learning progression curve (A) as well as learn from unexpected practical difficulties when implementing improvements in a work station. The latter holds also for Glotrain, but here the undergraduate students learn more about understanding how different processes are interacting and affecting each other.

For the company participants playing the games, the main contribution from Pedal Car game is in the field of LEAN improvements, whereas in Glotrain their competences related to holistic process improvement and re-engineering are improved. In both cases, we see that the ability to transfer the knowledge experienced during game play is higher for this group than for the students, even if they have no domains specific knowledge (i.e. not from automotive or tool and die making sector). Of specifically value for the learning effect is the debriefing sessions, but also during discussions as the game passes, the participants often discover similarities between the game and their own business. A typical business group represents a whole department in the company - the manager as well as the single machine operator. A common view in the company on the LEAN transformation is fundamental [18] and as a motivator for LEAN transformation, and yet a team building activity, the Pedal Car Game works well Evaluation forms), whereas the Glotrain works well for quality management improvements for in general.

In addition, analysing which factors being the triggering factors for ensuring flow and high user engagement as well as when the player experience that the games are pervasive, we see that it is imperative to align the goal in the game with the competence level of the player-i.e. it is imperative to know the competence level of each player in an inhomogeneous group, as well as be able to adapt the difficulties in the tasks so that each student stay in flow [19]. This can be done either via additional tasks (like in Trampbilsfabriken) or by having the same tasks, but requiring different granularity in the analysis and evaluation level. Furthermore, also the selection of KPIs are important for keeping- if the knowledge of the players is basic, parameters easy to understand and to measure like lead time, number of errors etc. should be used as target for game play. For players with a better system understanding, KPIs like throughput, quality measures at system level etc. need to be available, supporting system thinking and above all supporting the learning process at the highest level according to Blooms revised taxonomy.

Also in the set-up of the workshops, there are clearly difference related to different usage- the more experience a player have, the higher role the reflection periods play both for knowledge transfer as well as for the learning outcome. In the case studies we have used simple simulation based manual games, for which the KPIs are collected manually. In the case of Glotrain, we have an information system implemented in level 3. This can generate new KPIs and also collect data related to failure rate etc. that can be used to nurture the game play. However, the experience has shown that it is very important that the players understand how they are measured. This tends to have a higher value for industrial players, since they intuitive compare the KPIs in the game play with the KPIs normally measured within the company. Deviation between the two, if not understandable, leads to a decline engagement, since the simulation then is considered as unrealistic.

The adoption of pervasive mechanisms can be coupled with the specific set of tasks a worker needs to carry out, making sure that field tasks are correctly and entirely completed.

Pervasive games have the capacity to blend the real world into the virtual environment, employing physical and social aspects of the real world to stimulate learning, enhance the development of applied skills, and better the overall learning outcomes. However, it is important to consider that everyday tasks and problem solving are often mundane and imply activities that offer little to no challenge or reward [20]. Therefore, while pervasiveness has the capacity to enhance virtual experiences, games can also be used to augment challenge and motivation in the physical world.

Pervasive game mechanics:

- *Collaboration*. By applying a pervasive approach, students can interact with experts that activate in the field, enhancing their capacity to make informed choices in their simulation routine.
- *Blend the physical and virtual world*. By integrating the game into a real production facility players will be able to make meaningful decisions.
- *Treasure hunt and competition*. Elements of competition and exploration form the core theme. Treasure hunts and competition are known to have an instinctive attraction among people. Therefore, a combination of these provides an opportunity to generate a compelling theme for adopting safety measures or quality standards in the games. By employing a pervasive treasure hunt mechanic, players are given challenges, they need to unlock clues to solve riddles sequentially and win prizes to succeed in the treasure hunting. Treasure hunting can be an individual or a collective task, where participants can team up to solve clues quicker or can compete to see who can unlock treasures faster.
- *Pervasive daily quests.* These are given to players once per day. For example, to be able to activate the assembly stations, players need to check in first at the quality station and answer a question or a set of questions on quality control.
- *Pervasive unique quests.* These are available only once during the game play. They can be used for testing critical security knowledge.

Use QR/Data Matrix Codes. Using standard technologies in the form of a smartphone application that uses the camera feature to scan QR/Data Matrix codes integrated into the game, players can scan actual product barcodes and use the technical information associated with that product as the basis of the activity they perform in the simulated environment.

7 Opportunities and Limitation by Transferring the Physical Games to VR Environment

The previous section addressed research question 1, and delivered suggestions for elastic mechanics which have proven to work for keeping players in inhomogeneous groups in flow, immersed and engaged. This section will focus on the second question- the transfer of a physical game to a virtual reality (VR) environment. The reason for looking into VR is that the technology is quite well known to many of our participants. A large part has either experience from the automotive industry, where it is common to use. According to [21] "virtual environments and technologies (VR) have been widely used in the area of product engineering [22]". Even though there are problems with aspects like rendering, response time and that there are several reports on the limitation of devices such as Oculus Rift, there are many VR applications within education [23], but it is not obvious to that VR will bring any advantages in terms of learning outcomes compared with the existing physical games. Our considerations are therefore as follows: Currently, the games are embedded in workshops that mostly are parts of a larger course. It is a traditional workshop setting, where much of the learning takes place within the debriefing phase, i.e. the participants are interrupted in the flow. The facilitator needs to be experienced in order to observe, react and facilitate to what he sees, since only a few KPIs are delivered. By transferring the games to a VR, we expect that we can take advantage of game and learning analytics, and provide feedback while playing to facilitator and players. The feedback will be individualised in order to address the challenges we experience with our inhomogeneous groups. In the cases of being a part of a larger course, a digitalised game will also offer the opportunity to be integrated in the LMS if using LTI, which can support the student with additional material, if required. A classical simulation would bring some of the same advantages, but in both cases, it will be less possible to actually carry out the physical operation (i.e. assembling of wheels etc.). This is important for the course goals and how the players perceive the game. In addition, the VR environment would make it possible to run games in various environmental settings, which would be usable to illustrate – for instance - how different interior arrangements could affect the ability to move freely on a limited assembly area. Amongst disadvantages the lack of force feedback could be mentioned, which makes ergonomic evaluation more complex.

