LEVELING UP GAMIFICATION: TECHNOLOGIES & STRATEGIES FOR MORE EFFECTIVE GAMIFICATION DESIGN

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Amir Matallaoui

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Promotionsausschuss:

Vorsitzende: Prof. Dr. Knut Blind
Gutachter: Prof. Dr. Rüdiger Zarnekow
Gutachter: Prof. Dr. Andreas Eckhardt

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This thesis is dedicated to

my beloved parents Nouar Matallaoui & Khedija Majed,

my dear brother Ayoub & my sweet sister Maya,

my lovely wife Ines Rahrah and,

my charming little man Zuhayr & my darling princess Jumana.

-Amir-

Abstract

Gamification is broadly defined as the use of game elements in non-game contexts. Its development within various contexts spanning information systems to serious games has recently gained a wide adoption due to promising behavioral and psychological improvements. However, being generally deployed on top of existing systems, gamification usually brings an additional layer of complexity to the actual task. This complexity mostly induces a cognitive overload that hinders gamification to be perceived and the pursued objectives to be achieved. It is argued in this work that applying proven design theories and taking account of the gamification aesthetics is crucial for easing the induced cognitive load.

Further in this dissertation, two new technologies that were developed within the scope of this thesis are introduced. In addition to assisting gamification designer with applying given design theories, these innovative technologies would help industries, struggling with the high efforts of integrating gameful affordances, achieve more effective gamification, decrease factors such as project costs, development cycles, and resource consumption as well as improve the product quality.

To validate our arguments and evaluate the introduced technologies, different empirical studies have been conducted, in which different persons with different ages and backgrounds have participated. The outcomes of these studies have shown that for gamification to be well perceived and to achieve the pursued engagement and motivation objectives, it is indeed crucial for gamification designers to base their implementations on well-sustained design guidelines. Moreover, the introduced technologies were overall assessed as very apt.

Acknowledgement

This work would not have been possible without the enduring, constructive and kind support of many people.

First and foremost, I would like to thank my parents for showing faith in me and backing me all the way. I would never be able to pay back your prayers, love and affection. Special thanks to Ayoub and Maya for their generous care and love. I also owe thanks to a very special person, my wife Ines, for her unfailing love, support and understanding. Zuhayr and Jumana, I could have never imagined lovelier and more cheerful buddies. This incredible journey would have been boring and too short without you around, literally.

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Berlin, autumn 2018

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List of abbreviations

AS	Achievement System
AVG	Active Video Gaming
BS	Badge System
DSL	Domain-Specific Language
GaML	Gamification Modeling Language
GUI	Graphical User Interface
HCI	Human-Computer Interaction
IDE	Integrated Development Environment
IoT	Internet of Things
IS	Information System
JSON	JavaScript Object Notation
M	Median
MDA	Mechanics, Dynamics & Aesthetics
MDA	Model-Driven Architecture
MDSD	Model-Driven Software Development
MP	Multimedia Principles
MUD	Multi-User Dungeon
SD	Standard Deviation
TED	Technology, Entertainment & Design
UML	Unified Modeling Language
UX	User Experience
VR	Virtual Reality

1 Introduction

1.1 Motivation

Gamification is generally denoted as the use of game elements in non-game contexts (Deterding et al. 2011). During the last decade and thanks to the promising behavioral or psychological improvements, gamification has attracted increasing attention among information technologists and behavioral scientists (Cugelman 2013; Morschheuser et al. 2018; Palmer, Lunceford, and Patton 2012). However, despite the various favorable predictions and the positive expectations about its future, many experts argue that the lack of proper understanding of gamification design would lead to an important extent of unsuccessful implementations (Gartner 2012). These implementations are usually very plain and consist of a mere integration of simple game mechanics such as badges and points into the existing system. Gamification is however more complicated and different facets should be taken into consideration when implementing it (Morschheuser et al. 2017):

- Games are complex to implement (Schell 2008), need a multi-disciplinary knowledge (Sylvester 2013) and cannot be easily transferred on top of other systems.
- By deploying motivational affordances (Hamari and Koivisto 2015), gamification designers require amongst others a deep understanding of psychology and behavioral science.

This lack of knowledge and of satisfactorily successful implementations keeps on hindering gamification to be widely adopted despite all the promised positive outcomes like behavioral change and health promotion. According to (Phillips 2014), implementing gamification should follow a general approach as well as a consistent design process. Martin & Euchner (2012) and Kelley & Brown (2015) even argue that every business should follow such a process for any given purpose. Phillips (2014) claims that a robust design process should dispose of the following characteristics:

- ***Purposive***: there must be an objective, to which the designer should always refer.
- ***Human-centered***: the user-experience should be given the highest priority.
- ***Balanced***: between analytical and creative thinking.
- ***Iterative***: prototyping and testing.

Based on these characteristics, Werbach (2014) has developed a gamification design framework consisting of six steps (D6), namely:

1. ***Define*** the objective behind implementing gamification.
2. ***Delineate*** the sought user behavior with the given objective.
3. ***Describe*** the target group.
4. ***Devise*** activity loops with regards to progression and engagement.

5. ***Don't*** forget the fun.
6. ***Deploy*** gamification efficiently using appropriate tools.

Although very important, this framework has barely been deployed. Most of the works have simply mounted gamification on top of existing systems without considering recognized design processes and theories (Matallaoui, Koivisto, et al. 2017). It is, in this work, demonstrated how crucial it is, to consider these theories when implementing gamification and provide gamification designers with new technologies that would ease their task and make gamification deployment more effective.

This dissertation has been initiated during the author's employment between 2014 and 2015 as a research associate at the Department of Information and Communication Management of the Technical University of Berlin. The author has been part of the "Gamification as a Service" research project, whose main purpose was to "conceptualize, implement and evaluate a generic service platform for gamifying business applications" (Herzig 2014). By combining the practical work on this project with the theoretical academic research, the author has derived the research questions, which are presented and elaborated in the next section.

1.2 Research Objectives

The research questions addressed in this thesis are outlined in Table 1 alongside the corresponding scientific publications handling them. In addition to examining the state of the art in gamification design, this thesis exhibits theoretical as well as practical contributions, namely:

1 validating the importance of considering well-established design theories in designing effective gamification and

2 assessing the technologies that have been provided to gamification designers to help them work more efficiently by taking advantage of existing resources and automating design procedures.

The first research subject that have been examined was the state of the art in gamification design and application.

Research question 1: What is the state of the art of gamification and the effectiveness of deploying gamification features in serious contexts?

"We map the current state of research on the topic by analyzing and reporting the types of studied systems and their contexts, the game elements employed, the psychological and behavioral outcomes of the systems studied as well as the results reported in the literature." (Matallaoui, Koivisto, et al. 2017) "It is important to mention that only very few papers described the principles and guidelines on which they based their affordance designs. The majority however, have merely integrated given game mechanics without considering the underlying theories" (Matallaoui, Koivisto, et al. 2017)

It is argued in this thesis that taking consideration of design theories when implementing gamification leads to better effects on motivation and engagement. Therefore, and in the context of this hypothesis (the first research area), two research questions have been handled, namely:

Research question 2.1: Does deploying the multimedia principles make gamification more effective?

Since gamification is usually implemented on top of an existing system, it often brings with it another level of complexity. It is, in this research, shown that bearing in mind the different multimedia principles (Moreno and Mayer 1999) when implementing gamification could help reducing this complexity and managing the induced cognitive load.

Research question 2.2: How can semiotics be deployed to design more effective gamification?

Similar to the research question 2.1, this research has the objective of conceptually presenting an approach that helps making gamification more perceivable. "for the gamification designers to manage the cognitive load imposed on users, they should follow effective design strategies that shrink the extraneous load. We, in this work, argue that using the appropriate icons in the badge design helps make the badges more understandable and thus reduce the amount of the extraneous load." (Matallaoui 2018)

In addition to targeting effectiveness by deploying different design theories, gamification designers need to also make gamification keen and more appealing. To achieve that, these designers are provided with different tools, which have been implemented and evaluated in this thesis's second research scope.

Research question 3.1: How could the task of gamification designers be enhanced when developing exergames?

"A fundamental challenge in achieving an immersive exergaming experience is the disposition of appealingly designed virtual worlds. The development of such environments is however quite difficult and delicate. Due to this time-consuming and costly design task, different studies on exergaming were bound to the deployment of existing open source worlds for their systems. These worlds though were generally poorly designed and did not always satisfy the users' needs of enjoyment. One better alternative would be the use of high-quality virtual worlds available in the majority commercial games. […] We introduce in this work a new technology for accessing and gamifying 3D game environments"

Research question 3.2: How do domain-specific languages improve the task of gamification designers?

The last research question in this thesis deals with easing the job of gamification designers by automating the process of implementing gamification and serious games. It is shown that the implementation efforts can be significantly reduced. Moreover, the language introduces a

higher level of abstraction since the approach allows being independent from concrete technologies, platforms, or specific computational models."

Table 1. Research questions & corresponding publications

Nr.	Research Questions & topics		Publication
1	What is the state of the art of gamification and the effectiveness of deploying gamification features in serious contexts?		(Matallaoui, Koivisto, et al. 2017)
2	Deploying well-established design theories for better gamification		
	2.1	does deploying the multimedia principles make gamification more effective?	Matallaoui et al. IJSG2018 (under Review)
	2.2	How can semiotics be deployed to design more effective gamification?	(Matallaoui 2018)
3	Improving the task of gamification designers		
	3.1	How could the task of gamification designers be enhanced when developing exergames?	(Matallaoui, Ben-Sassi, et al. 2017)
	3.2	How do domain-specific languages improve the task of gamification designers?	(Matallaoui, Herzig, and Zarnekow 2015)

1.3 Research Methodology

According to (Alavi and Carlson 1992), empirical studies, which are commonly conducted to gather data and interpret it, may be classified into qualitative ones and quantitative ones. Recent times have seen these latter dominate the IS research, due to the general acceptance and authenticity of outcomes and hypotheses grounded on numerical and statistical data (Sarker, Xiao, and Beaulieu 2013). Nevertheless, qualitative research methods are to their turn gaining increasing consideration and have been also deployed in an important number of works. This is largely due to the fact that IS research has recently altered from investigating technological problems to finding solutions to organizational ones (Myers 1997). In addition to classifying research methods into qualitative and quantitative ones and according to (Wilde and Hess 2007), the employed paradigms may as well be classified regarding behavioral and design sciences. "The behavioral science paradigm seeks to develop and verify theories that explain or

predict human or organizational behavior. The design-science paradigm seeks to extend the boundaries of human and organizational capabilities by creating new and innovative artefacts" (Hevner et al. 2004). Since both behavioral and design sciences are important in carrying out research, this thesis comprises both behavioral-oriented as well as design-oriented works. Furthermore, both qualitative research and quantitative one were conducted (see Table 2).

Table 2. Research Methodologies Applied

		Paradigm	
		Behavioral science	**Design science**
Degree of formalization	**Quantitative**	Amir Matallaoui, Jonna Koivisto, Juho Hamari, Rüdiger Zarnekow. "How Effective Is 'Exer-gamification'? A Systematic Review on the Effectiveness of Gamification Features in Exergames." IEEE *Hawaii International Conference on System Sciences* 2017 Hawaii, USA	Amir Matallaoui, Class Gnerlich, Rüdiger Zarnekow. "Cognitive Load Matters; in Gamification Even More. An empirical Study on the Importance of Incor-porating the Multimedia Principles into Gamification Design." International Journal of Serious Games – under review Amir Matallaoui, "Towards More Effective Gamification: Does Deploying Semiotics Help Design Better Perceivable Badges?". IEEE 4th International Conference on Computer and Technology Applications, ICCTA 2018, Istanbul, Turkey
	Qualitative		Amir Matallaoui, Nizar Ben Sassi, Fikret Sivrikaya, Rüdiger Zarnekow. "Enhancing the Task of Exercise Gamification: An Expert View on the Adoption of a New Technology for Deploying Existing Virtual Environments in Virtual Urban Exergames". Pacific Asia Conference on Information Systems 2017 Langkawi, Malaysia

1.4 Included Publications

This dissertation is mainly an accumulation of different scientific papers (see Table 3). While dealing with slightly distinctive facets and research questions, these papers do follow a common thread that is shaped by the principal objectives of this thesis. The included publications were selected upon checking the relevant publication rankings related to information systems such as WKWI and VHB to guarantee high contribution.

Table 3. Included publications

Section		Publication
Nr.	Title	
2	Gamification: Theoretical Foundations	Amir Matallaoui, Nicolai Hanner, and Rüdiger Zarnekow. "Introduction to Gamification: Foundation and Underlying Theories." in "Gamification - Using Game Elements in Serious Contexts" 2016 Springer, 3-18 (accepted version) https://doi.org/10.1007/978-3-319-45557-0_1
3	Implementing Gamification: State of the Art	Amir Matallaoui, Jonna Koivisto, Juho Hamari and Rüdiger Zarnekow. "How Effective Is "Exergamification"? A Systematic Review on the Effectiveness of Gamification Features in Exergames." IEEE *Hawaii International Conference on System Sciences* 2017 Hawaii, USA (accepted version)* https://doi.org/10.24251/HICSS.2017.402
4	Multimedia Design Principles for More Effective Gamification	Amir Matallaoui, Class Gnerlich, and Rüdiger Zarnekow.„Cognitive Load Matters; in Gamification Even More. An Empirical Study on the Importance of Incorporating the Multimedia Principles into Gamification Design." IJSG2018 – under review
5	Designing Better Perceivable Badges by Deploying Semiotics	Amir Matallaoui, "Towards More Effective Gamification: Does Deploying Semiotics Help Design Better Perceivable Badges?". IEEE 4th International Conference on Computer and Technology Applications, ICCTA2018, Istanbul, Turkey https://doi.org/10.1109/CATA.2018.8398670 (accepted version)*
6	Improving the Task of Gamification	Amir Matallaoui, Nizar Ben Sassi, Fikret Sivrikaya and Rüdiger Zarnekow. „Augmenting the Task of Exercise Gamification: An Expert View on the Adoption of a New Technology for Deploying Existing Virtual Environments in Virtual Urban Exergames". Pacific Asia Conference on Information Systems 2017 Langkawi, Malaysia (accepted version) https://aisel.aisnet.org/pacis2017/125
7	Model-Driven Implementation of Gamification	Amir Matallaoui, Philipp Herzig, and Rüdiger Zarnekow. „Model-Driven Serious Game Development: Integration of the Gamification Modeling Language GaML with Unity3D". IEEE *Hawaii International Conference on System Sciences* 2015, Hawaii, USA (accepted version)* https://doi.org/10.1109/HICSS.2015.84

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The main inclusion criteria, to which particular attention has been paid, were the quality of the presented works as well as their coherence with each other. In order to achieve this coherence, we:

- classify the different research questions into two common key objectives (see section 1.2)
- give an overall theoretical introduction and foundations (see section 2)
- give a general conclusion regarding all the presented works (see section 8)

1.5 Thesis Structure

Alongside the actual introductory part, this thesis is structured as follows (see Table 4):

- **Section 2** provides the theoretical foundations, on which this dissertation is based. This section includes:
  - An introduction to the differences between 'play', 'game', and 'gamification'
  - An overview of the different theories, on which gamification is based.

- **Section 3** presents a systematic review on the effectiveness of gamification features in serious games in general and in exergames in specific. When reviewing the selected works, the following elements were identified.
  - The aims of the presented studies.
  - The types of the used systems.
  - The types of the physical activities that were targeted by the studies.
  - The motivational affordances implemented in the studies.
  - The psychological outcomes of the exergaming systems.
  - The types of the conducted studies in terms of methodology.
  - The findings of the studies.

- **Section 4** presents an empirical study on the importance of basing the gamification design on well-established design theories such as the multimedia design principles for better gamification perception and understanding. This section comprises:
  - the background and motivation behind this work.
  - a quantitative study, which has been conducted with the help of 241 participants.
  - a conclusion for this work, which includes a discussion of the study outcomes as well as its limitations.

- **Section 5** presents an approach on how to make gamification more effective by deploying semiotics.
  - Alongside the motivation behind this work, the test framework that was designed for our study is presented in this section. Thereby the quiz is introduced as well as the questionnaire, which have to be answered by the participants to evaluate their experience.

Table 4. Thesis structure

<table>
<tr><td>Chapter 1</td><td>
<table>
<tr><td colspan="5">Introduction</td></tr>
<tr><td>Motivation</td><td>Research objectives</td><td>Research methodology</td><td>Included publications</td><td>Thesis structure</td></tr>
</table>
</td></tr>
<tr><td>Chapter 2</td><td>
<table>
<tr><td colspan="5">Foundation</td></tr>
<tr><td rowspan="2">Play, game and Gamification</td><td colspan="4">underlying theories</td></tr>
<tr><td>motivation theory,</td><td>Player types</td><td>Achievement goal theory</td><td>Flow theory</td></tr>
</table>
</td></tr>
<tr><td colspan="2">Included studies & corresponding research questions</td></tr>
<tr><td></td><td>Paper</td><td>Research question</td></tr>
<tr><td>Chapter 3</td><td>How Effective Is ‘Exergamification’? A Systematic Review on the Effectiveness of Gamification Features in Exergames.</td><td>What is the state of the art of gamification and the effectiveness of deploying gamification features in serious contexts?</td></tr>
<tr><td>Chapter 4</td><td>Cognitive Load Matters; in Gamification Even More. An Empirical Study on the Importance of Incorporating the Multimedia Principles into Gamification Design.</td><td>Does deploying the multimedia principles make gamification more effective?</td></tr>
<tr><td>Chapter 5</td><td>Towards More Effective Gamification: Does Deploying Semiotics Help Design Better Perceivable Badges?</td><td>How can we deploy semiotics to design more effective gamification?</td></tr>
<tr><td>Chapter 6</td><td>Augmenting the Task of Exercise Gamification: An Expert View on the Adoption of a New Technology for Deploying Existing Virtual Environments in Virtual Urban Exergames</td><td>How could we enhance the task of gamification designers when developing exergames?</td></tr>
<tr><td>Chapter 7</td><td>Model-Driven Serious Game Development: Integration of the Gamification Modeling Language GaML with Unity3D</td><td>How do domain-specific languages improve the task of gamification designers?</td></tr>
<tr><td>Chapter 8</td><td>
<table>
<tr><td colspan="2">Conclusion</td></tr>
<tr><td>Theoretical contribution
Literature review
Gamification & multimedia principles
Gamification & semiotics</td><td>Practical contribution
Implementation of a new technology for deploying virtual worlds
Model-driven serious game development</td></tr>
</table>
Limitations and further research
</td></tr>
</table>

- **Section 6** presents a qualitative study assessing the adoption of a new technology that helps exploiting existing virtual environments in exergames. this section
  - presents a state of the art
  - states the different challenges and motivations behind this work
  - introduces an architectural concept of the presented technology. This architecture is then validated through a qualitative study that has been carried out with the help of gamification experts.