Currently, we are in the designing and mock-up phase. As described above, we have developed the mechanics we like to have flexible, and we have started on the development of the VR environment. This is however time consuming. Due to the costs of development if using professional developers, we are currently working on a prototype for concept testing with computer science students.

8 Conclusion and Summary

The analysis of the two games and how it can be adapted to different target groups shows that even with a standard setup of the games and just a small variation in objectives, a wide range of groups can benefit from the game. The production line/production system can be used for hands on experience for novelties, just as well as complex system investigations with try outs in robustness and evened out and balanced production flow. However, it is of profound importance to know what kind of group that enters the plant. Objectives aimed for masters students simply would not work in a BSc group. In order to improve the integration in the overall curricula as well as to take advantage of the possibility learning and gaming analytics can give, we are working on a new VR prototype.

Looking into the pervasive aspects, we see that a lot can still be done. Pervasiveness brings forth new opportunities to design more flexible approaches in education and work settings. Pervasive constructs in education not only bridges, but blends formal and informal learning, extending the learning journeys outside the classroom. This creates a more realist and practical learning process, supporting the transition to the labour market. For mechanical engineering, this perspective is particularly relevant since key disciplines and jobs associated with the field require students and workers go outside the classroom/office.

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Putting Serious Games in Context: The Energy Efficiency of Buildings Case

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Abstract. The paper invites to a reflection on the way energy efficiency (serious) games – i.e. those addressing the issue of behavioral change in individual energy consumption – are and should be designed to better fulfil the goals assigned to Demand Side Management programs, notably run by governments and utilities, with special respect to public buildings (i.e. other than private homes). We introduce three contextual design goals and contend that more can be done to exploit the potential of gamification in the domain at hand.

Keywords: Contextual design · Persuasive technology · Behavioral change

1 Introduction

Nowadays, serious games and gamification are widely and diversely applied, including in such domains as "green consumption" and the promotion of sustainable behavior in the population. Quite recently, Mazur-Stommen and Farley [7] built a database of 40 different games meant to influence user behavior on energy efficiency and sustainability. Previous research by Frederick Grossberg et al. [4] collected information on 53 serious games, 22 of which could be or were already part of a gamified demand management program run by a public utility. Despite the scanty evidence of added value and the time- and location-dependency of most documented trials, there is little doubt that The Holy Grail these programs are targeting is the 3–6% decrease in energy consumption records (only exceptionally reaching up to 10%) that a systematic and massive change of end user behaviors has the potential to generate, according to many observers [1–3, 6]. In this sense, energy efficiency games can be considered as an integral part of those persuasive technology systems that the literature on service design has explored with growing attention and intention [9].

This paper invites to a reflection on the way serious games – addressing the issue of reducing individual energy consumption – are and should be designed to better fulfil the goals assigned to Demand Side Management (DSM) programs. It does so by first highlighting two major limitations of currently known experiences, and then proposing three contextual design goals, showing their interdependencies and arguing that effective program gamification should fulfill them all.

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2 Limitations of Current Programs

First and foremost, the majority of DSM programs for energy saving do not address public buildings, but stay confined to private homes. For instance, a recent study by the JRC (Joint Research Centre) of the European Commission [8] analyzed 67 projects funded by the EU during 2011–2014 out of a database of 459 so-called smart grid initiatives. Overall, 63% targeted the residential sector only, while the remaining 37% addressed the residential in combination with the commercial, industrial or government sectors, but keeping the households in focus. The reason is quite straightforward: it is quite difficult to identify and engage all the various occupants of a functional building (be it an office, or a school or a gym) who do not pay the bills for the energy they use.

A second, important qualification is that the impact of DSM does not seem to materialize with the expected size and persistence over time. This issue is well known in literature (see e.g. [1]) and confirmed by the conclusions of the JRC study, which are twofold: a) the effectiveness of a more inclusive approach, based on user involvement and multi-stakeholder partnerships, cannot be documented from the cases analyzed; and b) same goes for the scalability and replication potential of community-oriented projects. Among the possible explanations, an interesting remark comes from Lewis et al. [6] and the diagram below (Fig. 1): most of these projects are actually one-off experiments, lacking the required level of integration (of approaches, activities, methods and tools used) to guarantee the desired level of results.

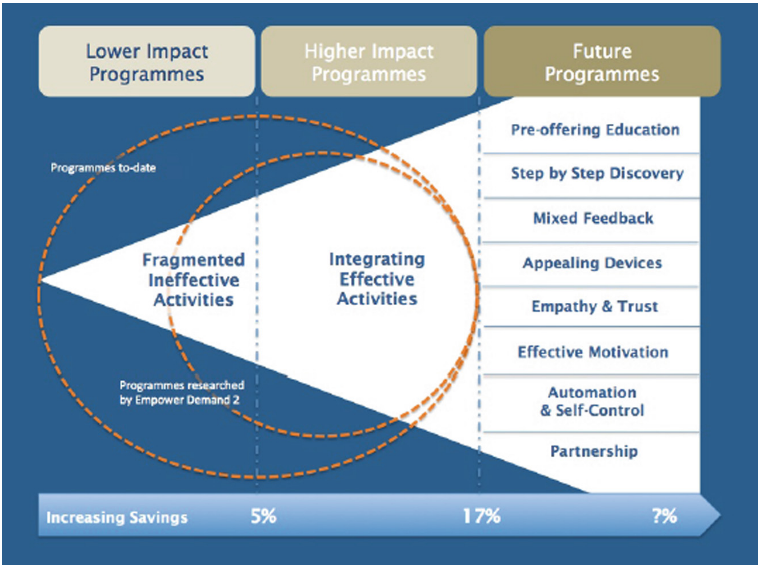

Fig. 1. Maturity levels of DSM programs (source: [15]).

To understand the contribution that gamification could bring to integration, the above list of elements of future DSM programs can be successfully compared with the

8-items typology of persuasive strategies defined by Halko and Kientz after an extensive literature search in the field of psychology to modify health related behaviors [5], as displayed in the following table (Table 1):

Table 1. Opportunities for gamification in future DSM programs.

DSM program elements	Persuasive strategy	Gamification's added value
Pre-offering education	*Instruction style:* authoritative	*Instruction style:* Non-authoritative
Appealing devices		
Mixed feedback	*Social Feedback:* cooperative	*Social Feedback:* competitive
Partnership		
Effective motivation	*Motivation Type:* extrinsic	*Motivation Type:* intrinsic
Empathy and trust		
Automation and self-control	*Reinforcement Type:* negative	*Reinforcement Type:* positive
Step-by-step discovery		

3 Proposed Approach

To promote effective gamification of DSM programs for energy saving we introduce a pragmatic approach based on three contextual design goals: Promoting the Acceptance of proposed measures, Understanding the Potential of a large-scale DSM deployment and Monitoring the Results of behavioral change in terms of improved energy efficiency of buildings. We see these as mutually reinforcing aspects, as the following graph displays (Fig. 2):

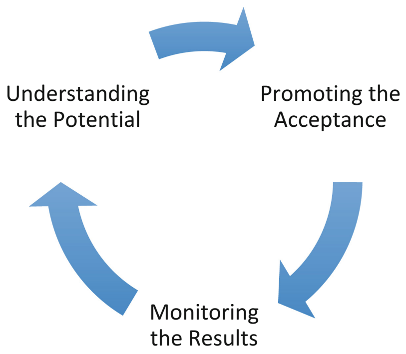

Fig. 2. The mutually reinforcing nature of proposed design goals.

Intuitively, offering the possibility to monitor the results of their engagement (e.g. via smart metering systems or the unravelling of the electricity bills) enables more users to understand the potential of behavioral change for an improved energy efficiency of existing buildings. In turn, a wider and deeper knowledge of the mechanisms by which

DSM can determine a sensible improvement of the current situation favors a broader acceptance of the behavioral prescriptions to be implemented. Finally, with the full and convinced engagement of all the building occupants (including occasional visitors and the people in charge of e.g. cleaning or periodic maintenance services or dairy supplies), the chances become much higher to reach the most ambitious targets of improvement and to keep them stable across time.

To highlight the value of this approach, we adopt the simple formula first introduced by IEA (the International Energy Agency) when elaborating on energy efficiency programs and how to increase DSM measures' uptake and impacts:

$$Potential^{*}\,Acceptance\;=\;Result \tag{1}$$

What the formula says is that potential per se is not the only target. Another is how to get sufficient acceptance of energy efficiency measures by the building users. Any huge number multiplied with zero will be zero! [10].

To make this approach operational, we will first of all need to map the stakeholders to be involved and create personalized ways of fruition of the developed innovations. Then the design of what can be considered as persuasive systems will have to be done in such a way that a growing share of the target population gets engaged in a permanent manner. Considering the "black box" of technology is difficult to penetrate, another possible option is to co-create the program details with the prospective users themselves, as predicated by the Living Labs methodology.

The individual DSM tools will then be customized and adopted in the different project pilots, according to the typology of (public) functional buildings and the characteristics of their occupants, e.g.: educational buildings regularly occupied by the same users (schools, universities, dormitories, kindergartens etc.), institutional buildings regularly occupied by public sector staff (offices, municipal seats etc.), cultural buildings occupied by diverse users, mostly occasional visitors during specific activities (libraries, museums, concert halls). In this context, the design of new serious games or the appropriation of some of them from the state of the art will be specialized by prospective audience and explicitly addressed towards the reduction of fragmentation and the increase of long term, permanent impact that are currently lamented as among the most crucial issues in the domain at hand.

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Creating Location-Based Augmented-Reality Games for Cultural Heritage

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Abstract. This half-day workshop is concerned with location-based AR games for cultural heritage. We explore location-based game mechanics and narrative structural techniques suitable for cultural heritage sites, as well as approaches to visuals and audio that can help create a feeling of immersion into the cultural content without losing a sense of presence in the cultural space. The workshop includes an introduction to, and hands-on tutorial with, the latest version of the Haunted Planet authoring tool, which allows such experiences to be created without programming skills. The workshop is intended to be of general interest, but is expected to be of particular interest to researchers and professionals from the cultural heritage industry and researchers in serious games for learning.

Keywords: Game design · VR/AR · Cultural heritage

1 Motivation

While location-based AR games have existed for well over a decade, it is only with the advent of blockbuster titles such as *Ingress* and *Pokémon GO* that the genre has really entered the public mainstream. The genre holds considerable potential for cultural heritage sites as a way to present historical and other types of content, and a number of experiences exist, ranging from early experiments such as *Geist* [13], *ReXplorer* [2] and *Viking Ghost Hunt* [4] to more mature approaches, such as *Jumieges 3D* [12].

A considerable challenge of location-based AR games is to offer a sense of *immersion* into the story/gameplay without losing a sense of *presence* in the physical space. For example, *Pokémon GO* excels at the former but fails at the latter, resulting in an experience that draws people into the gameplay at the cost of oblivity to the surroundings. While this may be acceptable for a non-cultural game experience, it is unsuitable for site-specific cultural heritage games where the site itself plays a crucial role in the experience. In this workshop, we explore the best design practices in for locative games that can help create a feeling of immersion into a site's cultural content without losing a sense of presence in the cultural space.

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2 Presence and Immersion

The term “presence” is often used as an abbreviation of “telepresence,” which is an area that has been subject to a considerable amount of research. However, here we are concerned with game experiences that take place in real cultural heritage sites, as distinct from games that are set in virtual representations of such sites. For this reason, we are not so much interested in telepresence, but rather in what is typically considered a broader notion of presence in the form of a “first order” mediated experience [9], i.e., the natural way that we as humans experience our surroundings through our natural sensory apparatus, such as sight, hearing, smell, etc.

The term “immersion” is used in game science to describe a particular type of feeling that may be experienced while playing a game. Brown and Cairns describe immersion during play as “a state facilitated by feelings of empathy and atmosphere” [3, p. 81]. Ermi and Mäyrä distinguish between three different types of immersion: sensory, challenged-based and imaginative [8]. Sensory immersion can be intensified with better graphics and sound; challenge-based by engaging gameplay, corresponding roughly to “flow” as described by Csikszentmihalyi [5,6]; and imaginative immersion as a “game experience in which one becomes absorbed with the stories and the world, or begins to feel for or identify with a game character” [8]. Of the three types of immersion, we argue that imaginative immersion is the one most suited for cultural heritage games that take place in real cultural heritage sites.