- **Section 7** introduces a model-driven architecture for designing and generating building blocks for serious games. This architecture deploys thereby the gamification modeling language GaML.
  - a validation of this architecture is given by going through the different steps of designing an achievement system in the context of an existing serious game.

- **Section 8** provides a brief summarization of all results drawn from the presented works. The limitations of these works are outlined with respect to the defined research objectives. Opportunities for further research are lastly presented.

2 Gamification: Theoretical Foundations

Title	Introduction to Gamification: Foundations and Underlying Theories
Authors	Amir, Matallaoui, Technical University of Berlin, Straße des 17. Juni 135, 10623 Berlin, Germany, amirqphj@mailbox.tu-berlin.de Nicolai, Hanner, Technical University of Berlin, Straße des 17. Juni 135, 10623 Berlin, Germany, nicolai.hanner@tu-berlin.de Rüdiger, Zarnekow, Technical University of Berlin, Straße des 17. Juni 135, 10623 Berlin, Germany, ruediger.zarnekow@tu-berlin.de
Published in	Gamification - Using Game Elements in Serious Contexts (Sammelband). Springer - (Matallaoui, Hanner, and Zarnekow 2017)
Abstract	This introductory article provides basic definitions, concepts and theories surrounding gamification that are used throughout the remainder of the book. It distinguishes gamification from other research areas, such as gameful design and serious games. It then goes on to introduce common game mechanics, achievement systems, game dynamics and aesthetics. The second part of the article focusses on underlying theories. It examines the influence of motivation theory, achievement goal theory and flow theory on gamification. The article also describes different player archetypes.
Keywords	Motivation theory, Game dynamic, Flow theory, Player types

2.1 Introduction

The usage of information systems is steadily increasing and its penetration in every day's life or work is becoming more important. Yet many information systems are only used out of necessity and not because of their appeal, particularly in a working or educational context. This leads to the demotivation of users, lower acceptance and unwanted behavior and outcomes. Consequently, the question arises: how can people be motivated to change their behaviors or explore other ways of doing things? We know a concept that is an inextricable part of humanity – "play" – doing something not ordinary and freely within boundaries of time and space by following strict rules to experience the feelings of excitement and joy (Huizinga 1955). Applying this concept has led to the term gamification that is used to describe an innovative approach using game mechanics in a non-gaming context (Deterding et al. 2011). It is an interdisciplinary approach to motivate users to achieve certain behavioral or psychological outcomes (e.g. learn faster, complete their personal profile, daily use of a specific platform).

Recent psychological studies have shown that enhancing (with game elements) information systems resulted in a significant increase of software adoption in business environments. This in turn had a positive impact on the effectiveness and efficiency of employees (Herzig, Ameling, and Schill 2012). Furthermore, gamification can lead to a change in the user behavior without resorting to extrinsic incentives such as monetary rewards or punishments. Gamification examples can meanwhile be found in different application fields such as sustainability, environmentally conscious behavior(Gnauk, Dannecker, and Hahmann 2012), enterprise resource planning, production and logistics (Herzig, Ameling, and Schill 2012) or also supporting innovation processes (Scheiner et al. 2012). Eventually, gamification has received augmented attention from research in recent years (see Figure 1).

As information systems are influencing our daily routines, they are acting as a mediator that enables conveying game mechanics to users in order to motivate them to accomplish their tasks in the given context. Many studies have shown that game mechanics can have a significant effect on the motivation and participation in non-playful contexts e.g. see (Yang, Ackerman, and Adamic 2011; Herzig, Ameling, and Schill 2012; Thom, Millen, and DiMicco 2012). Especially, latent factors such as joy, ease of use, workflow, and perceived usefulness of an application can directly be improved.

Whilst studies have proven the significant impact of game elements on user behavior and human psychology, there is a lack of application and research for specific domains within information systems and teaching.

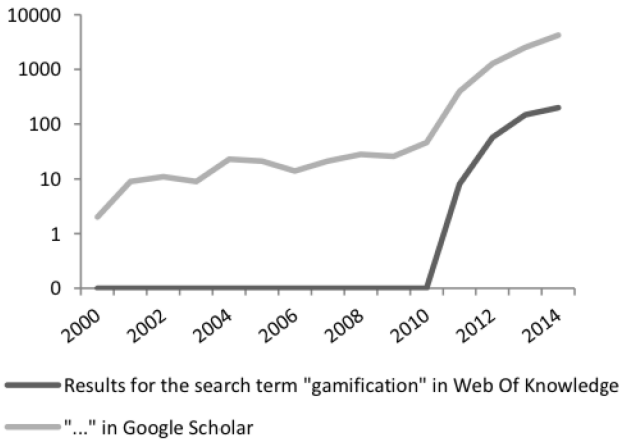

Figure 1. Published articles per year according to data bases

This chapter sets the basis of the book by introducing common concepts and theories in gamification. The section "foundation" contains the definition of gamification and the dissociation between gaming and game mechanics. The following section focuses on behavior theories and models. The chapter ends with a summary.

2.2 Foundation

In this section we introduce basic foundations for this book. It includes definitions as well as the distinction between gamification and games. Further we introduce game mechanics.

2.2.1 Definition

Gamification can be described as the integration of game mechanics into a non-game environment to give it a game-like feeling (Deterding et al. 2011). The essential purpose behind designing and implementing gamification within different types of services or applications (e.g. customer-oriented applications and online services) is to increase the customer's engagement, enjoyment and loyalty. Gamification is relatively a new term, hence there exists different definitions.

Definition 1. *Gamification is defined as the use of game design elements in non-game contexts (Deterding et al. 2011).*

The first definition of gamification is rather general and outlines the very basic idea and supports a probably very common understanding of the term gamification. Yet, the potential outcomes and goals stay undefined. The concept of gamification, however, is not new and its background originates in the digital media industry (Deterding et al. 2011). Researchers and professionals used the term "funware", which was back then defined by Zichermann and Linder (2013) as "the art and science of turning your customer's everyday interactions into games that serve your business purposes". Thereby, the authors underline a potential goal of gamification "serving a business purpose" and suggest that gamification can indeed be used to fulfil a business purpose. In this regard another definition can explain the term gamification:

Definition 2. *Gamification refers to a process of enhancing a service with affordances for gameful experiences in order to support user's overall value creation (Huotari and Hamari 2012).*

The second definition indicates that "the use of game design elements", here denoted as "affordances for gameful experience", may enhance the user's experience and outcome. It also refers to the utilitarian aspect of gamification, as it should support the value creation of the user.

2.2.2 From play to game and gamification

The term gamification itself made its first appearance in late 2010 (see Figure 1) enhanced by different industry players (Deterding et al. 2011). Furthermore, as a relatively emerging research term, gamification is still contested and many game and user experience designers have come up with other terms such as "gamefulness" and "gameful design". Yet, it is important to distinguish between various terms that might be related or be named in the context of gamification. One of these is the distinction between playing (paidia) and gaming (ludus) as those represent two different types of activities (Caillois and Barash 2001). According to Caillois and Barash (2001), playing involves free-form, non-rule-based and expressive actions, whereas gaming represents a rule-based and goal-oriented form of playing. He defines the game concept as "an activity that is voluntary and enjoyable, separate from the real world, uncertain, unproductive in that the activity does not produce any goods of external value, and governed by rules." (Caillois and Barash 2001). Established research theories on games and gaming consistently confirm the previous definition as they do as well characterize ludus through explicit rule systems and outcomes (Salen and Zimmerman 2004; Juul 2005).

With the goal of elaborating the previously mentioned definition of the "game" concept, McGonigal (2011) presented four fundamental features a game must have in order to fit in this classification of ludus and paidia:

- Clearly defined ***goals*** that provide players with a purpose for playing the game
- Consistently defined ***rules*** that represent the limitations and boundaries of how to achieve the given goals
- A steady ***feedback system*** that guarantees to the players that the goals can be reached, if the game rules are respected.
- The ***free will*** of accepting the participation in the game and thus following its rules to reach the goals.

It is obvious that many games come with various other features such as storytelling, interactivity or rewarding systems. However, these only form a further development and an enrichment of the basic features. Given this distinction between gaming and playing, McGonigal (2011) has subsequently introduced the concept of "gamefulness" which opposes to the term "playfulness".

Previous research in the field of human-computer interaction (in the context of gamification) was merely dedicated to the playfulness of the existing software systems. Research focusing on

the gamefulness of these systems however received less consideration despite the fact that the idea of adopting game elements in these systems was not totally new (eg Carroll 1982; Carroll and Thomas 1982; Malone 1982)

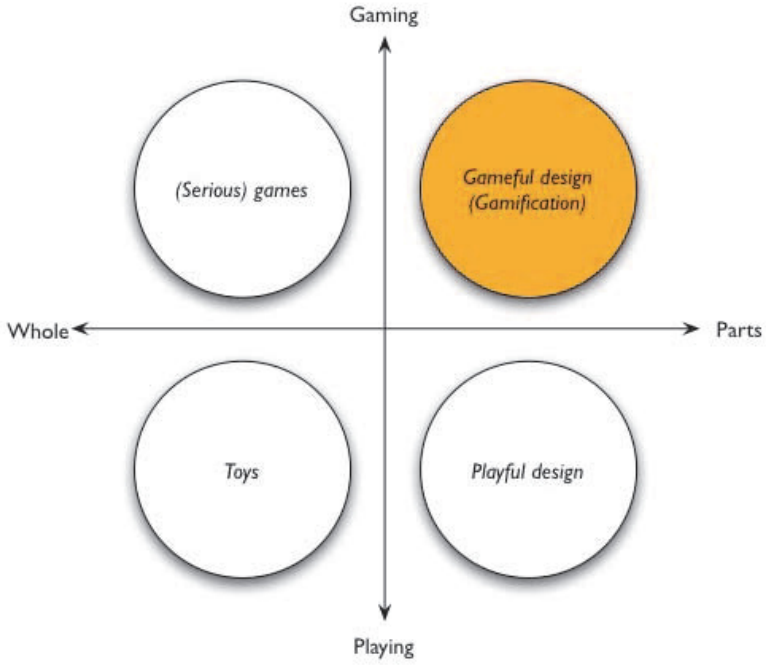

Figure 2. Gamification, Serious Games, Toys & Playful design (Deterding et al. 2011)

The definition of gamification by (Deterding et al. 2011) summarizes it as the use of game design elements in non-game contexts. This definition differentiates gamification from the other related concepts by two dimensions (see Figure 2). Whole vs. parts refers to the extent a product or service is using gaming elements.

For instance, gamification differs as it only partly uses gaming elements. Other aspects of the product/service stay untouched (e.g. a software still can be used to fulfil an operative task, but partly uses gaming elements to improve the enjoyment of using it) whereas serious games are complete games but may have an education or learning background (e.g. a game that teaches the problems of project management).

Gaming vs. playing indicates if the product/services are considering rule bound and outcome related elements (gaming) or if it fulfils solely playing aspect. e.g. it differentiates gamification from playful design, as gamification requires a rules-based design "you get X points by completing task X" and a goal orientation "get the most points". Despite the discussed distinction between playing and gaming, practical experiences (Salen and Zimmerman 2004; Barr, Noble, and Biddle 2007; Groh 2012) have shown that both concepts may be integrated together and hence this separation remains somehow theoretical.

2.2.3 Game mechanics, dynamics & aesthetics

In their TED talks, Chatfield (2010) and Priebatsch (2010) have presented different design principles for designing video games that, if consistently applied, may help the users engage more with the game world and flow better with the user experience it offers. They, moreover, argue that these principles may and should also be applied when "gamifying" a real-life situation to motivate the target group (e.g. enterprise employees, application users) to deal with the given tasks. The presented principles are summarily:

- Integration and display of a progress and experience measuring component such as progression bars
- Continuous and prompt feedback
- Provision of long-term as well as short-term goals
- Progressive rewarding for achieving given tasks
- Unanticipated and non-deterministic rewarding mechanism
- Offering a multiplayer mode (e.g. enhancing collaboration or/and challenge)

In order to apply these different fundamental principles of game and gamification design, it is important to consider the well-cited MDA (Mechanics, Dynamics & Aesthetics) framework (see Figure 3) introduced by Hunicke et al. in (2004). This figure defines games in terms of the three concepts that form the framework.

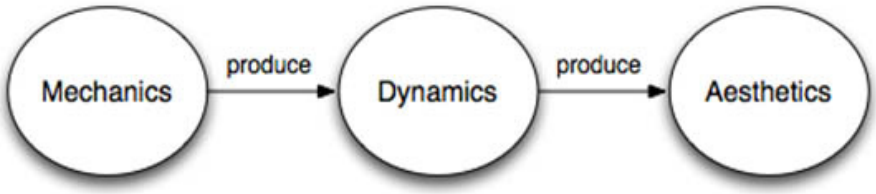

Figure 3. MDA Framework (Hunicke et al. 2004)

Following the structure of the MDA framework we now introduce these concepts:

Game Mechanics

"Game Mechanics describe the particular components of the game, at the level of data representation and algorithms." (Hunicke et al. 2004)

Game mechanics may highly push forward the users' motivation and engagement. Despite being interrelated, it is important to mention that game mechanics differ from game rules. These latter determine the endorsed behaviors that are pursued when implementing of the corresponding mechanics. E.g. implementing "game levels" (see below) is a game mechanic that basically allows users to level-up (e.g. upgrading the character's status) or/and level-down (e.g. downgrading ELO-rating when losing in a chess game) within a system. The behaviors/actions for which (because of which) the users level-up or down are defined in the game rules.

The common game mechanics are:

- **Points**, which are used to reward the users through different dimensions of the system.
- **Leaderboards**, which offer users the opportunity to compare themselves against other users among the system. Despite the fact that leaderboards are generally ubiquitous, designing them is a quite delicate task since it is crucial to ensure that they drive encouraging user behavior instead of pushing users to abandon the given goals.
- **Levels**, which play the role of indicators showing the user's activity through the system. It is important to mention that levels do not evolve linearly and the designer could often substitute their use by integrating a badge system.
- **Achievement systems (AS)**, which can be seen as "meta-tasks" (tasks over key-task) that provide further goals to the system users, independently of the actual main goals. In their paper Hamari and Eranti (2011) define achievements as follows: "Achievements are *goals* in an *achievement/reward system* (different system than the core game) whose fulfilment is defined through activities and events in other systems (commonly in the core game)." (Hamari and Eranti 2011)

The class diagram seen in Figure 4 shows an adapted interpretation of a possible achievement's structure presented in Hamari and Eranti (2011). Based on this diagram one can see that achievements consist mainly of three important parts, namely:

- An **identifier**, that consists of a name, through which the achievement is made unique, a description (hint) of the logic behind it and a badge, which encompasses its visualization.

- An achievement **unlocking-logic**, which entails:
  - A *trigger*: it could whether be an action done by the user (e.g. eat an apple) or an event (e.g. do not smoke for a week).
  - *Conditions*: on which the trigger is based
  - *Count*: the number of time the action or the event is triggered
  - *Pre-requirements*: are global requirements, which have generally nothing to do with the above mentioned conditions (e.g. complexity mode should be set to hard in order to achieve this task or you need to complete badge X before you can get Badge Y).

- A **Reward**, by which users are compensated for unlocking the achievement. This reward can whether be game-related (e.g. points), AS-related (e.g. by unlocking achievement X you fulfill one of the conditions for unlocking achievement Y) or application-external (e.g. users are rewarded a shopping coupon).

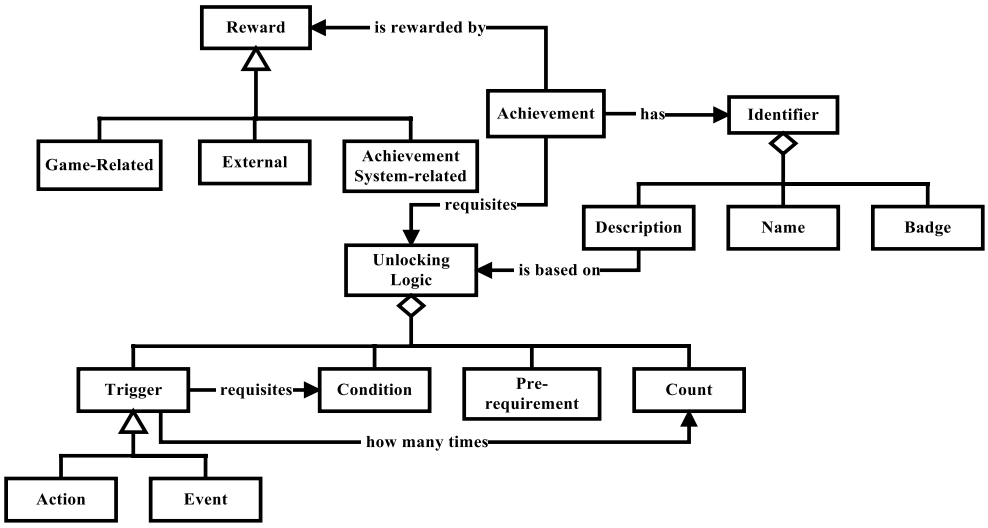

Figure 4. Achievement system class diagram (Matallaoui et al. 2015)

Game Dynamics

"Game dynamics describe the run-time behavior of the mechanics acting on player inputs and each other's outputs over time." (Hunicke et al. 2004)

Thus, dynamics form the reason behind the user's motivational behavior towards the game mechanics. It is crucial for game and gamification designers to target and satisfy the common desires of the different users. The common desires are (Bunchball Inc. 2010):

- **Rewards** are given to human beings after performing an action or showing some behavior in order to motivate them to repeat it.