3 Related Work

Projects such as *Geist* [13], *Oakland Cemetery* [7] and *Carletto the Spider* [14] have placed virtual storytellers in cultural heritage sites. This idea represents a straightforward digitization of a familiar entity: the human tour guide. While the idea is easy to understand for visitors, it is not how modern games tell stories, and the tour guide abstraction does not lend itself well to what narrative games do best: mystery, exploration, drama and adventure. Except for very short segments, few modern games feature guides who narrate the game’s story to the player, because players want to *explore* themselves. Studies support audiences’ desire for interactivity, such as Lombardo and Damiano whose data shows that the users given a virtual guide desire a high degree of interactivity at multiple levels [14, p. 18].

More sophisticated approaches to locative media for cultural heritage are projects such as *REXplorer* [2] and *Viking Ghost Hunt* [4,15]. Like modern games, which use techniques like environmental storytelling that allow a player to explore a storyworld and piece the snippets together themselves, locative games for cultural heritage can present a narrative as a puzzle to be explored, or solved to different degrees, depending on the players’ preferences. This has the advantage that players with different levels of interest in the cultural material can delve into it to a degree that is proportional to their interest level.

4 Locative Game Mechanics

Game design always involves choosing a collection of "game mechanics," the fundamental interactions through which the players interact with the game. In turn, "gameplay" arises from the game mechanics and the players' interaction with them. For locative games, there is a distinct set of game mechanics known to work well, for example territorial mechanics (related to controlling physical territory) and resource gathering (involving physical movement) as well as collection, levelling and training mechanics (e.g., as known from *Pokémon GO* and *Ingress*). Such mechanics help create a complex gameworld with complex challenges, which in turn extend the duration of the play experience. In game design, extending the duration of the play experience is often seen as desirable, but this is not necessarily so for cultural heritage games. Additionally, increasing the complexity of the game results in a higher level of attention required from the player than a simpler experience, not to mention a steeper learning curve. If we consider the three types of immersion proposed by Ermi and Mäyrä [8], it is clear that the complex gameworlds offered by *Ingress* and *Pokémon GO* offer primarily challenge-based immersion. Players are captivated by capturing portals and catching pokémon creatures, not by the sensory fidelity of the experiences. Imaginative immersion also plays a role in these types of games, but the fascination with the stories and worlds of *Ingress* and *Pokémon GO* is decidedly secondary to the challenge-based immersion experienced by the player at the time during real-world play. For such games, the attention is easily shifted from the player's immediate surroundings to the gameworld.

For locative cultural heritage games, mechanics like those adopted in *Pokémon GO* and *Ingress* are generally unsuited, because they sacrifice presence in the physical space for immersion into the gameworld. Instead, the best

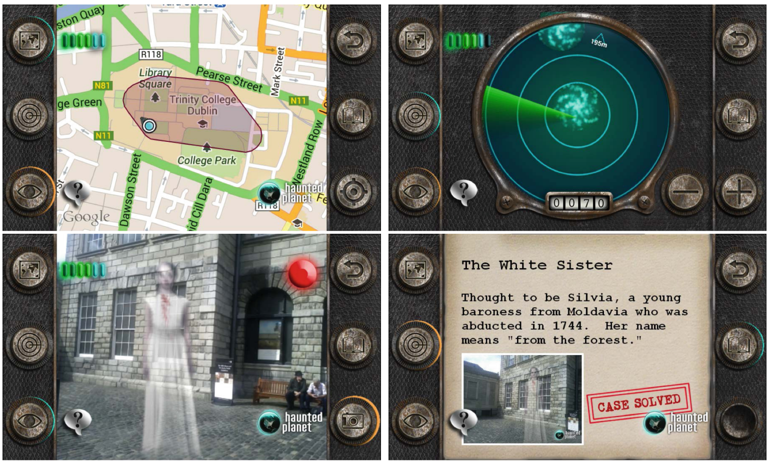

Fig. 1. Gameplay modes in *Bram Stoker's Vampires*. From top left: map, radar, ghost viewer and casebook. Active mode shown with blue glow (Color figure online).

locative game mechanics and gameplay for cultural heritage relate to physical navigation of the site and engagement with gameworld representations of objects of direct relevance to the site itself. For the former, search and scan mechanics in which players find their way through the site using navigational tools, such as maps, radars and dowsing, are particularly useful. Figure 1 shows examples of gameplay modes that facilitate such game mechanics from one of our own titles. Capture and collection mechanics are also helpful, especially if combined with puzzle mechanics that allow the collected game objects to be interacted with (e.g., combined) in order to solve a puzzle or discover a story. The challenges related to navigation and light-weight puzzle-solving result in a type of immersion that reverses the emphasis between challenge-based and imaginative immersion compared to *Ingress* and *Pokémon GO*.

5 Aesthetics: Visual and Audio Design

Visual and audio design range from abstract to representational [1], where abstract designs have a low degree of realism and representational designs have a high degree of realism. Most locative game experiences have relatively abstract aesthetics, such as the cartoony creatures in *Pokémon GO,* which by virtue of their design are placed as belonging squarely in the gameworld, not in the physical world. Rather than linking the gameworld with the physical world, these aesthetics result in a clear demarcation between them.

For cultural heritage games, it is more appropriate to develop visual and audio styles that link the gameworld with the physical space, rather than one that only emphasises the former. We have found that photorealistic visuals and audio help create a pretension to veracity that blurs the boundary between the gameworld and physical space and helps the immersion into the former coexist with presence in the latter. By blurring this boundary, we place a certain amount of uncertainty (especially through the use of sound [15]) about where the game objects belong, causing the player to pay extra attention to what is around them. For content that is historical, this approach not only blends the gameworld with the real world, but also mixes the past with the present.

6 Narrative Structures

Typical locative games, like *Ingress*, *Pokémon GO* and *Shadow Cities* take "a sandbox approach to narrative, offering a context absent of any inherent plot progression." [10]. Their narratives are best characterised as frames within which players can develop their own stories as a way to remember certain events. While this works well for game experiences that are intended to be long, it is less suited to game experiences intended to be of definite duration and in which there is a specific story to tell.

For locative cultural heritage games, it is therefore better to consider standard narrative structures, such as branching and decision points. The structures have the advantage that they are immediately familiar to many players, can be made more or less overt in the way they are presented, and that they lend themselves well to being used in physical space. For example, the act of choosing between two branches at a decision point can be a physical act of walking, or choosing between two different destinations within the site. In addition, we have found that certain narrative techniques from genre fiction work well. For example, Gothic storytelling often uses temporal and spatial transgressions [11], and time-travel as known from early science fiction (e.g., H. G. Wells) can also serve as a useful narrative mechanic that allows the past to merge with the present.