- **Status,** attention, recognition etc. are inherently needed by most humans. It is crucial for these latter to engage in some activities in order to gain the sought prestige and respect of other humans.

- **Achievement** and the need to accomplish a given task and to have goals are required by most people. Hence, these usually tend to look for new challenges and for setting new achievable goals to reach.

- **Self-expression** makes it possible for people to show that they are unique and distinguishable from others.

- **Competitions** help people achieve higher level of performance. People get motivated and satisfied when they line up and compare themselves against others.

- **Altruism** can be satisfied by making it possible for the community to give and receive gifts.

Table 5 shows the game mechanics that are appropriate for the different human desires. The dark points on the matrix diagonal indicates that most suitable mechanics that satisfies the given desire (e.g. leaderboards are best used to fulfill the desire of competition within humans).

Table 5. Human Desires X Game Mechanics (Bunchball Inc. 2010)

	Human Desires					
Game Mechanics	**Reward**	**Status**	**Achievement**	**Self Expression**	**Competition**	**Altruism**
Points	●	○	○		○	○
Levels		●	○		○	
Challenges	○	○	●	○	○	○
Virtual Goods	○	○	○	●	○	
Leaderboards		○	○		●	○
Gifting & Charity		○	○		○	●

○ Suitable mechanic

● Most suitable mechanic

Aesthetics

"Aesthetics describe the desirable emotional responses evoked in the player, when he interacts with the game system." (Hunicke et al. 2004)

According to the MDA framework, evoking emotional responses in people (e.g. fun, surprise…) while they interact with the system enhances their motivation and engagement.

Aesthetics encompass, as stated by (Hunicke et al. 2004):

- Sensation: Game as sense-pleasure
- Fantasy: Game as make-believe
- Narrative: Game as drama
- Challenge: Game as obstacle course
- Fellowship: Game as social framework
- Discovery: Game as uncharted territory
- Expression: Game as self-discovery
- Submission: Game as pastime

Aesthetics represent a hedonic aspect of games. In the gamification context aesthetics should represent the goal of the gamified system. e.g. the user feels satisfied if a task is completed by using gamified system. Thereby, the emotional responses should not distract the user from the desired outcome. As shown in section 3.4, very challenging and, therefore, frustrating game elements might diminish the user experience and take negative effect on the users' productivity.

2.3 Gamification underlying theories

As mentioned in the second section, the concept of gamification is not new, and therefore it is based on different other concepts and theories. Gamification can be strongly related to social science. In fact, many studies are based on well-known theories from social science like Self-Determination Theory (Ryan and Deci 2000), Job-Demand Resource Model (Demerouti et al. 2001) or Flow Theory (Csikszentmihalyi 1975; Csikszentmihalyi et al. 2005). This section gives, inter alia, a closer overview on examples of given theories that tried to explain user behavior and experience.

2.3.1 Motivation theory

"Motivation is defined as the process that initiates, guides, and maintains goal-oriented behaviors. It involves the biological, emotional, social, and cognitive forces that activate behavior." (Nevid 2007)

The typical starting point for motivation theory, are the physiological needs. These needs can be divided into two groups; the development of the concept of homeostasis, which refers to the body's automatic efforts to maintain a constant normal state of the blood stream, and the finding that appetites, which refers to giving our body what it needs (Maslow 1943).

Extrinsic Vs. Intrinsic Motivation

According to Nevid (2007) the different types of motivation are generally described as being either extrinsic or intrinsic:

.

- Extrinsic motivations are motivations that come from outside of the individual and often involve external rewards such as trophies, money, social recognition or praise.
- Intrinsic motivations are motivations that originate from within (inside) the individual, such as trying to solve a puzzle purely for the self-gratification of solving that puzzle.

In addition to these two general types of motivation, users usually follow and show different more particular motives for conducting given actions. Next, we introduce the different user types and their motivations.

2.3.2 Player types

In his work, Bartle (1996) defines four different archetypes of video game players, which themselves represent various kinds of motivations the players may have. The education and learning-related works presented in (Kim and Ko 2013; Hawlitschek and Köppen 2014; Conati and Zhao 2004) were for instance based on Bartle's categorization. It is important to mention that it is unlikely to find one single user representing exactly one single type; most of users commonly represent more than one type. It is also usual for users to alternate between different

archetypes throughout their learning experiences. These types are next described based on (Bartle 1996):

- **Killers** represent competitive users who enjoy challenging other users and winning against them. Triumphing is the key goal killers pursue.

- **Achievers** characterize the type of users whose main incentive is to accumulate points, to level up and to get higher rankings.

- **Socializers** represent the kind of users who use the application as a bridge to get in contact with other users and to interact with them. The community is a vital stimulus for the users of this type.

- **Explorers** represent the type of users who want to discover the application as well as its boundaries. Exploring the application is users' main drive.

Bartle projected the mentioned archetypes onto the diagram illustrated in Figure 5. This latter should be read as follows:

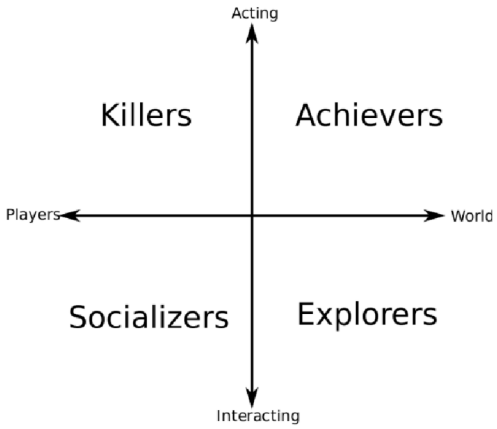

Figure 5. Bartle's player types (Bartle 1996)

- Killers act on other players.
- Achievers act on the world.
- Socializers interact with other players.
- Explorers interact with the world.

2.3.3 Achievement goal theory

One of the recent and growing features in gamified systems and serious games is the introduction of achievement systems.

Following the structure of the MDA framework we now introduce these concepts:

Game Mechanics). These systems form a meta-game that provides the target group with additional goals that are independent of the main goals. On account of this, gamification designers have theorized that these meta-games may be an important means for enhancing the

user's engagement. They, however, had to be cleverly integrated and categorized in order to achieve the pursued behavior.

Based on (Galli and Fraternali 2014) and considering the different player types we introduced (see section 2.3.2 Player types), we list in this section the different existing types of achievements:

- **Instructors** are used to guide the users through the learning process. They ensure that given actions are mastered by the users so that they can be used to progress with the learning experience. The advantages of providing such achievements include encouraging the users to understand and interact with the system as well as motivating them right from the start to get the needed knowledge and skills. (E.g., going through onboarding tutorials)

- **Quests** are unlocked when users, for instance, accomplish significant tasks. A quest is usually awarded once when its required conditions are fulfilled for the first time. The key goal for having such achievements is to continuously keep users involved.

- **Content Discovery** achievements encourage users to explore the application. They ensure that these are at least aware of all the existing modes and features the application is offering and have gone through them.

- **Socializer** achievements are awarded when users undertake certain tasks within the community. This type of achievements encourages the collaborative learning and thus enhances the overall musical performance of the users.

- **Grinder** achievements are unlocked when a task is repeated a given number of times. They represent an easy to implement type of achievements and are deployed to incite users to master particular actions, which are considered crucial for the further use of the application.

- **Herculean Tasks** represent a type of achievements that are awarded when users accomplish relatively difficult and hard to perform tasks. These achievements, requiring decent skills, can be as a matter of course unlocked only by experienced users.

- **Trophies** are only awarded to few users in the community, since they are designed in a way that mutually excludes other users from getting them.

- **Loyalty** achievements are awarded to users which in fact show loyalty towards the application. Although inciting users to spend real money on the game, this type of achievements is extremely used by the application community.

2.3.4 User experience: Flow theory

The flow theory is based on the notion of positive psychology, which mainly focuses on the human intrinsic strengths. It has been defined by Seligman and Csikszentmihalyi (2014) as "the study of positive emotion, positive character, and positive institutions". Csikszentmihalyi, as one of the pioneers in the field of positive psychology, was captivated by the fact that some people, despite their tremendous losses during the war, were still able to be happy and show their happiness while others could not. It was then that he produced the flow theory by treating happiness as a "positive, personal state of being" (Whitson and Consoli 2009).

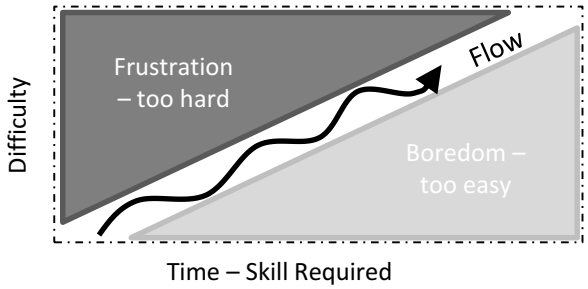

Figure 6. Flow theory (Csikszentmihalyi 1990)

Csikszentmihalyi (2008) defined happiness in the context of accomplishing a task as not getting bored on the one hand and not feeling anxious on the other hand (see Figure 6). He further states that the flow theory can be seen as "a theory of optimal experience based on the concept of flow - the state in which people are so involved in an activity that nothing else seems to matter. The experience itself is so enjoyable that people will do it even at great cost, for the sheer sake of doing it." (Csikszentmihalyi 2008)

Csikszentmihalyi (2008) identified different characteristics of flow. The ones that are directly related to motivation and engagement and should be taken in consideration when designing gamification are:

- A challenging activity that requires skills
- Merging of action and awareness
- Concentration on the task at hand
- Clear goals and feedback

2.4 Summary

This introductory chapter has shown that gamification has become an ever more studied concept in research. Results from various studies support the idea that the application of gamification could significantly contribute towards the efficiency of human work and the enjoyment of executing it. Thereby, gamification can be applied in many contexts, as it partly introduces game elements into a product or a service. It is important to mention that gamification does not require the gamified product or service to turn into a complete "game".

Consequently, we introduced two definitions of gamification which represent different perspectives on its application and outcomes.

These definitions show that just "gamifiying" a system would not be meaningful if the wanted goals, the desired outcomes and the utilitarian task that should be completed have not been set and clearly defined. To achieve these goals, mechanics, dynamics and aesthetics play an important role (Hawlitschek and Köppen 2014) and have been presented in section 2.2.3. Game mechanics represent the design posibilities and mechanisms that allow to integrate game elements into a spesific non-gaming context.

Game mechanics are probably the most significant part of gamification, since leaderboards, points and achievement systems are the primary features of a gamified system. Yet, only under the consideration of game dynamics and aesthetics, the game mechanics could be shaped and used in a meaningful way to achieve changes of human behavior towards more motivation and further engagement. Under the section "Gamification Underlying Theories", we gave a closer overview on examples of given theories that tried to explain user behavior and experience. We thereby started by briefly introducing the motivation theory and mark out the differences between intrinsic and extrinsic motivation. Subsequently, we gave an introduction to the different Player Types (Bartle 1996) that shows that human motivation and their actions in a gameful context can be classified according to various kinds of motivations these players may have. Furthermore, and before concluding this section with an introduction to the Flow Theory, we outlined different achievement types, which form a meta-game that provides the target group with additional goals.

3 Implementing Gamification: State of the Art

Title	How Effective Is "Exergamification"? A Systematic Review on the Effectiveness of Gamification Features in Exergames
Authors	Amir, Matallaoui, Technical University of Berlin, Straße des 17. Juni 135, 10623 Berlin, Germany, amirqphj@mailbox.tu-berlin.de Jonna, Koivisto, School of Information Sciences, University of Tampere Finland, jonna.koivisto@uta.fi Juho, Hamari, School of Information Sciences, University of Tampere Finland, juho.hamari@uta.fi Rüdiger, Zarnekow, Technical University of Berlin, Straße des 17. Juni 135, 10623 Berlin, Germany, ruediger.zarnekow@tu-berlin.de
Published in	Proceedings of the 50th Annual Hawaii International Conference on System Sciences - (Matallaoui, Koivisto, et al. 2017)
Abstract	Physical activity is very important to public health and exergames represent one potential way to enact it. The promotion of physical activity through gamification and enhanced anticipated affect also holds promise to aid in exercise adherence beyond more traditional educational and social cognitive approaches. This paper reviews empirical studies on gamified systems and serious games for exercising. In order to gain a better understanding of these systems, this review examines the types and aims (e.g. controlling body weight, enjoying indoor jogging…) of the corresponding studies as well as their psychological and physical outcomes. This paper particularly reviews the deployed motivational affordances and the effectiveness of incorporating gamification features in exergames. The review shows overall positive psychological outcomes (e.g. enjoying exercise) as well as behavioral ones (e.g. decreasing sedentariness) about exergames. Its findings inform about the current state of the research on the topic, based on which, suggestions for further research are outlined.
Keywords	Exergaming, Gamification, Motivation, Active playing, Engagement

3.1 Introduction

Recent years have seen a rapid increase in the use of games and game elements for motivating people towards various behaviors. Approaches such as gamification and serious games (Huotari and Hamari 2012; Deterding et al. 2011) are increasingly adopted in various contexts ranging from exercise and health (Warburton et al. 2007) to education (Matallaoui, Herzig, and Rudiger 2015), ecological behavior (Vara et al. 2011) and work productivity (Smith 2011). More specifically these developments refer to the application of elements familiar from games to new contexts, i.e. gamification, or developing a full-fledged game for a certain purpose other than entertainment alone, i.e. serious games (Deterding et al. 2011; Huotari and Hamari 2012).

One of the most prominent fields where gamification and other gameful approaches have been implemented is the health and exercise field (Pasch et al. 2009; Warburton et al. 2007). Digital games and gameful systems for exercise, commonly shortened as exergames, have been developed extensively during the past few decades (Bogost 2005). However, due to the technological advancements allowing for more widespread and affordable use of various sensor technologies, the exergaming field has been proliferating in recent years. As the ultimate goal of implementing the game elements to any non-entertainment context is most often to induce motivation towards the given behavior, similarly the goal of the exergaming approaches is supporting the user to engage in various physical activities and promoting health benefits via the system use.

A common problem in the use of the systems is the novelty effect (Farzan et al. 2008; Koivisto and Hamari 2014), which refers to the initial increase in use of the system due to the excitement and interest over a novel system. To overcome this challenge, various design elements common to games may be employed in exergaming approaches (Hamari, Koivisto, and Sarsa 2014) similarly to digital games in general. Since gamification presents an innovative and subtle set of solutions for enhancing user motivation and engagement with the systems (Hamari, Koivisto, and Sarsa 2014), we found it important to explore to which extent the gamification concepts were applied. This analysis would help exergame designers as well as further research to effectively integrate gamification features into their systems.

In this study we review the current body of literature of empirical research on virtual reality-based exergaming. We map the current state of research on the topic by analyzing and reporting the types of studied systems and their contexts, the game elements employed, the psychological and behavioral outcomes of the systems studies as well as the results reported in the literature. The findings of the review provide insight on the state of empirical research on using, amongst others, virtual reality-based exergaming systems as well as on the effectiveness of the approach for motivating users towards physical activity. Furthermore, potential gaps in the current body of literature are identified.

3.2 Related works

Different works have attempted to review current studies on the effectiveness of exergames in enhancing physical activity and decreasing sedentariness. In our work, however, we also review the extent to which motivational affordances and gamification elements (i.e. badges, levels…) are actually deployed in exergaming in order to sustain behavior change and promote physical activity.

Biddiss and Irwin (2010) present a systematic review that provides a quantitative outcome of the current state of the art of active video gaming (AVG). They thereby precisely assess its effectiveness in overcoming different barriers to physical activity in children and youth and in helping them promote their health and well-being. To conclude, the review, which includes (n=18) case studies, states that AV games enable "light to moderate physical activity".

Larsen et al. (2013) provide as well a systematic review delivering a quantitative synthesis of the current studies considering the physical effect of exergames. The review only considered the effects in healthy elderly and reports several results varying from remarkable improvements to no mentionable effects. Thus, it was difficult to the authors to generalize their findings into broad recommendations. The small number of the reviewed studies (n=7) might also form a limitation for this work.

In (Mark et al. 2010), the authors review existing literature concerning interactive exercise video games. The reviewed papers (n=19) show positive results regarding the physical activity of both adults and children. The authors state for instance an increase in oxygen uptake and heart rate in contrast to traditional video games.

The stated works as well as various others (Lamboglia et al. 2013; Sween et al. 2014; Verheijden Klompstra, Jaarsma, and Strömberg 2014) mutually review the effectiveness of exergaming in enhancing rehabilitation and stimulating physical activity. These works did exclusively consider reviewing the outcomes of exergames focusing rather on motion controls. Although practically sharing the same outcome, namely assenting that exergames present a potential way to enact physical activity, none of the reviews has emphasized on the exergame design and the integration of game mechanics. It is worth mentioning here that the authors of the recently published review (Alahäivälä and Oinas-Kukkonen 2016) go beyond the mere investigation of the outcomes of the studied gamified health systems (n=15) to analyzing their different depicted persuasion contexts.

3.3 Conceptualization of exergaming

In accordance with (Huotari and Hamari 2012) and (Hamari, Koivisto, and Sarsa 2014) we consider the exergames to comprise of three essential elements: 1) the motivational affordances, i.e. the game elements employed in the system, e.g. progress, badges, or leader boards, 2) the psychological outcomes that are induced by the motivational affordances, i.e. the psychological processes (e.g. competition, achievement, self-expression) through which the affordances

motivate the user towards the encouraged activities, and finally, 3) the resulting and pursued behavioral and quasi-medical outcomes (attitudes) (e.g. increased physical activity, measured health benefits) (see Figure 7).

Hence, in this literature review, and based on this conceptualization, we collect the different motivational affordances implemented in the reviewed studies, the resulting psychological outcomes and the behavioral & quasi-medical outcomes.