7 Deployment Issues

Deploying locative cultural heritage games comes with its own set of challenges. Generally speaking, the cultural heritage industry does not have many early adopters of new technologies; operators tend to be cautious in trying new ideas based on new technologies, and often also have very limited budgets. An additional complexity is that cultural material and sites need to be treated with sensitivity to their historical and cultural value.

A distinct advantage of smartphone-based locative games is that they do not require physical infrastructure to be placed across the site, making them easy to install, maintain and even adapt. For example, installation can be done with a simple visual display with a QR code to a download link at the site entrance. Adapting an existing experience by changing the points of interest can be done simply by changing the software.

8 Haunted Planet Authoring Tool

Till date, Haunted Planet Studios has published three games that engage with cultural heritage in various different ways: *Bram Stoker's Vampires* reflects on the literary heritage of the famous novel *Dracula* in the Irish writer's alma mater in Dublin, Ireland; *The Amazing Transfabulator* engages with the Victorian heritage and modern cultural practices of the community in Oamaru, New Zealand; and *Carolan's Last Tune* brings to life Irish myth and music in Galway, Ireland. Our current efforts include an authoring tool that will allow people without programming skills to develop games on a par with those developed by us, including equivalent fidelity in terms of audio and visual fidelity as well as narrative complexity. The current version can be found at http://make.hauntedplanet.com/.

Author Bio

Dr Mads Haahr is a Lecturer in Computer Science at the University of Dublin, Trinity College. Mads is a true multidisciplinarian, holding degrees in Computer Science (PhD) as well as English Literature (BA), and has been making location-based AR games for cultural heritage since 2008. He is Founder, CEO and Creative Director of Haunted Planet Studios, whose flagship title *Bram*

Stoker's Vampires is a cultural heritage location-based AR game that has won multiple game industry awards and was also a finalist in the 2016 Heritage in Motion Awards awarded by the European Museum Academy. Mads is also the Founder of the Internet's premier true random number service RANDOM.ORG.

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“Skipping the Baby Steps”: The Importance of Teaching Practical Programming Before Programming Theory

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Abstract. As programming becomes one of the most sought-after skills in today’s digital world, the demand for computer literate coders is ever-increasing. However, programming novices face many challenges when learning programming theory and syntax, showing the highest failure rates at university level. This study proposes a new syntax-based serious game solution which teaches programming novices C-Style syntax and programming theory. It aims to provide an alternative to block-based programming environment tools like Scratch and aims to better understand how novice programmers learn best today. The proposed solution focuses on two key areas which have shown the most promising results: motivation and syntax. The solution also focuses on reinforcing good programming practices to provide the novice with guidance to transition them to computer programming. The results show that the proposed application users saw an increase of 62.5% in their programming test results in comparison to 34.17% in Scratch users. Overall, the participants using the proposed tool were more positive about their experience, describing it as ‘very fun’ and ‘a very good educational experience!’. Results suggested that participants were not intimidated by the syntax where 9 out of 10 participants have said that they feel more comfortable about programming in the future. Not only that, but encouragingly, novices wanted the proposed application “to be more complex” challenging the perceptions novices have about programming. Overall, the results support the hypothesis that the proposed syntax-based application is a more motivational and effective tool in transitioning novices to computer programming.

Keywords: Serious games · Learning environment · Motivation · Practice learning · Syntax

1 Introduction

Programming has become an increasingly important skill to learn in today’s digital society (Watson and Li 2014). Many businesses fail due to the shortage of skilled computer programmers (Crowne 2002). Because of this, it has become critical to train the next generation of programmers. Learning difficulty in novices emerges from the unfamiliarity with instructional thinking and the difference from traditional subjects

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that the students are exposed to in school. Watson and Li (2014) performed a statistical analysis of pass rate data in worldwide introductory programming courses. It was reported that highest rate of student failure occurred at university level with a 66.4% pass rate. The results were even lower in a large classroom setting with a pass rate of 65.4%. Although this figure might not seem alarming, it does pose a concern in the way students are taught programming. Watson and Li also found that teaching novices in a class of 30 or less students, drastically increased the class pass rate to 80.1%. The study concluded that novice programmers perform best under a well-supported and guided process.

2 Related Work

There are several solutions which have been developed to tackle the challenges of programming:

- Code Combat: is an RPG style serious game which teaches novices how to program in a choice of Python, Javascript, Lua or Coffee Script language. The playes the game by controlling a warrior character using real coding syntax in the player's chosen language, providing the novice transferable skills to computer programming. Code Combat uses in-built functions (e.g. walk(5)) which hide a big part of the program that are responsible for the most commonly used activities in the game (e.g. walking), leaving the novice wondering whether the function "walk()" is part of the programming language they are using (Code Combat n.d.).
- Lightbot: is a simple serious game puzzle which aims to teach novice programmers the basics of how computers handle instructions. It uses tiles to teach the concept of functions, loops and other basic principles. However, the puzzle itself does not show or teach any code to the player and the use of an isometric design complicates the user interaction with the application (Lightbot n.d.).
- Scratch: is a block-based learning environment tool designed for children which aims to teach programming principles through the use of blocks. It teaches novices computational concepts such as loops, conditions and functions. However, Scratch uses natural-language to name the blocks used in their application, which limits the child's exposure to the proper programming terminology such as a "for loop" or a "function". Natural-language programming is syntax which closely resembles the English language (Scratch n.d.).

3 The Proposed Application

This paper proposes a task-driven serious game application which aims to teach novices the necessary programming theory and C-Style programming syntax to ease their transition to computer programming. The study places Scratch and the proposed application under close inspection to find out to what extent the proposed application is more motivating and effective in transitioning novices to computer programming in comparison to Scratch.

We begin the paper with an introduction to block-based programming environments, analysing the current popularity of the software. The paper then discusses other related work that attempts to solve programming problems. We present our study design and discuss in detail the decisions made behind the programming test questions and questionnaire. Once the novices perform a programming test before and after the use of the application and complete a short questionnaire describing their experience, the results are analysed and summarised.

The study predicts that more students using the proposed application will do better in the programming test than Scratch users. Mostly caused by the lack of exposure to syntax and programming terminology Scratch users will have in comparison to the proposed application users. It also predicts that the proposed application users will be more motivated when completing tasks in real code, learning directly how games work unlike Scratch where users might struggle to make connections from blocks to real code in the future.

4 Literature Review

4.1 Block-Based Learning Environment

In 2003, Michael Resnick and Andrés Monroy-Hernández developed Scratch. Since then, it has become the ever-popular solution to programming challenges, so much so, that the use of Scratch is now considered to be standard practice in a number of educational institutions. For example, Atilim University in Turkey incorporated the use of Scratch into their computer science curriculum to help engage children with computer programming (Ozoran et al. 2012). However, despite this, novices are still finding it difficult to engage with programming (Watson and Li 2014).

4.2 Natural-Language Programming

Since the beginning of computer programming, natural-language programming has been heavily debated. Natural-language programming is syntax which closely resembles the English language similarly to high level languages. This in turn makes it easier for the novice programmer to learn and predict syntax. Bruckman and Edwards performed a study which analyzed the online interactions of ‘sixteen children who issued a total of 35,047 commands on MOOSE Crossing’, an educational Multi-User Domain for children. (1999). Out of that number, a total of 2970 errors were observed and out of those, there were 314 natural-language errors. That is, when an error represents a word in English and the child is unable to differentiate it from coding syntax. 41.1% of children could resolve the errors with ease and 20.7% with greater difficulty. Most of the errors were resolved by guessing, which highlights the benefits of natural-language programming. On the other hand, some of the errors were caused by students assuming a presence of an object that did not exist. Natural-language programming also has its limitation, including the number of available functions. As the study shows, out of the sixteen children, only nine programmed at least a single script and out of those nine, only five reached a basic scripting level.

Although, there is evidence to show that it becomes easier for children to predict syntax and overcome errors, it also creates many other syntax problems. Consequently, the proposed solution in this paper will use a high-level C-Style programming language syntax. C-style syntax bridges the gap between the most powerful languages in game/web/software development. Learning C-Style syntax means you can easily pick up other languages in the C family like C#, Javascript and C++ and many more. It can provide the opportunity for a programming novice to learn advanced techniques quicker in the future unlike the natural-language programming solution.

4.3 Rising Popularity in Gaming

Based on newzoo's Global Game's Market 2017 report, there are roughly 2.2 billion gamers in the world today (Newzoo 2017). With the growing popularity in gaming, it is not surprising that so many programming learning environments are incorporated into games to engage their target audience. However, where they succeed in motivation and engagement, they lack in teaching the user programming terminology and syntax. This paper attempts to overcome this challenge by teaching programming syntax early and directly relating their love for gaming and code. It attempts to spark user curiosity into how games they love are made and hopefully create long lasting motivation to learn.

4.4 Block-Based Learning Environment

Looking at Scratch's monthly active user statistics, it is clear to see that the popularity of Scratch is only rising. The number of new Scratch users and projects rose dramatically in September months starting in 2013 and falls in the summer months. This suggests that Scratch is mostly being used in educational institutions and students are not maintaining interest in the summer months (Scratch n.d.). However, due to the growing popularity of Scratch, it is becoming the conventional tool to teach programming principles in educational institutions. The application proposed in this paper will be tested against Scratch to compare whether the current educational standard could be improved. This will provide a better understanding of block-based and serious game solutions and give an insight into how novice programmers learn best today.

4.5 The Advantages of Scratch

One of the key advantages of using Scratch is that it is easier to use than the conventional text-based code editing environments like Visual Studio (Weintrop and Wilensky 2015). A study on student perceptions of block-based programming conducted by Weintrop and Wilensky has identified key features which makes Scratch easier to use. One of which is Scratch's blocks serving as a memory aid. If a novice wants to make the character walk, he/she could simply navigate to the "motion" tab and see the block that controls the character.

However, it can be argued that this will only create problems in the future. Yorah Bosse and Marco Aurélio Gerosa conducted a study investigating patterns of difficulties related to programming learning. 34 students filled out diaries about their programming curriculum studies. The data from the diaries was later analysed and it was revealed that the most occurring problem, with 13 occurrences, faced by students was "syntax error". One student even said "the program didn't execute … I don't know how to solve". Which opens a debate between the studies conducted by Weintrop and Wilensky and Bosse and Gerosa - Should we teach programming syntax earlier? Although Scratch is easier to use than text based programming environments, it can be argued that once all of the benefits of Scratch are taken away, the novices have to make a new learning curve of adapting to programming syntax which is a long process on its own. The proposed application in this paper aims to address the issues of syntax and investigate whether a serious game solution which teaches C-Style syntax can prove to be an effective solution to this problem. Although syntax learning curve is bigger, it could pay off if introduced at an earlier stage.

4.6 Downfalls of Scratch

Other block-based environment problems began to surface as Moreno and Robles have found in their study (2015). One hundred random projects were downloaded and analyzed using two automatic bad programming detection plugins. The results revealed that 79% of projects used default object naming and 62% had unused code repetition. Object naming in Scratch is often automatically assigned when a sprite is created, as SpriteX. In programming, however, the user is forced to create a variable name and so this bad example of programming practice is avoided. This is something that is addressed in the proposed serious game solution. The user is encouraged to type the entire code solution themselves without auto-typing or default naming tools. This will ensure that proper programming practices are enforced early on.

This research directs this paper to investigate syntax-based serious game environments in comparison to Scratch which might shine a new perspective on how novice programmers learn best today.

5 Method

5.1 Breakdown of Method

This section describes a serious game level-based solution developed to teach programming novices C-Style programming syntax and basic programming principles including if statements, variables, for loops and functions.

The serious game level-based solution was designed in Adobe Illustrator and developed in Unity 5.5.0 gaming engine using C#. The levels required for the novice to program a box across to the exit using C-Style code, avoiding any obstacles along the way. Such that they need to lower a platform to form a solid road for the box to cross, or to get off a moving platform at the right time to reach the exit. The serious game solution is comprised of six levels, providing hints for the novice to follow to proceed on to the next task. Various levels are divided into sub-tasks for the purpose of demonstrating the advantages of programming techniques used and to break up the levels into manageable tasks. Each level is designed to increase in difficulty and aims to teach a new programming technique in every level. The tutorials provided in each level explain in plain English what each technique does and what each part of the code means, so the novice can gain a better understanding of programming theory and become more confident about programming in real life scenario in the future.