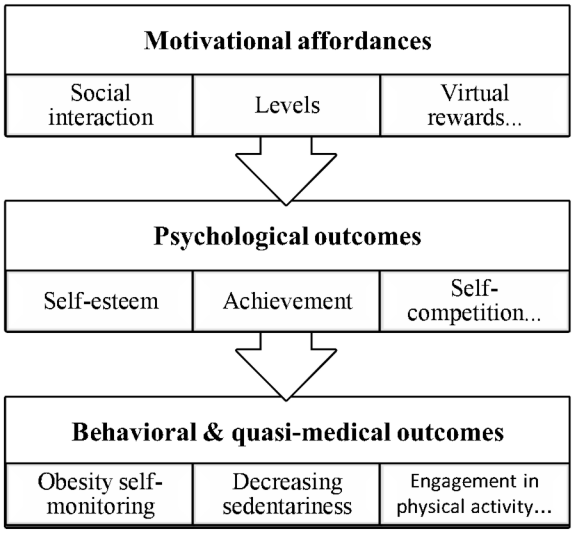

Figure 7. Conceptualizing exergaming

3.4 Literature review

The literature review was conducted by following the guidelines provided by Webster and Watson (2002). See Figure 8 for the flowchart regarding the literature review process.

Firstly, literature searches were conducted in the Scopus database, which was chosen as it is the largest database of academic works. We defined the following search query that was used for the literature search: (TITLE-ABS-KEY ("virtual realit*") AND (TITLE-ABS-KEY (exerc*) OR TITLE-ABS-KEY("physical activ*")) AND TITLE-ABS-KEY (gam*) AND NOT (TITLE-ABS-KEY (therap*) OR TITLE-ABS-KEY (rehab*))). We targeted by using the term "gam*" both games and gamified systems. The terms "exerc*" and "physical activ*" were used to identify the papers dealing with exercise and active playing. With this search query the search terms were looked for from the metadata (title, abstract, and keywords) of the papers. The search was conducted in 5/2015, included all papers written prior to this date and at that time resulted in 164 hits.

The initial search results were then screened for inclusion based on the following criteria:

1. The paper is in English
2. The paper is published on a peer-reviewed venue.

3. The full paper is available (abstracts only studies are eliminated).
4. The paper is relevant for the scope, i.e. it is about the use of virtual reality (as a gameful element) to motivate exercise and physical activity, but not used as a form of *institutional* therapy/rehabilitation. The paper must describe the system in detail and thus may also be considered if it comprises gamification and game design).
5. The paper is empirical (data has been gathered from research subjects).
6. The methodology of the study is clearly defined.

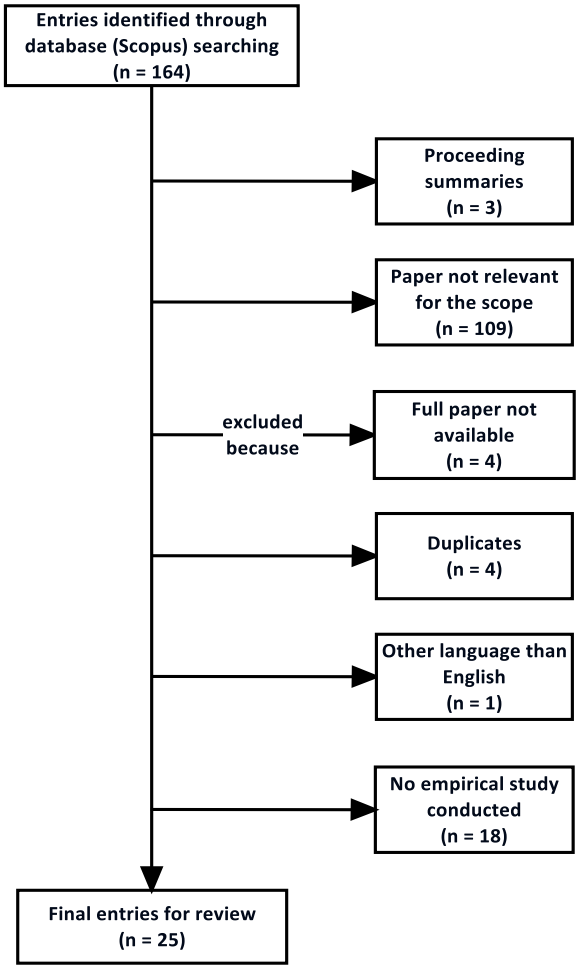

Figure 8. Flowchart of literature review process

Following the example of (Larsen et al. 2013), we implicitly deployed McGonigal's definition of a game (McGonigal 2011) to point ***game-based physical activities***. The definition states that games should consist of four main components, namely: (1) a goal to achieve, (2) rules to follow, (3) a feedback system for people to track their progress and (4) the voluntary acceptance of the three first elements. Hence, the selected studies meet the following definition adopted from Osorio, Moffat, and Sykes (2012), McGonigal (2011), and Larsen et al. (2013): "a digital game that require players to (voluntary) perform physical exertion to play and where the game has specific goals, rules, and a feedback mechanism".

Further, we denote by ***Quasi-medical*** the type of different gamified systems and exergames that were designed and developed for therapeutic and rehabilitation purposes.

We designate by ***virtual-Reality based exergames*** different immersive systems using a virtual world and typically involving visuals and sound. Although some studies did not meet our definition and requirements for VR systems (e.g. (J. J. Lin et al. 2006)), we decided to retain them since they did deal with game design and mechanics and were therefore relevant to our review. After this process, 25 papers were identified as relevant for the literature review (see Figure 8).

3.5 Analysis & results

The high-level research inquiry shared between the reviewed papers is whether amongst others virtual reality-based exergaming can effectively promote physical activity. In our analysis process, the following elements of the studies were scrutinized and identified.

1. The aims of the presented studies.
2. The types of the used systems.
3. The types of the physical activities that were targeted by the studies.
4. The motivational affordances implemented in the studies.
5. The psychological outcomes of the exergaming systems.
6. The types of the conducted studies in terms of methodology.
7. The findings of the studies.

Besides grouping the studies regarding their types (quantitative, qualitative or mixed) and how positive their reported results were (points 6,7), we believe that classifying these former in regard to the points (1 to 5) would enable further research to efficiently design and analyze gamification systems. In addition to these criteria, we have also investigated the different systems for their home-compatibility. This point however will be presented in future work. The findings of the review are reported in the following subsections. For a more detailed summary of the reviewed studies, see Appendix.

3.5.1 Study purpose & behavioral outcomes

The aims of the studies were analyzed and the purposes were categorized as behavioral, quasi-medial or mixed (behavioral & quasi-medical together). Based on the analysis, the majority of the papers explored the effectiveness of exergaming in engaging and motivating people to exercise (see Table 6). Furthermore, many of the reviewed papers also investigated the value of exergames as a means of cure and treatment for various medical conditions.

None of the studies had the intention to investigate how appropriate the used systems ware for the aimed behavioral or quasi-medical purposes

Table 6. Types of the study purpose

Study purpose	Paper
Behavioral	Berkovsky et al. 2010 - Cui et al. 2009 - Finkelstein et al. 2011 - Guixeres et al. 2012; Guo and Quarles 2013 - Hanneton and Varenne 2009 - Higuchi, Ueno, and Rekimoto 2014 - Hossain, Hassan, and Alamri 2013 - Landry and Pares 2014 - Le et al. 2012; Lin et al. 2006 - Monteiro et al. 2014 - Nguyen et al. 2012 - Pasch et al. 2009 - Plante et al. 2003 - Singh et al. 2011 - Snyder, Anderson-Hanley, and Arciero 2012 - Warburton et al. 2007 - Zhang et al. 2012
Quasi-medical	Chowdhury et al. 2014 - Guixeres et al. 2012 - Hossain, Hassan, and Alamri 2013 - Hsieh et al. 2014 - C.-Y. Lin and Chang 2015 - Mazzone et al. 2013 - Singh et al. 2011 - Mark et al. 2010 - Wi, Kang, and Jang 2013

3.5.2 System types

Next, we analyzed the system types employed in the studies. These were categorized in terms of being either 1) existing gaming technologies (e.g. Nintendo Wii, Xbox Kinect) with which existing physical activity-oriented games (e.g. Wii Fit, Kinect Sports Rivals) were used; 2) gamification of an existing system (e.g. modifying an existing game by adding motion-based input to fulfill the targeted behavior); or 3) an exclusively developed custom-tailored system for the purposes of the study.

While the majority of the studies (see Table 7) have exclusively developed custom-tailored systems for the study's purpose, some did simply use existing commercial technologies. A limited number of studies however, tried to take advantage of existing games and to change the sedentary playing mode to an active one by implementing motion-based game input.

None of the studies however have outlined the challenges of creating a whole system from scratch or the compromises made for the mere use of available systems.

Table 7. Used system

System type	Paper
Existing system	Guixeres et al. 2012 - Hanneton and Varenne 2009 - Monteiro et al. 2014 - Pasch et al. 2009 - Plante et al. 2003 - Singh et al. 2011 - Wi, Kang, and Jang 2013
Gamified system	Berkovsky et al. 2010 - Guo and Quarles 2013 - Warburton et al. 2007

Exclusively developed system	Chowdhury et al. 2014 - Cui et al. 2009 - Finkelstein et al. 2011 - Guixeres et al. 2012 - Higuchi, Ueno, and Rekimoto 2014 - Hossain, Hassan, and Alamri 2013 - Hsieh et al. 2014 - Landry and Pares 2014 - Le et al. 2012 - C.-Y. Lin and Chang 2015 - J. J. Lin et al. 2006 - Mazzone et al. 2013 - Nguyen et al. 2012 - Snyder, Anderson-Hanley, and Arciero 2012 - Van Schaik et al. 2008 - Zhang et al. 2012

3.5.3 Targeted activities

Furthermore, we analyzed the types of activities targeted by the systems employed in the reviewed studies. Exercising activities such as cycling and running were common implementations. In addition to these, we have noticed a vast deployment of the existing commercial console-based exergames such as Wii Fit and Kinect-based games.

In this review, we have designated by "fun sports" the simulated recreational activities usually offered in bundle-like video games (e.g. Wii Sports which include amongst others boxing, golf and bowling). Moreover, more specific activities such as muscle conditioning were also present in the reviewed studies (see Table 8).

Table 8. Targeted physical activity

Physical activity	Paper
Fun sport	Berkovsky et al. 2010 - Guo and Quarles 2013 - Landry and Pares 2014 - C.-Y. Lin and Chang 2015 - Pasch et al. 2009 - Singh et al. 2011 - Wi, Kang, and Jang 2013
Cycling	Zhang et al. 2012 - Warburton et al. 2007 - Snyder, Anderson-Hanley, and Arciero 2012 - Plante et al. 2003
Aerobics	Cui et al. 2009 - Finkelstein et al. 2011 - Guixeres et al. 2012 - Le et al. 2012 - J. J. Lin et al. 2006 - Mazzone et al. 2013 - Monteiro et al. 2014 - Nguyen et al. 2012 - Plante et al. 2003 - Snyder, Anderson-Hanley, and Arciero 2012 - Van Schaik et al. 2008 - Warburton et al. 2007 - Zhang et al. 2012
Muscle conditioning	Chowdhury et al. 2014 - Mazzone et al. 2013
Balance	Cui et al. 2009 - Finkelstein et al. 2011 - Guixeres et al. 2012 - Hanneton and Varenne 2009 - Higuchi, Ueno, and Rekimoto 2014 - Singh et al. 2011 - Hsieh et al. 2014; -Nguyen et al. 2012
Speed	Finkelstein et al. 2011 - Guo and Quarles 2013 - Higuchi, Ueno, and Rekimoto 2014 - Hossain, Hassan, and Alamri 2013 - Landry and Pares 2014

3.5.4 Motivational affordances

We have collected in this literature review various types of motivational affordances (see Table 9). Whether deployed together or individually, these components, also referred to as game mechanics, may highly push forward the users' motivation and engagement. Studies that deployed existing commercial exergames (e.g. Wii Fit) took advantage of the provided game design and mechanics (points, levels, leaderboards…), whereas the authors of the papers presenting both, gamified systems and exclusively developed systems, had to implement their own mechanics.

Given this fact, it is curious that none of the studies that were based on an exclusively developed application reported deploying a badge system. Since badges are one of the most commonly used mechanics in gamification (Hamari, Koivisto, and Sarsa 2014) for motivating the users, it is interesting that the effectiveness of this mechanic has not been studied in the exclusively developed systems.

It is important to mention that only very few papers described the principles and guidelines on which they based their affordance designs. The majority however, have merely integrated given game mechanics without considering the underlying theories such as (Bartle und R. 1996).

Table 9. Deployed motivational affordances

Mechanic	Paper
Avatars	Cui et al. 2009 - Higuchi, Ueno, and Rekimoto 2014 - Hossain, Hassan, and Alamri 2013 - J. J. Lin et al. 2006 - Le et al. 2012 - Mazzone et al. 2013 - Monteiro et al. 2014 - Nguyen et al. 2012 - Pasch et al. 2009 - Singh et al. 2011 - Plante et al. 2003 - Snyder, Anderson-Hanley, and Arciero 2012 - Zhang et al. 2012
Points	Chowdhury et al. 2014 - Finkelstein et al. 2011 - Guixeres et al. 2012 - Hossain, Hassan, and Alamri 2013 - Pasch et al. 2009 - Plante et al. 2003 - Singh et al. 2011 - Zhang et al. 2012
Progress	Guo and Quarles 2013 - Hanneton and Varenne 2009 - J. J. Lin et al. 2006 - Pasch et al. 2009 - Monteiro et al. 2014 - Singh et al. 2011 - Snyder, Anderson-Hanley, and Arciero 2012
Social interaction	Cui et al. 2009 - Landry and Pares 2014 - J. J. Lin et al. 2006 - Monteiro et al. 2014 - Snyder, Anderson-Hanley, and Arciero 2012 - Zhang et al. 2012
Levels	Guixeres et al. 2012 - Hanneton and Varenne 2009 - Guo and Quarles 2013 - Landry and Pares 2014 - J. J. Lin et al. 2006 - Zhang et al. 2012
Story	Hossain, Hassan, and Alamri 2013

Virtual goods	Berkovsky et al. 2010 - Finkelstein et al. 2011 - Higuchi, Ueno, and Rekimoto 2014 - Landry and Pares 2014 - Zhang et al. 2012
Ranking	Finkelstein et al. 2011 - J. J. Lin et al. 2006 - Zhang et al. 2012
Rewards	Berkovsky et al. 2010 - Finkelstein et al. 2011 - Singh et al. 2011

3.5.5 Psychological outcomes

Psychological outcomes, which may also be considered as the system dynamics according to Hunicke's MDA framework (Hunicke, LeBlanc, and Zubek 2004), form the reason behind the user's motivational behavior towards the deployed motivational affordances. It is hence essential for exergame designers to target and satisfy the common desires of the different users. For instance, the need to accomplish a given task and to have goals to *achieve* is required by most people. Hence, these usually tend to look for new challenges and to set new achievable goals to reach.

People are steadily looking for experiences that give them the possibility and the opportunity to *express themselves* and to show that they are unique and distinguishable from others. People usually also tend to *compete* and compare themselves against others. Thus targeting this dynamic would help them achieve higher level of performance.

Table 10 summarizes the different psychological outcomes found in the reviewed studies.

Table 10. ***Psychological outcomes & dynamics***

Dynamic	Paper
Competition	Berkovsky et al. 2010 - Chowdhury et al. 2014 - Finkelstein et al. 2011 - Hanneton and Varenne 2009 - Guo and Quarles 2013 - Landry and Pares 2014 - Nguyen et al. 2012 - Pasch et al. 2009 - Snyder, Anderson-Hanley, and Arciero 2012
Enjoyment	Berkovsky et al. 2010 - Landry and Pares 2014 - Le et al. 2012 - Nguyen et al. 2012 - Pasch et al. 2009 - Monteiro et al. 2014 - J. J. Lin et al. 2006 - Plante et al. 2003 - Zhang et al. 2012
Achievement	Chowdhury et al. 2014 - Guixeres et al. 2012 - Guo and Quarles 2013 - Hanneton and Varenne 2009 - J. J. Lin et al. 2006 - Landry and Pares 2014 - Monteiro et al. 2014 - Van Schaik et al. 2008
Self-expression	Cui et al. 2009 - Finkelstein et al. 2011 - Higuchi, Ueno, and Rekimoto 2014
Status	Cui et al. 2009 - Guixeres et al. 2012 - Hanneton and Varenne 2009 - Hossain, Hassan, and Alamri 2013 - Hsieh et al. 2014 - Mazzone et al. 2013 - Monteiro et al. 2014 - Singh et al. 2011 - Wi, Kang, and Jang 2013
Self-competition	Hossain, Hassan, and Alamri 2013 - C.-Y. Lin and Chang 2015 - J. J. Lin et al. 2006 - Singh et al. 2011 - Mazzone et al. 2013 - Van Schaik et al. 2008 - Wi, Kang, and Jang 2013

3.5.6 Type of conducted studies

Table 11 categorizes the reviewed studies based on the type of the conducted study. As we can notice in the table, most the studies followed a quantitative approach. This is rather understandable and was expected since quantitative research is frequently used for evaluations focusing on impacts such as user satisfaction, system usage rates and effectiveness.

Table 11. Type of conducted studies

Method	Paper
Qualitative*	Guo and Quarles 2013 - Hanneton and Varenne 2009 - C.-Y. Lin and Chang 2015 - Pasch et al. 2009
Quantitative**	Berkovsky et al. 2010 - Chowdhury et al. 2014 - Cui et al. 2009 - Guixeres et al. 2012 - Hsieh et al. 2014 - Landry and Pares 2014 - Le et al. 2012 - Mazzone et al. 2013 - Monteiro et al. 2014 - Nguyen et al. 2012 - Singh et al. 2011 - Snyder, Anderson-Hanley, and Arciero 2012 - Plante et al. 2003 - Zhang et al. 2012 - Warburton et al. 2007 - Wi, Kang, and Jang 2013 - Van Schaik et al. 2008
Mixed methods***	Hossain, Hassan, and Alamri 2013 - Higuchi, Ueno, and Rekimoto 2014 - J. J. Lin et al. 2006
* including interviews and other qualitative observations. ** including experiments, log data analyses and quantitative questionnaires. *** usually include a larger quantitative part and, for example, user interviews or forum discussion analyses.	

3.5.7 Reported results

Studies' results: Table 12 gives an overview of the reported results. These were generally positive, and concluded that using virtual reality-based exergames may enhance the motivation and engagement for exercise.

Some of the studies however, stated that introducing game elements to older adults did not have the pursued positive effects. This can be clarified with the fact that this target group is typically not familiar with such concepts.

Table 12. Reported results

Results	Paper
positive	Chowdhury et al. 2014 - Finkelstein et al. 2011 - Guixeres et al. 2012 - Higuchi, Ueno, and Rekimoto 2014 - Hossain, Hassan, and Alamri 2013 - Hsieh et al. 2014 - Landry and Pares 2014 - C.-Y. Lin and Chang 2015 - Monteiro et al. 2014 - Nguyen et al. 2012 - Snyder, Anderson-Hanley, and Arciero 2012 - Wi, Kang, and Jang 2013 - Zhang et al. 2012

Partially positive	Berkovsky et al. 2010 - Cui et al. 2009 - Guo and Quarles 2013 - Hanneton and Varenne 2009 - Landry and Pares 2014 - J. J. Lin et al. 2006 - Pasch et al. 2009 - Mazzone et al. 2013 - Plante et al. 2003 - Singh et al. 2011 - Warburton et al. 2007 - Van Schaik et al. 2008
Not discussed	Le et al. 2012

Role of gamification features: When mapping Table 12 together with Table 9 (from 5.4 motivational affordances) we notice that studies reporting fully positive results have deployed in average 2 to 3 game mechanics in contrast to studies reporting partial positive results, which have only deployed 1 to 2 game mechanics. This could support our assumption that gamification elements and motivational affordances should be highly considered when developing exergames.

3.6 General shortcomings in the literature

In the course of our systematic review we could identify different shortcoming, namely:

- Although 84% of reviewed studies were quantitative, the sample sizes except 3 studies were often relatively small (median N = 21)
- Most of the given statistics were merely descriptive and no inferences and deductions were presented
- Some studies did not deploy validated scales for the measurement of the different behaviors and outcomes
- Different studies were simply based on user evaluation and did lack control groups
- Generally, the studies were carried out in rather short timeframes
- A linkage to prior theory was missing in most of the papers.

3.7 Strengths & limitations of the review

To the authors' knowledge, this is the first work, in which a systematic review on the deployment of game-based motivational affordances in exergames and gamified exercise systems was conducted. However, the limitations of this work should be mentioned. For instance, the search for this review included only hits for the keywords "virtual reality*" and "gam*" in addition to exercise related terms. Since the use of keywords importantly differs in this rather new area, a further search for keywords, like "interactive computer play" or simply "video game", could have brought more results and broadened the spectrum. Moreover, language and publication biases might have occurred since we have only considered inspecting published studies in English. Besides, we have exclusively used Scopus for our research. Although we estimate that this database encompasses most of the relevant gamification and exergame studies, other databases like PubMed and Web of Knowledge could have also been considered.

3.8 Conclusion

Physical activity is clearly important to public health and exergames represent one potential way to enact it. The promotion of physical activity through gamification and enhanced anticipated affect also holds promise to aid in exercise adherence beyond more traditional educational and social cognitive approaches that tend to dominate this literature. A review of this literature can help identify what we know so far and highlight important future directions.

In this paper, we reviewed the contemporary literature focused on serious exergaming and its impact on behavioral adherence and potential mediators. We thereby examined the types and aims of the studies as well as their outcomes. This paper focuses precisely on the deployed motivational affordances and the corresponding results. The findings of the paper indicate a partially to fully positive outcomes of the reviewed studies. Nevertheless, we noticed that most studies, which developed a new exergame from scratch or tried to 'exergamify' an existing game, did solely concentrate on changing the game input mode from static (e.g. button based) to active one (e.g. motion based) and did not focus on the gamification design principles and guidelines. For instance, quite few studies (Finkelstein et al. 2011; Nguyen et al. 2012) have considered designing a game experience following the Flow theory (Csikszentmihalyi 1975) and none of the studies had investigated the type of their participants (e.g. according to Bartle's (1996) classification). Moreover, none of the studies had implemented an achievement and badges systems for their exergames.

To conclude, several studies were identified, which considered the task of game design and the deployment of gamification features for promoting physical activity. However, further and theory-based studies, granularly examining the effectiveness of different gamification elements and mechanics in exergames, are needed.

4 Multimedia Design Principles for More Effective Gamification

Title	Cognitive Load Matters, in Gamification Even More. An Empirical Study on the Importance of Deploying Multimedia Design Principles in Gamification to Reduce Cognitive Load.
Authors	Amir, Matallaoui, Technical University of Berlin, Straße des 17. Juni 135, 10623 Berlin, Germany, amirqphj@mailbox.tu-berlin.de Class Gnerlich, Technical University of Berlin, Straße des 17. Juni 135, 10623 Berlin, Germany, claas.gnerlich@tu-berlin.de Rüdiger, Zarnekow, Technical University of Berlin, Straße des 17. Juni 135, 10623 Berlin, Germany, ruediger.zarnekow@tu-berlin.de
Published in	International Journal of Serious Games IJSG2018(under review)
Abstract	**Context**: Being generally deployed on top of other existing systems, gamification usually brings with it a further layer of complexity to the existing task. Hence, in order for the cognitive load to be minimized and thus for the implemented gamification to be perceived, we argue that besides coming up with elaborated gamification mechanics, taking account of the gamification aesthetics is very crucial. **Objective**: In this paper, we address a design gap in the deployment of gamification in serious contexts such as education, health and work. We have thereby examined the importance of applying established design theories such as the multimedia principles in the implementation of gamification and serious games and in reducing the induced cognitive load. **Method**: We have conducted a quantitative study, in which 241 persons with different ages and backgrounds have participated. The study consisted of an IQ-like series of puzzles, to which two different designed badge systems were implemented. The participants were afterwards given different weighted questions related to their perceptions of both badge systems. **Results**: The study evaluation shows that badges that were designed based on the different multimedia principles were significantly better perceived than badges, whose implementation did not follow verified design guidelines and was carried out by merely adding badges into the existing system. **Conclusion:** We concluded that for gamification to be well perceived and to achieve the pursued engagement and motivation objectives, it is crucial for gamification designers to base their implementation on the well-recognized multimedia principles. In general, taking proven HCI design theories into account is indispensable for designing effective gamification and serious games.
Keywords	Gamification design, Cognitive load, Multimedia principles, Effective design

4.1 Introduction

Thanks to their ubiquitous and universal nature, researchers have been investigating the deployment of games into further and more serious domains like health, business and education. This practice of integrating game elements into non-game environments is referred to as gamification (Deterding et al. 2011), which is further defined by Huotari and Hamari (2012) as the "process of enhancing a service with affordances for gameful experiences in order to support the user's overall value creation". Gamification has been applied in many domains such as education (Iosup and Epema 2014; Bartel, Figas, and Hagel 2015), health improvement (Warburton et al. 2007; Cui et al. 2009; Finkelstein et al. 2011), and marketing (Kalantzis and Vasileios 2017). The main objective of gamifying these domains is to promote the user's engagement and motivation and hence improving and bettering the sought outcomes.

Gamification, however, is not the mere task of adding game-related elements such as points, badges, and rankings on top of existing systems. In (Aparicio et al. 2012; Werbach and Hunter 2012) the authors claim that various aspects should be considered in order to ensure a proper and efficient implementation of gamification. These include understanding the target audience (e.g. Bartle's player types that suit MUD (Bartle 1996)), defining the pursued objectives, considering the appropriate game mechanics, and applying established HCI theories as well as game design models and techniques.

In this work, we show that effective gamification should take consideration of the different HCI designing guidelines. We start by outlining the background and motivation behind our work. We then present a quantitative study that we have conducted with the help of 241 participants. Thereby we introduce the test, for which we have developed a badge system, with different badge designs. We conclude our work by discussing the study outcomes and by stating the study limitations.

4.2 Background and motivation

4.2.1 Related Works

Achievement systems have been one of the most considered motivational affordances in gamification studies (Hamari 2017). Many of these latter have investigated the effectiveness of integrating badges in motivating people to engage more with the given task.

Denny (2013) has presented an experiment, in which the effects of integrating an achievement system within an online learning and social knowledge sharing tool named PeerWise were measured. The author states that by incorporating such a badge system, the students' contribution rate to the tool as well as the amount of time spent on it have considerably increased with no notable reduction of the answers' accuracy. The author comes to the conclusion that badges, if properly integrated, could be a potent stimulus in educational contexts. Furthermore, in (Haaranen et al. 2014), the authors go through the design and

implementation of two badge systems within two different learning management systems. The benefits as well as the flaws of the integration of each system are presented and discussed. Based on these two practical experiences, the authors specify some general guidelines and functional requirements that badge systems should generally follow. Those guidelines ensure amongst others the technical and the design compatibility of the badge system with the application, its reusability, and students' confidentiality.

However, many studies have also mentioned that badge systems did not always fulfill the sought task of motivating and engaging people due, amongst other, to poor design (Gartner 2012). To the authors' knowledge, no earlier works have based the design of the presented badge systems on well-established HCI theories.

4.2.2 Legibility of the gamification elements

Marache-Francisco and Brangier (2013) state that "the gamification dimension is considered and perceived through two main dimension, namely: a graphical one and a persuasive one." (see Figure 9)

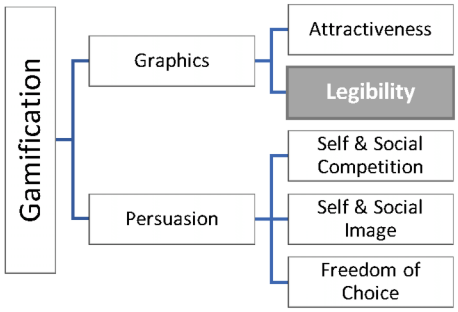

Figure 9. Dimensions of gamification design (Marache-Francisco and Brangier 2013)

Since gamification usually means deploying game mechanics on top of existing systems, gamification designers should pay close attention to the new level of complexity (the one caused by the perception of the gamification mechanics) added to the existing one (the original complexity produced by dealing with the existing system). According to Sweller, van Merrienboer, and Paas (1998) there exist three types of cognitive load, namely:

- Intrinsic load, which is imposed by the original system/task itself.
- Extraneous load, which is imposed by the way the information is presented.
- Germane load, which is devoted to processing the given information.

Hence, one important task of the gamification designers is managing the cognitive load placed on users by following effective design strategies that decrease the extraneous load and avoid a possible overload. In (Moreno and Mayer 1999) the authors present the multimedia principles and argue that these latter help reduce the cognitive load when designing multimedia content.

4.2.3 Multimedia Principles

In this section, we give an overview of the different multimedia principles (Mayer 2002; Moreno and Mayer 1999) that were deployed in our study:

- ***Coherence principle (MP1):*** "People learn better when extraneous words, pictures and sounds are excluded rather than included". The reason for this principle is that people focus better on the essential task if peripheral material is eliminated.

- ***Signaling principle (MP2):*** "People learn better when cues that highlight the organization of the essential material are added." The rationale for this principle is that people learn more efficiently if their attentions are called to the key material.

- ***Spatial contiguity principle (MP3):*** "People learn better when corresponding words and pictures are presented near rather than far from each other on the page or screen." The reason for this principle is that spatial contiguity makes it easier for people to build connection between the matching components of the material.

- ***Temporal contiguity principle (MP4):*** "People learn better when corresponding words and pictures are presented simultaneously rather than successively." Similar to the former multimedia principle, the reason for this one is helping people build connection between the corresponding components of the material as well.

- ***Segmenting principle (MP5):*** "People learn better from a multimedia lesson is presented in user-paced segments rather than as a continuous unit." The justification behind this principle is that segmenting helps people process and focus on one step of the process at a time.

- ***Pre-training principle (MP6):*** "People learn better from a multimedia lesson when they know the names and characteristics of the main concepts." The rationale for this principle is the fact that pre-training allows people to simply focus on the causal connection between the components of given material after having already learned about their different names and characteristics.

- ***Multimedia principle (MP7):*** "People learn better from words and pictures than from words alone." The rationale for this principle is that using the verbal channel alongside with the visual one is better than only using the verbal channel to process information.

- ***Personalization principle (MP8):*** "People learn better from multimedia lessons when words are in conversational style rather than formal style." The reason for this principle is that conversational style evokes a "sense of social presence" in people, which leads to more engagement.

4.3 Study

This section comprises three different sections. In the first section, we give an introduction to the game, on which the study is based. Next, we outline the different badge designs that were presented to the participants during the experiment. Finally, we present an evaluation of the gathered data, based on the hypotheses made in an early section.

4.3.1 Test

In this study, we have sought a challenging task, which primarily requires a high amount of concentration. For that we have decided to implement the *paper folding test*, in which the participants are given a sequence of folds in a piece of paper, which is then punctured using a hole punch. The goal here is to imagine how the paper would look like when unfold (i.e. how many holes would the unfold paper have and where are these positioned) by selecting the right answer from the listed suggestions. The paper folding test is "one of the most established tests of spatial visualization" (Davis and Spatial Reasoning Study Group 2015), which is defined in (Miller and Bertoline 1991) as the ability "to imagine the rotation to imagine the rotation of a depicted object, the folding and unfolding of flat patterns, and the relative changes of positions of objects in space"

Figure 10 shows an example of a possible test. The two figures at the left of the vertical separation line show how the paper was fold (in this case only once) and how often it has been punctured (in this case also only once at the upper left corner). To the right of the separation line, possible answers has been listed, from which the participant should pick the right one.

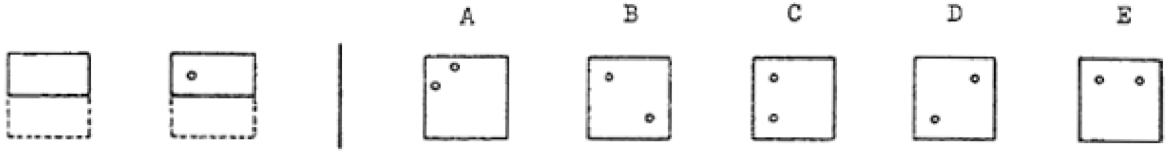

Figure 10. Paper folding test (http://steinhardtapps.es.its.nyu.edu)

Figure 11 shows the different folding steps as well as the unfolding ones after punching the hole. In this case picking the answer (c) would be the right choice.

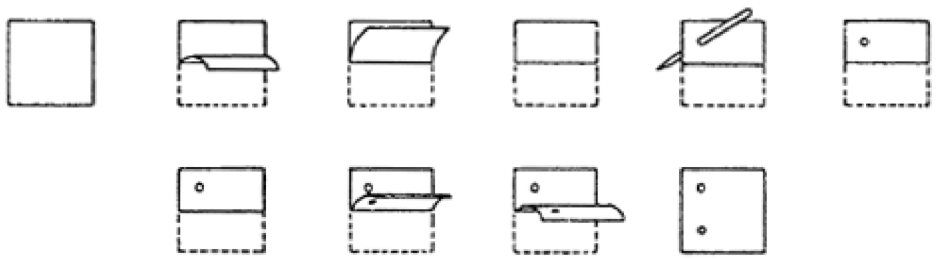

Figure 11. paper folding example solution

The developed website is essentially composed of the tests as well as the corresponding questionnaires (see 10.4 Chapter 4).

4.3.2 Different badge designs and corresponding hypotheses

Optimized badges

We designate by "optimized badges", the badges that were designed based on the multimedia principles (see Figure 12). Taking MP1 in consideration, these badges are coherently designed and do not contain superfluous information. Nevertheless, to satisfy MP7 and based on the common achievement structure (Hamari and Eranti 2011), the graphical representation of the badges consists of two main parts, namely a picture and a corresponding text (label). These latter are formulated in a rather personalized manner that address the participant (e.g. "you're halfway there!" instead of "50% of the question were answered." or "you're fast!" instead of "speed badge unlocked."). The corresponding pictures were highlighted using flat colors and shadows. Being flat, "the design looks simpler, spacious and has less distraction. It lets the users focus on the content that matters…"[1]. Lastly, when a badge is unlocked, its components appear on the screen adjacent (contiguous) to each other and at the same time. This fulfils the spatial and temporal contiguity.

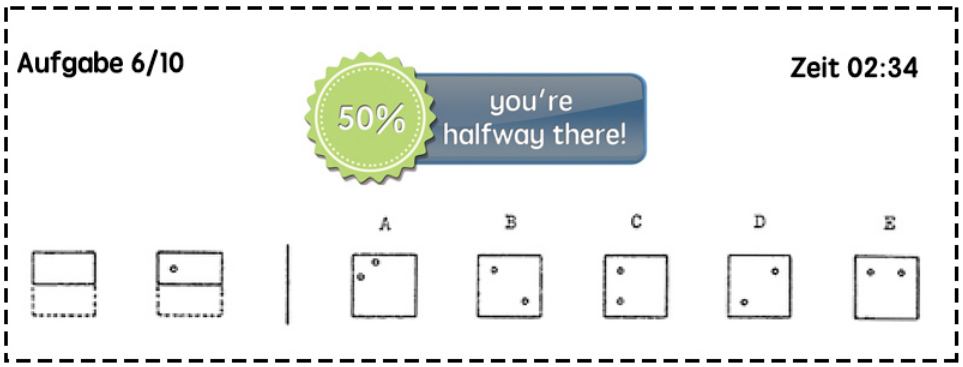

Figure 12. Optimized badge

Badges with extraneous parts

The badge in Figure 13 looks very eccentric and may distract the participant from concentrating on the main task. Such a design lacks relevance and hence violates the multimedia coherence principle (MP1). Contrary to the presumed intention of making the participant better notice the badges and get the sought impact, adding superfluous parts to the badges may critically affect the overall cognitive load and add an unnecessary extra layer of perception complexity.