The serious game level design was replicated as closely as possible on a block-based programming tool called Scratch - the conventional learning tool used in schools and higher education institutions around the world. Unlike in the proposed tool which teaches the novice C-Style code syntax, the novice here needs to use Scratch's coding blocks to complete the tasks. The tutorials for both applications follow the same style of wording but the tutorial content changes from explaining what a for loop is in the proposed tool, for example into what a repeat block does in Scratch. Unlike the proposed application where users see and learn code, tutorials in Scratch show the novice the solutions and hints in Scratch blocks.

The study hopes to uncover various features which might aid the novice to learn programming theory in an environment which is not filled with scary code syntax. It also aims to find out whether the programming syntax and programming principles used in the proposed tool are too difficult for a programming novice to pick up in a short space of time and if it can prove to be a good alternative to block-based programming tool Scratch to transition novices to computer programming. It aims to investigate whether Scratch's programming blocks can provide the same level of learning as a syntax-based serious game solution proposed in this paper.

To measure the effectiveness of each solution, two groups of ten novice programmers have been recruited. The participants were randomly arranged in such a way that will give each group an even split of female and male novices. Each participant completed a questionnaire to establish their programming ability and gain a little bit of insight about who they are. The participant then completed a six-question programming test which comprised of four qualitative answer responses and two quantitative answer responses to establish whether the novice might be able to make an educated guess about the correct answer to each question. The participant was then given an application to use - either Scratch or the proposed solution in this paper. The participants then complete a short questionnaire asking about their experience with the application and giving both quantitative and qualitative responses to gain a better idea of where the shortcomings and strengths of each application lie. The participants are then required to repeat the programming test that they have completed before to see whether their responses improve, deteriorate or not change after the use of the application.

5.2 Subjects

The subjects for this experiment were young adults aged 20–25, majority of whom are Coventry University students who volunteered to participate in the test scenario. In total there were 20 subjects, 7 females and 13 males. None of the subjects have ever programmed in the past nor have they ever used a block-based programming tools.

5.3 Conditions

Participants recruited had to be over the age of 18, never programmed before and who have never used Scratch before. There were no other additional conditions needed.

The programming test is structured to test the novice's knowledge of programming theory as well as test their understanding of syntax. Before the applicants get to use the application, it was important to establish whether he/she can make an educated guess about what certain programming principles are and determine what output is generated by a piece of code.

Three out of six questions in the programming test ask users to describe a keyword or a programming technique in an open-ended response to gage understanding of how a novice might interpret the terminology presented. The remaining three questions are multi choice questions which focus on programming syntax and their understanding of programming processes. For example, one of the questions ask for the novice to select the correct output for the code provided to establish whether the novice is able to make an educated guess about the correct answer.

The questionnaire given to the novices after the use of the software covers their experience with the software they were using. It looks at what application features they enjoyed, ones they didn't and most importantly see how the application used could be improved in their opinion. It aims to uncover the most important aspects of software that novices find useful in terms of motivation and effectiveness to learn.

6 Evaluation of Results

This section describes the process of analysing qualitative and quantitative data collected in this study. It summarises the findings and outlines the conclusions which can be made from the results.

The following describes the process of analysing the qualitative data gathered from the programming test. It comprises of four open scenario questions where the participants can answer the questions in their own words. The collected qualitative data is matched against certain rules which have been predetermined to analyse whether the novice answered the question correctly and to what degree. The summary of these results is displayed in Table 1.

Table 1. Qualitative score analysis of programming test per question (after application use)

Score	Application									
	Scratch					Proposed Application				
	Question					Question				
	1	2	3	4	Total	1	2	3	4	Total
1	4	2	8	2	16	0	6	2	0	8
2	6	6	2	8	22	4	4	1	2	11
3	0	2	0	0	2	6	0	7	8	21
Total	10	10	10	10	40	10	10	10	10	40

The first part of the research question asks to what extent is a syntax-based serious game solution more motivating than Scratch. To answer this question, the qualitative and quantitative data has been extracted from the questionnaire.

The data shows that overall, the participants using the proposed serious game solution were more motivated to use the tool again in the future despite the difficulty of learning C-Style syntax. This was backed up by the comments in the questionnaire. Participants who used the proposed application were on average more positive about their experience describing it as “a very good learning experience!”, “very fun”, “I love it!”, “insightfully stress inducing”, “very educational”. In contrast, participants who were using Scratch gave a mixture of positive and negative feedback, describing their experience as “frustrating”, “long winded”, “challenging”, “quite fun” and noted that “too much time was needed to learn the interface”. They have also commented on the UI used in Scratch to be bothersome, drawing attention to the larger learning curve that the participants need to make in a short space of time before they can comfortably use the application and to begin to tackle the task at hand.

The questionnaire then followed up with a question asking the participants to rate from 1 to 5 (1 being the lowest) whether they would use this tool again in the future. Scratch received an average score of 2.7 out of 5. Whereas, the proposed application had an average rating of 4.4 out of 5.

To further analyze the reason behind the ratings, the participants were also asked how the application they were using could be improved. To improve the proposed application, participants suggested “the application could be more complex”, “more levels, more story”, “different design”, “more steps explaining what is happening”. In comparison to the feedback, Scratch users recommended to implement a “different UI and maybe a definition for each block”, “more information about what is happening behind the blocks”, “some sort of visual feedback when something goes wrong”, “it would be nice to learn some theory”.

The overall results discussed above suggests that the proposed application is more motivating than Scratch.

The second part of the research question asks to what extend is a syntax-based serious game solution more effective in transitioning novices to computer programming in comparison to Scratch. To answer this part of the question, it is important to analyse the programming test results that each participant completed before and after the use of an application. Table 3 summarizes the programming results per question of each application, comparing the before and after results of the programming test averages.

Table 2. Average programming test score improvement (measuring before and after results)

Question	Scratch	Proposed application
1	0%	65%
2	50%	20%
3	10%	75%
4	35%	85%
5	50%	40%
6	60%	90%
Total	34.17%	62.5%

Table 3. Quantitative programming test results (after using the application)

Question	Scratch	Proposed application
5	7	8
6	6	10
Total	13	18

The levels are designed in such a way that would reiterate what the novices have learnt. For example, the user must always move the box to the exit either by using a repeat block in Scratch or by using a for loop in C-Style syntax in the application to accomplish this.

Looking at results from question 4 (which required novices to understand the output and theory of for loops) Scratch users only improved their score by 35% likely due to the unfamiliarity with the for-loop syntax or syntax in general. As opposed to the application users who have been using code from the beginning showing an increase of 85% in their score. It is reasonable to suggest that the reiteration of syntax is a useful technique to use when first introducing programming to novices. Promisingly, most application participants could recall the for-loop syntax and even remember the theory behind the method to fully understand how many iterations the for loop will make. So much so, that 8 out of 10 participants scored full points unlike Scratch users of which whom none did.

Serious games play a big part in demonstrating what a piece of code or block can do by visualising its effect instantaneously. Application users have the advantage of writing code, reading the theory behind it and seeing it put to action as you hit Run. Although Scratch users are also able to see what a block can do, they have struggled to make the same level of connection between a block and code syntax. Most importantly, identifying that to transition to code, there are no shortcuts – we must teach syntax right away.

On average, the proposed application users have experienced a programming result growth of 62.5% in comparison to Scratch users who have a seen a lower growth rate of 34.17%.

It is also important to evaluate the results from question 3, (which asks novices to describe what a function is) where only 10% of Scratch users have seen a programming result improvement in contrast to the 75% in the proposed application user results. This is likely caused by the lack of use of the keyword "function" in Scratch. When Scratch users created a function, rather than seeing a block called "create a new function", they saw "create a new block", which had a heavy impact upon their results. A similar scenario is again evident in question 1, as even though novices were moving the box in every level using the "repeat block" in Scratch and the for loop in the proposed application, the lack of exposure to the keyword "for loop" in Scratch has been clearly reflected in the results gathered. Ironically, they were using the for loop without ever knowing of it.

Level 2, however, is one question which Scratch users did better on than the proposed application users when asked to describe a variable. This could be the result of the tutorial text wording used in the proposed application, as "variable" is only mentioned once in the entire application. In Scratch, however, users must actively navigate to the corresponding navigation panel via Scratch UI and click on "create a new variable" button, followed by a window pop-up reiterating the word "variable" once more. This was missing in the proposed application and it can be argued that this was the reason for the poor results.

Following the programming test, the novices were asked whether they feel more comfortable about programming in the future, if given the opportunity. Overwhelmingly, 9 out of 10 participants who used the proposed application said yes. As opposed to, 4 out of 10 participants who used Scratch said yes. The overall results discussed above suggest that the proposed application is a more effective tool to transition novices to computer programming.

7 Discussion

Due to the limitations of Scratch it was difficult to perfectly replicate the proposed application to the standard planned. Behind the scenes of the proposed application, there are a number of processes which run every frame to check if the user has completed the first task. Once a task is complete, a new tutorial pops ups guiding the user through the next stage. However, Scratch is quite limited in that regard as it does not have background code in the same manner as a gaming engine does. This meant that to replicate the tutorial screens the novice would have to manually call a function to let the application know that the player has progressed to the next stage, creating confusion and adding extra steps for the novice to complete. Because of these limitations, the tutorial text was handed out to the Scratch users in paper format. This minimized bias as no extra code was revealed nor did the user must perform additional tasks.

It is important to note that the proposed solution gives the novice the tools that they might expect to see in a classic programming editor, like a debug button and error messages. The error messages are worded in a way that would allow a novice to understand what the error means specifically in the task they are working in. This is the first glimpse a novice would have to a debugger, further easing transition to programming. The same, however, could not be done in Scratch due to the development limitations faced. Evidenced by the only debugging tool available in Scratch - the "say "hello"" box which further demonstrated the limitations of Scratch.

The serious game scenario in Scratch and in the proposed tool tested the novices with tasks like making the box move to the exit using blocks/C-Style code, creating functions which take in an object in the proposed tool and a string in Scratch followed by an integer. It was observed that 4 participants out of 10 using Scratch kept the default naming that was provided with the block as "string1" and "number1" supporting Moreno and Robles findings (2015). In contrast, the proposed tool participants had to name the objects exactly or they would be unable to continue to the next level. This reinforcement introduces novices to good programming practice whilst the Scratch users could follow the instructions provided or not. Due to the limitations of Scratch error messages were not introduced unlike in the proposed tool.

The code blocks in Scratch would remain after each level whereas in the application the code is wiped clean every level to reinforce what the novices have learnt in previous levels. To be able to "wipe" the code and minimize bias in Scratch it was necessary to divide the project with all levels into individual levels which would then make sure that code that they have already constructed is not readily available for them to use again.

Although the proposed application as it stands is quite limited to a single/couple solutions per level, to further develop the application the user would be allowed to experiment with code. It was planned to have multiple solutions to a problem and even let the novice move the exit to the box, demonstrating the flexibility of code.

It is still difficult to judge how successful block-based programming is when it comes to transitioning students into the conventional syntax-based programming. Part of the problem of answering this question is the lengthiness of time Scratch gets tested over as this type of transition often happens over long periods of times with the combination of other modules studied by student at the same time. This makes it difficult to pinpoint which feature in block-based programming tool is successful and often, the entire environment is taken as a whole, making these types of studies susceptible to issues conflation. It would be interesting to perform this study over a longer period, when novices are comfortable with the UI of Scratch and see whether the results would differ. However, it is encouraging to see, that time does not mean less is learnt. Rather, time is valuable and we should use it to learn what matters.

8 Conclusions

Overall, the results presented in this study suggest that the proposed syntax-based serious game application has a place in the market. Participants using the proposed application were overall more positive about their experience, rating it 4.4 out of 5 in comparison to Scratch user rating of 2.7 out of 5. The proposed application users were also more motivated about programming in the future, where overwhelmingly 9 out of 10 participants have said they would feel more comfortable about programming in the future. The feedback even went on to say that some novice programmers using the proposed application would like more levels and for the levels to be more complex. In comparison, some novices who used Scratch wanted to learn more about how the blocks are working. The participants using the proposed application also performed better on the programming test than Scratch users, demonstrating an average improvement rate of 62.5% as opposed to Scratch's 34.17%. To conclude, the results in this study suggest that the proposed application is a more motivational and effective tool to transition programming novices to computer programming.

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