H1: optimized badges, which have a coherent design, are better perceivable than badges with extraneous content.

[1] http://www.hongkiat.com/blog/long-shadow-design

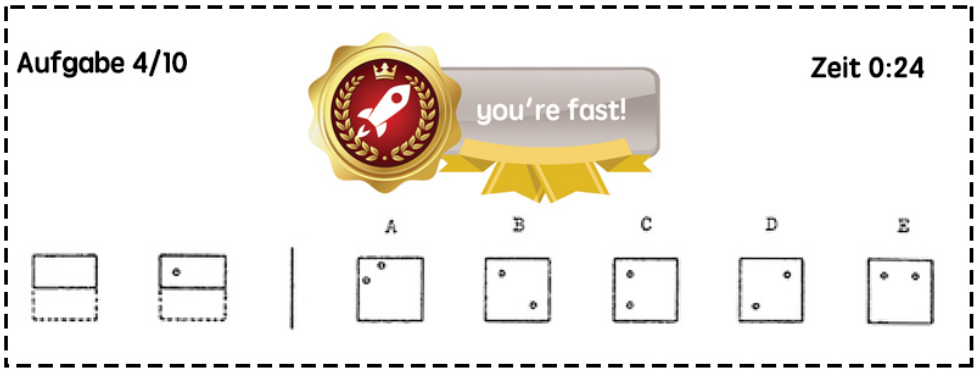

Figure 13. Extraneous design

Badges with no highlighting

As seen in Figure 14, the badges have a plain design and do not dispose of any highlighted parts that are present in the optimized badges. Given the current situation that involves a high concentration, a badge design with such faded colors does not respect the signaling principle (MP2) and thus makes it difficult for the participant to notice the badges and get the pursued motivation.

H2: badges with no subtle emphasizing of the given components are less noticeable than the optimized badges (that consider the signaling principle).

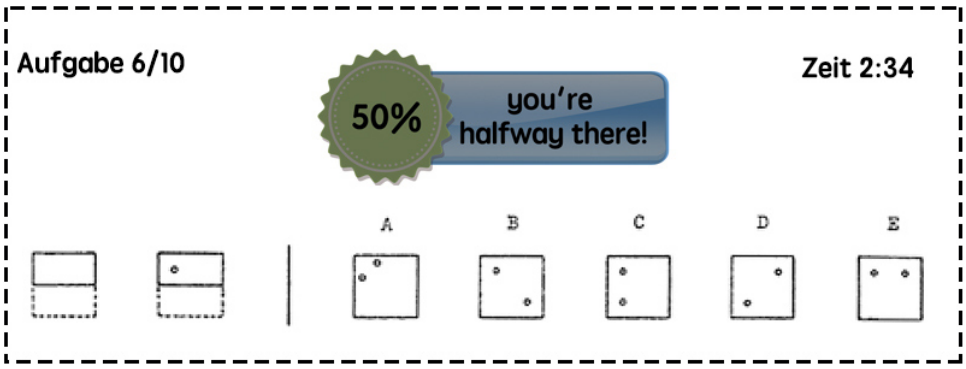

Figure 14. No highlighting

Badges with separated picture and label

The badge design in Figure 15 violates the spatial contiguity principle (MP3). In contrast to the optimized badges, the picture and its corresponding label are separated from each other. It is important to mention that when a badge is unlocked, its different parts appear at different spots of the screen. This will lead to a higher cognitive load and thus disturb the participant from concentrating on the main task.

H3: badges, whose design takes consideration of the spatial contiguity principle, are better perceivable than badges, which have their components (picture & label) emerge far from each other on the screen.

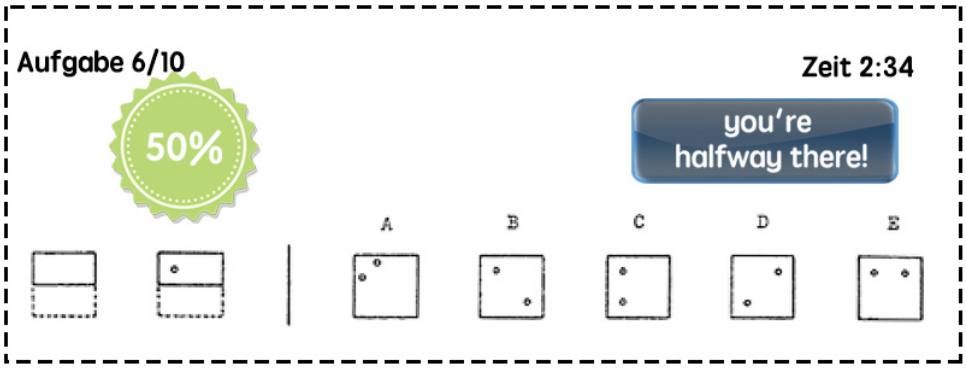

Figure 15. Separated parts

Asynchronous fade-in of badges' components

Unlike the concurrent display of the optimized badges' components, the pictures and labels in this study section are shown asynchronously (see Figure 16). When a goal is achieved and the corresponding badge is unlocked, the badge's label fades in the screen and only after it fades out (after 1.5 seconds) the badge's picture is shown. This behavior violates the multimedia temporal contiguity principle (MP4) and irritates the participants.

H4: badges, which have their components fade in simultaneously, do consider the temporal contiguity principle and are hence better perceived than badges, whose pictures and labels fade in asynchronously.

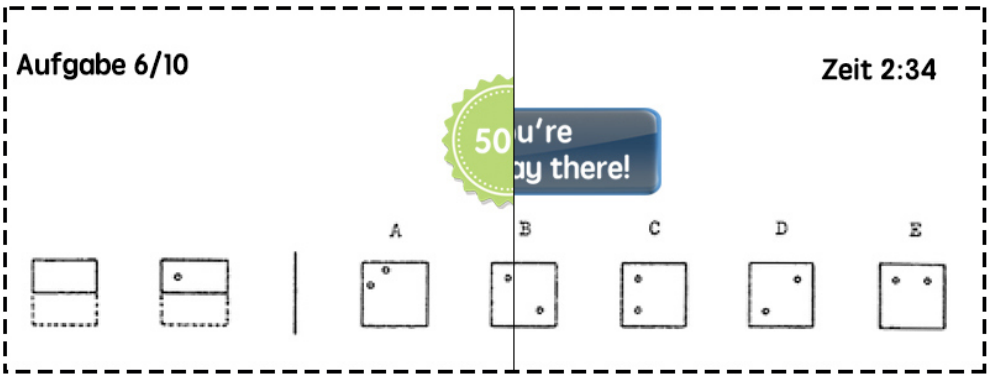

Figure 16. Asynchronous fade-in of the badge parts

Concurrent revealing of all unlocked badges

Based on the optimized badges, we have set-up a scenario that does not take account of the multimedia segmenting principle (MP5). In contrast to revealing the unlocked badge as soon as the matching conditions are fulfilled, the badges in this case are shown altogether (see Figure 17). Such badges are barely noticeable when piled up together and thus lose their real-time motivating characteristics.

H5: badges that are shown in a rather segmented way (as soon as they are unlocked) are better perceived and thus more effective than badges that do not consider the multimedia segmenting principle and are shown collected at the end of the study.

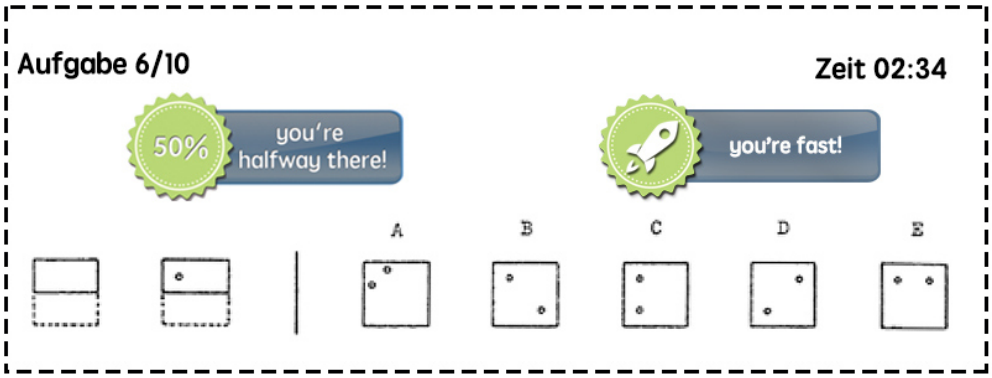

Figure 17. Concurrent fade-in of the badges

Pre-announced badges

Contrary to the rather sudden display of the achieved badges in the previous sections, the participants in this case are aware of the badges' presence. Before starting the game, all the badges that may be unlocked are introduced (with their corresponding descriptions) to the participants. Based on the multimedia pre-training principle (MP6), getting familiar with the upcoming contests and psychologically preparing for them help the participants to set goals, track the collected achievements and hence perform better.

The locked badges (see Figure 18) are grey-shaded; the very first badge (labelled: "Great, you accepted the challenge!") is however unlocked and reveals a lucid and colorful state, whose intention is to already motivate the participants to unlock the other badges and bring them as well to such 'pleasing' state.

H6: badges that are introduced to the participants before starting the assignment take account of the multimedia pre-training principle and are thus better perceived and pursued than badges that suddenly emerge in the screen with no initial notice.

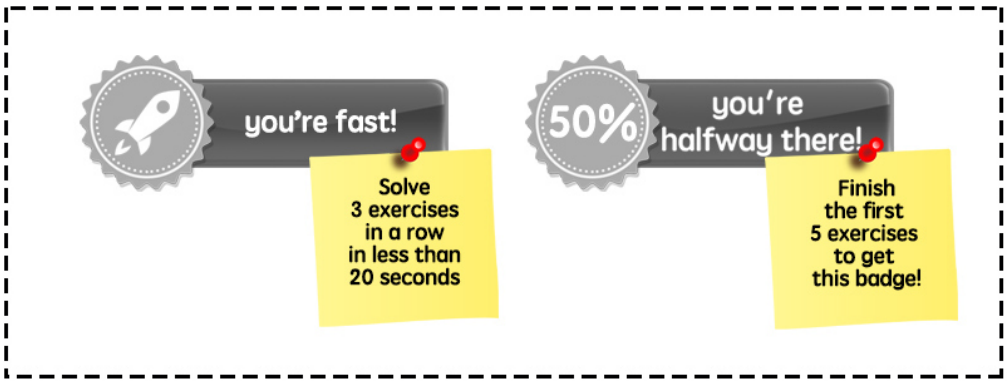

Figure 18. Pre-announcing badges

Pure text and picture-free badges

In contrast to the optimized badges, which consist of labels and pictures as well, the badges in this instance are only formed of text. We have basically omitted the picture of each of the

optimized badges and only have shown its label whenever it got unlocked (see Figure 19). Dismissing the graphics when designing the badges violates the multimedia principle. (MP7)

H7: badges that consist of a text and a picture as well are better noticed and thus more effective than badges that do not consider the multimedia principle and contain pure text.

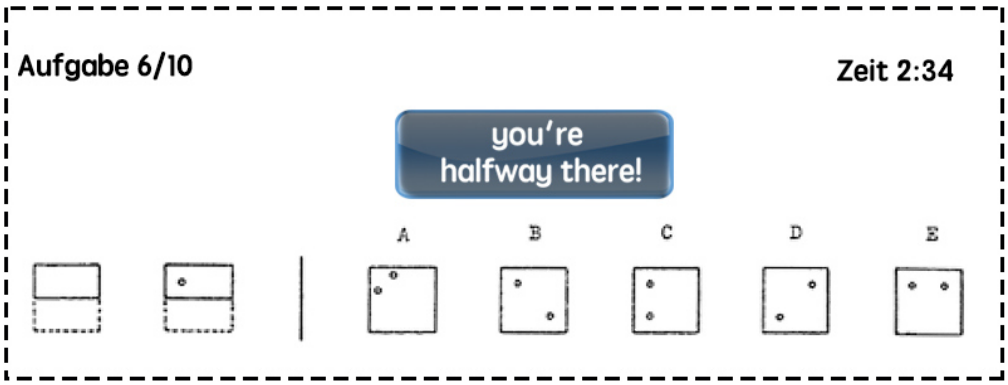

Figure 19. Text-only design

Non-personalized badges

As mentioned earlier when introducing the optimized badges, the labels were formulated following a personalized and motivating style. Contrary to this approach and neglecting the multimedia personalization principle (MP8), the badges in this study section are conveyed in a rather formal and non-personalized manner (see Figure 20).

H8: badges, whose labels were formulated in a relatively personalized and non-conventional way are more engaging and more stimulating than badges with non-personalized labels.

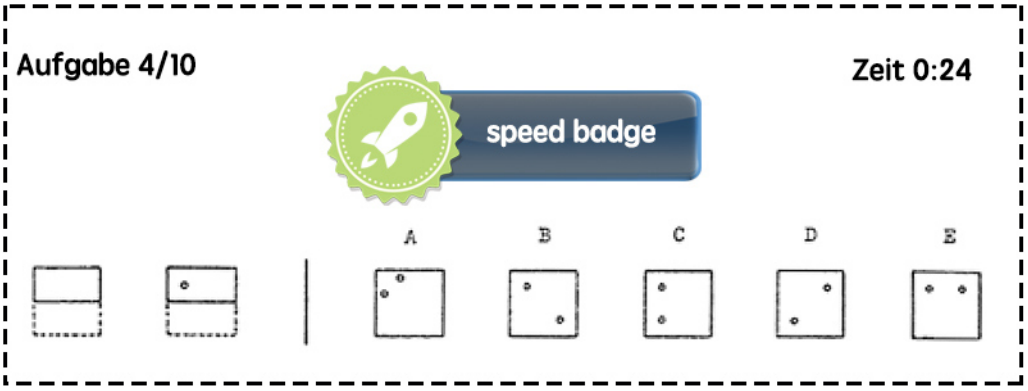

Figure 20. Non-personalized badge

4.4 Results

4.4.1 General results

In this section, we present the details of the study as well as the information gathered during the process of data analysis. The study was conducted with a sample of 241 people of different ages. Table 13 shows the different age groups of the participants.

Table 13. participants' age structure (P2)

Age	Count	%
< 17	5	2,0%
18 – 24	39	16,2%
25 – 34	164	68,1%
35 – 44	22	9,1%
45 – 54	10	4,2%
> 55	1	0,4%
	241	100%

The majority of the participants (89,8%) were familiar with the concept of badges whereas for only 10,2%, this notion of rewarding and motivation was entirely new. However, only 11,2% from the participants who were familiar with this gamification mechanic knew this concept under the name of "badges". 49,7% were in fact more familiar with the term "achievement" than with the term "badge" and for good 39,1% the term "trophy" was the most common one. It is important to mention than that none of the participants (0%) did not recognize any of the given denotations.

Since the placement of the badges is one of the issues we are approaching in this study, we thought about asking the participants about the common spots of badges on the screen. We have thereby only considered the answers of the participants who were actually familiar with the concept of badges. The answers show that 29,5% believe that badges usually appear on the top-left corner of the screen, whereas 33,6 have picked the top-right one. Exactly 15% of the participants hold that the common position of the badges is on the bottom-left while 17,2% have opted for the bottom-right corner and only 4,7% consider the center of the screen as the most common spot. Moreover, the participants were given the option to provide their opinion in free text about displaying badges in the middle of the screen and the majority have stated that this could be very irritating and distracting from the main task.

Table 14 shows the different player types, into which the participants could be categorized. Even though we could recognize a light similarity, the results (killer 36.2%, achiever 57.1%, explorer 65.4%, & socializer 69.4%) differ from those of the measurements carried out by Zichermann and Cunningham (2011) (killer 20%, achiever 40%, explorer 50%, & socializer 80%). This could be partly due to the facts that we did not differentiate between gamers and non-gamers and that each player type was handled using only one question.

Table 14. distribution of player types

Player type	statistics		%
Killer (max. 9)	M SD n	3,2 2,21 241	36,2%
Achiever (max. 9)	M SD n	5,1 2,14 241	57,1%
Explorer (max. 9)	M SD n	5,8 2,43 241	65,4%
Socializer (max. 9)	M SD n	6,2 2,43 241	69,4%

Table 15 shows that around 15% of the participants rarely play video games, whereas more than 72% play games regularly. Even though one could assume that there is a strong connection between regular playing of video games and being familiar with badge systems, the correlation in our case is rather average r=49. Accordingly, we could conclude that many participants are familiar with badges even if they do not regularly play video games and that they were acquainted with them in other contexts. To prove this, further studies should be conducted.

Table 15. Playing frequency (P10)

Value	Count	%
1 (not at all)	22	9,1%
2	15	6,2%
3	27	11,2%
4	31	12,9%
5	59	24,5%
6 (to a great extent)	87	36,1%

Table 16 shows that around 70% of the participants understand the unlock-mechanism behind the badge systems, whereas more than 13% had no idea and 16,5% were unsure about it. This presents a quite good correlation (r=71) between being familiar with badges and understanding the underlying unlocking mechanism.

Table 16. Familiarity with badge systems (P11)

Value	Count	%
1 (definitely not)	24	10%
2	8	3,3%
3	8	3,3%
4	32	13,2%
5	39	16,2%
6 (definitely)	130	54%

In order to carry on with the study, we had to ensure that the participants did feel the time pressure and that the cognitive load was relatively high. The corresponding results can be seen in Table 17 They show that, during the first test, the mental effort was quite important (M=3.72, SD=0.83, Median=4), the given tasks were rather difficult (M=3.2, SD=0.85, Median=3), and the participants had to process more than one information simultaneously (M=4.25, SD=1.31, Median=4) under high time pressure (M=3.63, SD=1.23, Median=4).

The results of the second test show that all means and medians have decreased by at least one point. This was expected, since both tests had more or less the same content and the participants had gotten familiar with the website and the study environment.

Table 17. Study results on mental exertion and time pressure

	Test 1		Test 2	
Mental effort (max. 5)	M	3.72	M	2.51
	SD	0.83	SD	1.05
	Median	4	Median	3
	n	241	n	241
Difficulty (max. 5)	M	3.27	M	2.01
	SD	0.85	SD	1.21
	Median	3	Median	2
	n	241	n	241
Simultaneous information processing (max. 5)	M	4.25	M	2.5
	SD	1.31	SD	1.07
	Median	4	Median	3
	n	241	n	241
Time pressure (max. 5)	M	3.63	M	2.19
	SD	1.23	SD	1.02
	Median	4	Median	2
	n	241	n	241

4.4.2 validation of the hypotheses

Badges with extraneous parts – H1

The test combinations T01 (badges with extraneous parts in the 1st test) and T10 (badges with extraneous parts in the 2nd test) were respectively taken by 17 and 24 participants. By means of these tests the following hypothesis has been examined:

H1: optimized badges, which have a coherent design, are better perceivable than badges with extraneous content.

Table 18 shows the results of the participants' perception (left) and understanding (right) of the optimized badges juxtaposed to the results of their perception and understanding of those

with superfluous content. The results of the 1st test of the combination T01 denote a very good awareness of the badges (M=4.83, SD=0.51, Median=5). The results of the second test demonstrate that the optimized badges were just as perceivable as the ones in the former test (M=3.3, SD=0.97, Median=3). In contrast to the first combination, the results of test1 of T10 depict an inferior perception of the introduced badges (M=3.6, SD=1.1, Median=3), with which the badge perception in test2 was very comparable (M=3.1, SD=0.91, Median=3).

Table 18. Badge perception (left) and understanding (right) in T01 and T10

	Test1 / Q6		Test2 / Q16	
T01	*M*	4.83	*M*	3.3
	SD	0.51	*SD*	0.97
	Med.	5	*Med.*	3
	n	17	*n*	17
T10	*M*	3.6	*M*	3.1
	SD	1.1	*SD*	0.91
	Med.	3	*Med.*	3
	n	24	*n*	24

	Test1 / Q7		Test2 / Q17	
T01	*M*	4.64	*M*	3.2
	SD	0.47	*SD*	0.87
	Med.	5	*Med.*	3
	n	17	*n*	17
T10	*M*	4.5	*M*	3.3
	SD	0.91	*SD*	0.98
	Med.	5	*Med.*	3
	n	24	*n*	24

Similar to the perception check, the outcome of the badge understanding in the 1st test of the combination T01 was quite positive (M=4.64, SD=0.47, Median=5). The understanding of the badges in the 2nd test did barely differ (M=3.2, SD=0.87, Median=3). The understanding's outcome of the badges of the 2nd test in T10 was to its turn relatively equal (M=3.3, SD=0.98, Median=3) to the rather good results of the 1st test (M=4.5, SD=0.91, Median=5).

The hypothesis could therefore not be confirmed, since the badges with extraneous content were as good perceived and understood as the optimized ones. This was not expected and could be due to the relatively minor number of participants in these tests (n=17 & n=24) or to the present design (the badges could have been designed more unaccustomedly)

Badges with no highlighting – H2

The test combinations T02 (badges with no highlighting in the 1st test) and T20 (badges with no highlighting in the 2nd test) were respectively taken by 16 and 17 participants. By means of these tests the following hypothesis has been examined:

H2: badges with no subtle emphasizing of the given components are less noticeable than the optimized badges (that consider the signaling principle).

Table 19 lays out the results of the participants' perception and understanding of the different badge types presented in T02 and T20. In the test combination T02 the badges with no applied highlighting were quite good perceived (M=4.56, SD=0.41, Median=4). The

optimized badges were slightly better perceived (M=3.92, SD=0.57, Median=4). In the test combination T20, the optimized badges were very good perceived (M=4.41, SD=0.49, Median=4.5) whereas the badges with no applied highlighting failed in this combination to gain the sought attention (M=1.42, SD=0.32, Median=1.5).

Table 19. Badge perception (left) and understanding (right) in T02 and T20

	Test1 / Q6		Test2 / Q16	
T02	*M*	4.56	*M*	3.92
	SD	0.41	*SD*	0.57
	Med.	4	*Med.*	4
	n	16	*n*	16
T20	*M*	4.41	*M*	1.42
	SD	0.49	*SD*	0.32
	Med.	4.5	*Med.*	1.5
	n	17	*n*	17

	Test1 / Q7		Test2 / Q17	
T02	*M*	4.2	*M*	3.61
	SD	0.2	*SD*	0.68
	Med.	4	*Med.*	3.5
	n	16	*n*	16
T20	*M*	4.72	*M*	2.24
	SD	0.46	*SD*	0.48
	Med.	4.5	*Med.*	2
	n	17	*n*	17

Alike the perception test, both badge types, those with no applied highlighting and the optimized ones were well understood in the combinations T02: (M=4.2, SD=0.2, Median=4) (M=3.61, SD=0.68, Median=3.5). In T20 and in contrast to the optimized badges, which were yet again well understood (M=4.72, SD=0.46, Median=4.5), the badges with no applied highlighting did induce a relative ambiguity (M=2.24, SD=0.48, Median=2).

The hypothesis H2 could therefore be confirmed, since the badges with no highlighted content were worse perceived and less well understood than the optimized ones. It is important to mention that even though the badges with no highlighting were less well perceived and understood in T20, no conclusions can be drawn regarding the impact of the tests order on the badge grasping. This would have to be examined in a further study. If necessary, the method and style of highlighting content should be inspected as well.

Badges with separated picture and label – H3

The test combinations T03 (badges with separated parts in the 1st test) and T30 (badges with separated parts in the 2nd test) were respectively taken by 23 and 15 participants. By means of these tests the following hypothesis has been examined:

H3: badges, whose design takes consideration of the spatial contiguity principle, are better perceivable than badges, which have their components (picture & label) emerge far from each other on the screen.

The results of the participants' perception as well as understanding of the badges introduced in T03 and T30 are outlined in Table 20. The badges in the 1st test of T03 were poorly perceived

(M=2.15, SD=1.09, Median=2) by the participants. This was actually expected since those badges had their labels and pictures separated from each other. The optimized badges, which did consider the spatial contiguity principle, were clearly better perceived (M=4.19, SD=0.44, Median=4) than the former. The outcome of the combination T30 differ slightly from T03: in the 1st test, the optimized badges were averagely perceived (M=3.0, SD=0.89, Median=3). Nevertheless, the badges with separated components still gained barely the same awareness as the optimized ones (M=2.54, SD=1.41, Median=2.5).

Table 20. Badge perception (left) and understanding (right) in T03 and T30

	Test1 / Q6		Test2 / Q16	
T03	*M*	2.15	*M*	4.19
	SD	1.09	*SD*	0.44
	Med.	2	*Med.*	4
	n	23	*n*	23
T30	*M*	3.0	*M*	2.54
	SD	0.89	*SD*	1.41
	Med.	3	*Med.*	2.5
	n	15	*n*	15

	Test1 / Q7		Test2 / Q17	
T03	*M*	3.2	*M*	4.1
	SD	1.09	*SD*	0.79
	Med.	3	*Med.*	4
	n	23	*n*	23
T30	*M*	4.89	*M*	2.2
	SD	0.87	*SD*	1.2
	Med.	5	*Med.*	2
	n	15	*n*	15

The badges in the 1st test of T03 were passably understood (M=3.2, SD=1.09, Median=3), whereas the participants' understanding of the badges in the 2nd test were better (M=4.1, SD=0.79, Median=4). In the 1st test of T30 the deployment of the optimized badges was flawlessly understood (M=4.89, SD=0.87, Median=5). The understanding of the badges with separated components was clearly inferior (M=2.2, SD=1.2, Median=2).

The hypothesis H3 could therefore be confirmed as expected, since the participants had it much easier and more comfortable to perceive the badges with connected components (the optimized badges) than those with separated ones. It was also shown that the tests' order was irrelevant since the perception and understanding of the badges that did not consider the spatial contiguity principle were in both cases equally poor.

Asynchronous fade-in of badges' components – H4

The test combinations T04 (asynchronous fade-in in the 1st test) and T40 (asynchronous fade-in in the 2nd test) were respectively taken by 16 and 11 participants. By means of these tests the following hypothesis has been examined:

H4: badges, which have their components fade in simultaneously, do consider the temporal contiguity principle and are hence better perceived than badges, whose pictures and labels fade in asynchronously.

Table 21 shows the results of the participants' perception as well as grasping of the badges presented in the tests T04 and T40. In the 2nd test of T04, the perception of the badges was obviously better (M=4.24, SD=0.98, Median=5) than in the 1st test (M=3.25, SD=1.2, Median=3). This was actually expected since the pictures and the corresponding labels of the 1st test's badges did not fade in synchronously. The outcomes of T40 did barely differ from those of T04 with a relatively good perception of the optimized badges in the 1st test (M=4.31, SD=0.86, Median=4) and a quite poor one in the 2nd test (M=1.23, SD=0.33, Median=1), compared to test1.

Table 21. Badge perception (left) and understanding (right) in T04 and T40

	Test1 / Q6		Test2 / Q16	
T04	*M*	3.25	*M*	4.24
	SD	1.2	*SD*	0.98
	Med.	3	*Med.*	5
	n	16	*n*	16
T40	*M*	4.31	*M*	1.23
	SD	0.86	*SD*	0.33
	Med.	4	*Med.*	1
	n	11	*n*	11

	Test1 / Q7		Test2 / Q17	
T04	*M*	3.78	*M*	4.27
	SD	1.28	*SD*	1.05
	Med.	4	*Med.*	5
	n	16	*n*	16
T40	*M*	4.72	*M*	1.42
	SD	0.41	*SD*	1.05
	Med.	5	*Med.*	1
	n	11	*n*	11

Although the badges of the 1st test in T04 were relatively good understood (M=3.78, SD=1.28, Median=4), the optimized ones in test2 still managed to get better understanding (M=4.24, SD=1.05, Median=5). In contrast to T04, the 2nd test of T40 shows that the badges with asynchronous fade-in of the different components were clearly less well grasped (M=1.42, SD=1.05, Median=1) than the optimized badges of test1 (M=4.72, SD=0.41, Median=5).

The hypothesis H4 could consequently be confirmed as expected, since the participants, in contrast to the optimized badges, did barely manage to perceive and understand the badges with asynchronous fading of the components. The test outcomes also show that the hypothesis was confirmed in both combinations and that the order of the appearance of the different badge types was irrelevant.

Concurrent revealing of all unlocked badges – H5

The test combinations T05 (concurrent badges in the 1st test) and T50 (concurrent badges in the 2nd test) were respectively taken by 15 and 10 participants. By means of these tests the following hypothesis has been examined:

H5: badges that are shown in a rather segmented way (as soon as they are unlocked) are better perceived and thus more effective than badges that do not consider the multimedia segmenting principle and are shown collected at the end of the study.

The results of the participants' perception as well as understanding of the badges introduced in T05 and T50 are correspondingly outlined in Table 22. The perception of the badges in the 1st test of T05 was quite low (M=2.58, SD=1.42, Median=2). This was actually expected since all the badges were revealed at the same time. To their turn, the optimized badges, which did separately appear, were better perceived (M=3.7, SD=1.28, Median=4). This was also the case in the 1st Test of T50, where the badges that were shown in a segmented way were very good perceived (M=4.8, SD=0.83, Median=5), whereas the concurrent revealing of the unlocked badges led to a clearly worse perception (M=1.2, SD=0.6, Median=1).

Table 22. Badge perception (left) and understanding (right) in T05 and T50

	Test1 / Q6		Test2 / Q16	
T05	*M*	2.58	*M*	3.7
	SD	1.42	*SD*	1.28
	Med.	2	*Med.*	4
	n	15	*n*	15
T50	*M*	4.8	*M*	1.2
	SD	0.82	*SD*	0.6
	Med.	5	*Med.*	1
	n	10	*n*	10

	Test1 / Q7		Test2 / Q17	
T05	*M*	2.58	*M*	4.67
	SD	1.46	*SD*	0.47
	Med.	2	*Med.*	5
	n	15	*n*	15
T50	*M*	4.62	*M*	1.62
	SD	1.22	*SD*	0.82
	Med.	5	*Med.*	1
	n	10	*n*	10

The outcomes of the understanding tests did barely differ from those of the perception's. With (M=2.58, SD=1.46, Median=2) the badges in the 1st test of T05 were rather poorly understood. The understanding of the badges in the 2nd test of T05 was clearly better (M=4.67, SD=0.47, Median=5). In the 1st test of T50, the results of the badges' understanding were very good (M=4.62, SD=1.22, Median=5), whereas the results of the 2nd test, in which the badges appear totally in parallel, were definitely inferior (M=1.62, SD=0.82, Median=1).

As expected, the hypothesis H5 could therefore be confirmed: the participants had it much simpler to perceive and understand the badges as soon as they are unlocked than to react to all the badges unlocked simultaneously at the end of the session. It was also shown that the tests' order was irrelevant since the perception and understanding of the badges that did not consider the segmenting principle were in both cases equally poor.

Pre-announced badges – H6

The test combinations T06 (pre-announced badges in the 2nd test) and T60 (pre-announced badges in the 1st test) were respectively taken by 16 and 8 participants. By means of these tests the following hypothesis has been examined:

H6: badges that are introduced to the participants before starting the assignment take account of the multimedia pre-training principle and are thus better perceived and pursued than badges that suddenly emerge in the screen with no initial notice.

The results of the participants' perception and understanding of the badges introduced in T06 and T60 are correspondingly outlined in Table 23. The perception of badges was very good in the 2nd test of T06 (M=4.58, SD=0.56, Median=4.5) and relatively worse in the 1st one (M=2.2, SD=0.6, Median=2). For the test combination T60, the perception's results were fairly good in the 2nd test (M=4.06, SD=1.4, Median=4) and very slightly better in the 1st one (M=3.4, SD=0.8, Median=3.5).

Table 23. Badge perception (left) and understanding (right) in T06 and T60

	Test1 / Q6		Test2 / Q16	
T06	*M*	2.2	*M*	4.58
	SD	0.6	*SD*	0.56
	Med.	2	*Med.*	4.5
	n	16	*n*	16
T60	*M*	3.4	*M*	4.06
	SD	0.8	*SD*	1.4
	Med.	3.5	*Med.*	4
	n	8	*n*	8

	Test1 / Q7		Test2 / Q17	
T06	*M*	2.8	*M*	4.2
	SD	0.5	*SD*	0.8
	Med.	2.5	*Med.*	4
	n	16	*n*	16
T60	*M*	4.2	*M*	4.1
	SD	0.25	*SD*	0.4
	Med.	4	*Med.*	4
	n	8	*n*	8

The deployment of the badges was good understood in the 2nd test of T06 (M=4.2, SD=0.8, Median=4) and the understanding was a little worse in the 1st test (M=2.8, SD=0.5, Median=2.5). In T60, the understanding of the badges was also quite good in the 2nd (M=4.1, SD=0.4, Median=4) and slightly increased in the 1st test (M=4.2, SD=0.25, Median=4).

The hypothesis H6 could be confirmed, since the participants had it easier to grasp the badges that had been introduced to them at early stage than to deal with the badges that appeared for the first time while playing. The tests' order was also irrelevant in this case, as the pre-announced badges were better perceived and understood in both tests.

Pure text and picture-free badges – H7

The test combinations T07 (picture-free badges in the 1st test) and T70 (picture-free badges in the 2nd test) were respectively taken by 11 and 9 participants. By means of these tests the following hypothesis has been examined:

H7: badges that consist of a text and a picture are better noticed and thus more effective than badges that do not consider the multimedia principle and only contain pure text.

Table 24 outlines the results of the participants' perception and understanding of the badges presented in the tests T07 and T70. The results of the 1st test of T07 show that the perception of the text-only badges was very poor (M=1.2, SD=0.82, Median=1). The optimized badges in the 2nd test were much better perceived (M=4.66, SD=0.33, Median=5). The results of the test combination T70 show that the participants' perception of the text-only badges was again quite worse (M=1.6, SD=0.85, Median=1) than the optimized ones in test 1 (M=4.6, SD=1.2, Median=5).

Table 24. Badge perception (left) and understanding (right) in T07 and T70

	Test1 / Q6		Test2 / Q16	
T07	*M*	1.2	*M*	4.66
	SD	0.82	*SD*	0.33
	Med.	1	*Med.*	5
	n	11	*n*	11
T70	*M*	4.6	*M*	1.6
	SD	1.2	*SD*	0.85
	Med.	5	*Med.*	1
	n	9	*n*	9

	Test1 / Q7		Test2 / Q17	
T07	*M*	1.24	*M*	4.8
	SD	0.44	*SD*	0.85
	Med.	1	*Med.*	5
	n	11	*n*	11
T70	*M*	4.46	*M*	1.2
	SD	0.22	*SD*	0.4
	Med.	5	*Med.*	2
	n	9	*n*	9

The badge understanding results did barely differ from those of the perception. In both test combinations, the deployment of text-only badges was obviously worse understood than the optimized badges. In the 1st test of T07 the understanding of the text-only badges was very poor (M=1.24, SD=0.44, Median=1) and in the 2nd test of T70 the understanding was clearly worse than that of the optimized badges (M=1.2, SD=0.4, Median=2).

The hypothesis H7 could be confirmed as expected, since the participants had it obviously more comfortable to perceive the badges containing both picture and text label than those with merely pure text. It was also shown that the tests' order was irrelevant, since the perception and understanding of the badges that did not consider the multimedia principle were in both cases equally poor.

Non-personalized badges – H8

The test combinations T08 (personalized badges in the 2st test) and T80 (personalized badges in the 1st test) were respectively taken by 17 and 22 participants. By means of these tests the following hypothesis has been examined:

H8: badges, whose labels were formulated in a relatively personalized and non-conventional way are more engaging and more stimulating than badges with non-personalized labels.

Table 25 presents the results of the participants' perception of the badges introduced in the tests T08 and T80. In the 1st test of T08 the badges were good perceived, even though they were not personalized (M=4.1, SD=0.52, Median=4). The optimized badges with the personalized labels were nevertheless better perceived (M=4.24, SD=1.05, Median=4). In T80, the results of the 1st test were quite good (M=4.46, SD=1.4, Median=5) and so were the results of the 2nd one in comparison (M=3.46, SD=1.2, Median=3).

Table 25. Badge perception (left) and understanding (right) in T08 and T80

	Test1 / Q6		Test2 / Q16	
T08	*M*	4.1	*M*	4.24
	SD	0.52	*SD*	1.05
	Med.	4	*Med.*	4
	n	17	*n*	17
T80	*M*	4.46	*M*	3.46
	SD	1.4	*SD*	1.2
	Med.	5	*Med.*	3
	n	22	*n*	22

	Test1 / Q7		Test2 / Q17	
T08	*M*	4.39	*M*	4.2
	SD	1.2	*SD*	0.45
	Med.	4	*Med.*	4
	n	17	*n*	17
T80	*M*	4.55	*M*	2.26
	SD	0.45	*SD*	0.88
	Med.	5	*Med.*	2
	n	22	*n*	22

The badge understanding results did barely differ from those of the perception. In both test combinations, the deployment of personalized badges has led to better understanding results. In the 1st test of T08, even though the understanding of the non-personalized badges was quite significant (M=4.39, SD=1.2, Median=4), the badges with personalized content did manage to get better results (M=4.2, SD=0.45, Median=4). In the 2nd test ofT80 the understanding was clearly equal to that of the optimized badges (M=2.26, SD=0.88, Median=2).

As expected, the hypothesis H8 could therefore be confirmed: the participants had it much simpler to perceive and understand the badges that were custom-tailored and had personalized labels. It was also shown that the tests' order was irrelevant since the perception and understanding of the badges that did consider the personalization principle were in both cases equally better.

Core thesis

After having evaluated the outcomes of each implemented multimedia principle individually, in this section the results of the following core thesis are outlined.

Badges, that were designed and build with regards to the multimedia principles are better perceived and understood than those that did not consider these principles.

For this purpose, the test combinations are divided into two groups. The first group (125 participants) includes the test combinations T01 to T08. In these combinations, the optimized

badges emerged in the second test. The other group (116 participants) consists of the test combinations T10 to T80. In these combinations, the optimized badges emerged in the first test.

The overall results of the participants' perception and understanding of the badges are correspondingly outlined in Table 26. For the first group, the perception of badges was quite poor in the 1st test (M=2.34, SD=0.87, Median=2) and obviously better in the 2nd one (M=4.0, SD=0.85, Median=4). For the second group, the perception's results were quite good in the 1st test (M=4.2, SD=1.16, Median=5) and did worsen in the 2nd one (M=2.37, SD=0.96, Median=3).

The badge understanding results did not differ much from those of the perception. For the first group, the understanding was average in the 1st test (M=3.6, SD=0.86, Median=3) and relatively better in the 2nd one (M=4.08, SD=0.71, Median=4). For the second group, the understanding was quite good in the 1st test (M=4.6, SD=0.6, Median=5) and did pretty worsen in the 2nd one (M=2.55, SD=0.8, Median=2).

Table 26. Overall badge perception (left) and understanding (right)

	Test1 / Q6		Test2 / Q16	
T01,T02,	*M*	2.34	*M*	4
T03,T04,	*SD*	0.87	*SD*	0.85
T05,T06,	*Med.*	2	*Med.*	4
T07,T08	*n*	131	*n*	131
T10,T20,	*M*	4.2	*M*	2.37
T30,T40,	*SD*	1.16	*SD*	0.96
T50,T60,	*Med.*	5	*Med.*	3
T70, T80	*n*	116	*n*	116

	Test1 / Q7		Test2 / Q17	
T01,T02,	*M*	3.6	*M*	4.08
T03,T04,	*SD*	0.86	*SD*	0.71
T05,T06,	*Med.*	3	*Med.*	4
T07,T08	*n*	131	*n*	131
T10,T20,	*M*	4.6	*M*	2.55
T30,T40,	*SD*	0.6	*SD*	0.8
T50,T60,	*Med.*	5	*Med.*	2
T70, T80	*n*	116	*n*	116

The core hypothesis could therefore be confirmed, since the participants had it obviously more comfortable to perceive and understand the badges, whose design conforms with the multimedia principles. It was also shown that the tests' order was irrelevant, since the perception and understanding of the badges that did not consider the multimedia principles were in both cases equally poor.

4.5 Discussion & limitations

This paper reports results of a study on incorporating the multimedia principles into the design of a badge system. Concretely, eight hypotheses based on eight principles were examined for accuracy. The hypotheses H2 – H8 were to a greater extent confirmed, since the badges,

whose design had taken in consideration the multimedia principles were better perceived and understood than the other badges. Only H1 could not be confirmed and thus did not meet our expectations. This may be due to the fact that the badge (see Figure 13) did not really have extraneous parts but rather other colors and guise.

One also interesting multimedia principle that we did not examine in our study is the modality principle. This latter states that "people learn better from graphics and narrations than from graphics and on-screen text". The rationale for it is that by listening to the text instead of reading it, people use their verbal channels and hence offload the visual ones, which may focus solely on the graphics. Taking account of such principles when designing gamification would make this more effective. For instance, let's consider a game like "Zombies, Run!"[2]: an immersive running game, in which players, while running, listen to various audio stories to uncover the game missions. It would not be wise for this game like this to implement a badge system that uses graphics. Implementing badges that are based on sound and narration would be more suitable and would motivate the runners engage more with the current mission in real time.

Regarding the questionnaires, some questions were found ambiguous and were misunderstood by the participant and have to be improved. For instance, many participants thought of the badge positioning when dealing with the question Q8 "The presentation of the badges was inappropriate.", whereas the question was not only about the positioning but also about its design, presentation, and understanding.

Ultimately, it is important to mention that even if 241 people participated in the study, the absolute number for each individual test varied between 8 and 24. Although the overall results speak in favor of deploying the multimedia principle when designing badges, the partial results may not be considered very reliable.

4.6 Conclusion

Gamification is usually built on top of an existing system. This generally means adding a further level of complexity and further elements for the user brain to perceive and interact with. In order to manage the induced cognitive load, we have in this work examined the effects of considering the multimedia principles when implementing gamification. We have thereby carried out a quantitative study that consisted of a serious game, on top of which two badge systems were implemented, respectively taking account of the multimedia principles in the first one and eliding them in the second one. The evaluation of the questionnaires that the participants had to answer after each section of the study shows that the badges, whose design has implemented the multimedia principles were notably better perceived and understood than the other badges. This brings us to the conclusion that it is crucial for gamification designers to generally consider the multimedia principles as well as further established HCI design guidelines in their designs.

[2] https://zombiesrungame.com/

5 Designing Better Perceivable Badges by Deploying Semiotics

Title	Towards More Effective Gamification: Does Deploying Semiotics Help Design Better Perceivable Badges?
Authors	Amir, Matallaoui, Technical University of Berlin, Straße des 17. Juni 135, 10623 Berlin, Germany, amirqphj@mailbox.tu-berlin.de
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Abstract	**Context**: By definition, gamification is the application of game design elements in non-game contexts. This deployment of gamification usually induces a further layer of complexity on top of the current task. Thus, to minimize the caused cognitive load, we argue that taking account of the gamification aesthetics is as important as deploying different and elaborated gamification mechanics. **Objective**: In this paper, we deal with the cognitive overload made by the deployment of gamification in serious contexts such as education, health and work. We thereby emphasize on the importance of applying established design theories such as semiotics (the signs theory) in reducing the caused cognitive load. **Method**: We have therefore designed a quantitative study, to which we have invited participants with different ages and backgrounds. The study consists of a series of puzzles (taken from a prior study of ours), to which two achievement systems with different badges (icons) were designed. The participants have afterwards to answer various weighted questions related to their perceptions of both achievement systems. **Hypothesis**: In this work, we argue that badges, whose icon design takes consideration of the signs theory are better perceived than badges, whose design did not follow this theory.
Keywords	Gamification, Cognitive load, Signs theory, Achievement systems, Badge design

5.1 Introduction

The task of deploying game elements into non-game domains (serious domains) is denoted as *gamification* (Deterding et al. 2011). This latter is further defined by Huotari and Hamari (2012) as the "process of enhancing a service with affordances for gameful experiences in order to support the user's overall value creation". Due to their pervasive and universal characteristics, researchers have been examining the utilization of games into advanced and more serious fields like well-being, industry and education. Different domains have witnessed the integration of gamification; these include, amongst others, education (Iosup and Epema 2014) and health (Chowdhury et al. 2014; Guixeres et al. 2012; Hossain, Hassan, and Alamri 2013). The main purpose behind gamifying these fields is to foster the user's engagement and motivation and thus to improve the sought outcomes.

Gamification, however, does not simply lie in adding game-specific features on top of current systems. According to (Aparicio et al. 2012; Werbach and Hunter 2012), different facets should be carefully taken into consideration to ensure an accurate and effective implementation of gamification. These include amongst others: defining the pursued goals, deploying the appropriate game mechanics, understanding the target audience (e.g. Bartle's player types (Bartle 1996)), and on the meta-level, taking account of established HCI and design theories. In this paper, we argue that for gamification to be fruitful, it should consider the various and well-established HCI and design guidelines. We start the paper by introducing the background and motivation behind our work. We then present the test framework that was designed for our study. Thereby, we introduce the test itself as well as the questionnaire, which the participants will have to answer to evaluate their experience.

5.2 Background & motivation

5.2.1 Perception of gamification elements

The authors in (Marache-Francisco and Brangier 2013) argue that gamification is perceived and dealt with through two core dimensions, namely: a graphical dimension and a persuasive one. The former includes attractiveness as well as the legibility aspect. Gamifying an existing task usually means deploying game mechanics on top of the existing system. Hence, gamification designers should pay attention to the new level of complexity, which is caused by dealing with the emerging gamification mechanics and the existing one.

According to Sweller, van Merrienboer, and Paas (1998) there exist three types of cognitive load, namely:

- ***Intrinsic load:*** refers to the complexity imposed by the original task.
- ***Extraneous load:*** refers to the complexity imposed by the way the information is presented.
- ***Germane load:*** refers to the complexity imposed by processing the given information.

Thus, for the gamification designers to manage the cognitive load imposed on users, they should follow effective design strategies that shrink the extraneous load. We, in this work, argue that using the appropriate icons in the badge design helps make the badges more understandable and thus reduces the amount of the extraneous load.

5.2.2 Signs theory

Despite the different algorithms and approaches, creating flawless and appropriate visualizations has always been a non-trivial task (Chandler 2007). Information Visualization deals mainly with the task of representing some facets of the extensive information; two of the most important questions to give an answer to are a) what exactly needs to be represented and b) how to represent it.

According to Piez (2002), a good information visualization should consider the given data, the limitations of the human cognitive system, and the social context. For scientific visualization, the social context includes amongst others, the current scientific theories as well as the conventional meanings of the used signs and symbols. In the following section, we are going to have a deeper look into the signs theory by giving a short overview on two of the most important semiotic models, namely De Saussure's dual semiotic model and Pierce's triangular one.

De Saussure's semiotic model: the diagram in Figure 21 represents De Saussure's semiotic model. De Saussure sees each sign as an interplay between a concept and its corresponding sound or image.

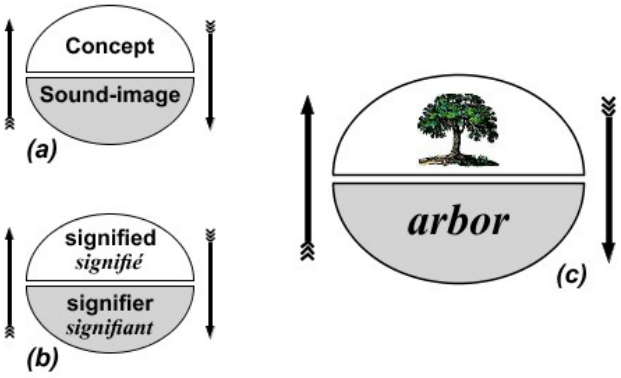

Figure 21. De Saussure's semiotic model
[A reconstruction of Saussure's schema of the sign (Piez 2002)]

The concept is called a 'signified' and the sound (respectively, the image) in it is called a signifier. A sign denotes the relation between the signifier and the signified. The idea that the signifier refers to a concept and not to an object or a thing was already developed by John Locke and explained in his work "An Essay concerning Human Understanding" (Locke 1796). This latter argues that "a linguistic sign is not a link between a thing and a name, but between a concept and a sound pattern." (De Saussure 2004)

Pierce's semiotic model: Whilst De Saussure defines semiotics as a science that studies the role of signs as part of social life, the philosopher Charles Pierce sees in it the formal doctrine of signs, which was closely related to Logic (Peirce, Weiss, and Hartshorne 1931). For Pierce, "a sign is something which stands to somebody for something in some respect or capacity" (Peirce, Weiss, and Hartshorne 1931).

In contrast to De Saussure, who offered a dyadic semiotic model (signified & signifier), the model that Peirce, Weiss, and Hartshorne (1931) have developed is triadic and consists in:

1. a ***representamen***: this is the form of the sign; it does not need to be a material form.
2. an ***interpretant***: which is *not* the interpreter and refers to the meaning or the sense the sign makes.
3. an ***object***: the pragmatic 'thing' that a sign refers to.

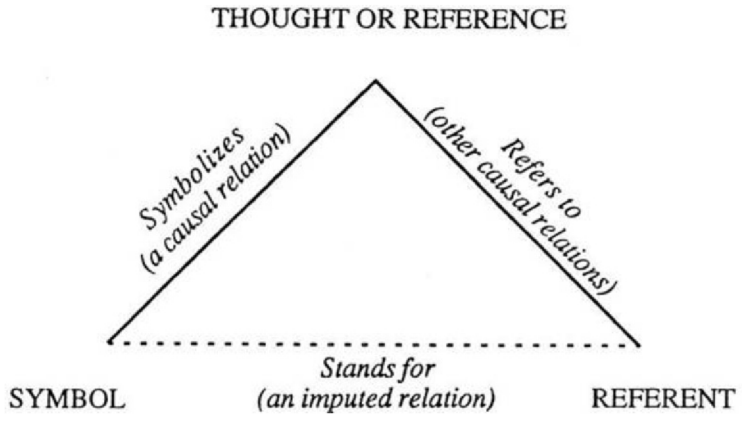

Figure 22. Ogden & Richards semiotic model (Peirce, Weiss, and Hartshorne 1931)

The representamen and the interpretant in Pierce's semiotic model are respectively similar to the signifier and the signified in De Saussure's model. The diagram in Figure 22 shows the 'semiotic triangle' of Ogden and Richards (1989). The terms used in this diagram are 'symbol', 'thought or reference' and 'referent'. These constitute a basic formulation of Pierce's model:

- *symbol* ~ representamen
- *thought* or reference ~ interpretant
- *referent* ~ object

We can see that there exists no clear relationship (dashed line in the diagram) between the symbol and the referent and, unlike the abstraction of the signified by De Saussure, the referent is an 'object'.

Based on the introduced semiotic models, Pierce has presented three types of signs (see Figure 23), which we will later consider in the design of our study's badges:

1 *Symbol*: A sign whose relation to the object is arbitrary or conventional.

2 *Index*: is a sign that can be designed through the relation between the indication and the object. For example, smoke is a sign of fire and the mercury going up in a thermometer is a sign of a raising temperature.

3 *Icon*: is a sign that is similar to the signified whether visually, acoustically... (kikeriki, miau, maps, etc.)

Figure 23. Icon, Index & Symbol examples [pinimg.com]

For the sake of ubiquity, some visual icons and symbols as well as earcons have started gaining relevancy and are being more common for users. Earcons are for the audio channel as icons are for the visual channel (e.g. the sound we hear when emptying the trash on the computer, the sound made by the game when Super Mario gets a coin…).

Making use of these 'signs' allows interface designers and, in our case, gamification designers to take advantage of speculations made up due to repeated viewing and listening to these symbols by end-users. We, in this study, focus more on deploying these types, since they play an important role in the graphical design of badges.

5.3 Study

This chapter contains three different sections. In the first section, we introduce the test, on which the experiment is based. The second section outlines the different badge designs that were presented to the participants and the corresponding hypothesis. Finally, we present an evaluation of the gathered data, based on the hypotheses made earlier.

5.3.1 Experiment

In this study, the participants will be given a sequence of folds in a piece of paper (see Figure 24), which is then punctured using a hole punch. To solve the puzzles, the participants have to

imagine how the paper would look like when unfolded (i.e. how many holes would the unfolded paper have and where are these positioned) by selecting the right answer from the listed suggestions.

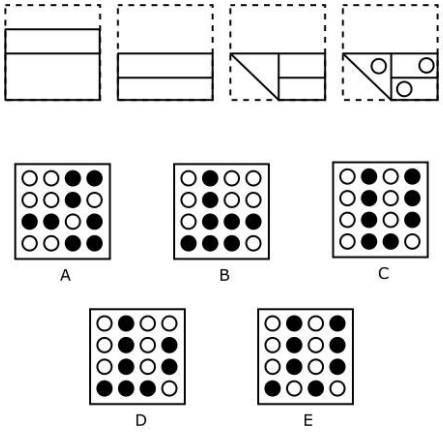

Figure 24. Paper folding game

5.3.2 Different badge designs & corresponding hypotheses

In the design of the different achievements, we have considered the general functional requirements. In other words, it conforms to the meta-model presented in (Matallaoui, Herzig, and Zarnekow 2015), which shows a simplified interpretation of a possible achievement's composition.

According to Hamari and Eranti (2011), an achievement consists of a name, a description of the unlocking logic and a badge, which forms the graphical representation of the achievement.

Figure 25. Different badge icons
(left) general graphical representation
(right) a badge using a rabbit as a sign for "being fast"

Taking account of the context, the gamification mechanics (in our cases the achievements) need to be perceived in order to obtain the sought behavior. We argue in this work that the badge (left) (see Figure 25) can be better perceived than the "normal" usual star.

Using a running rabbit as an index for speed is better perceivable and hence more motivating than the normal badge in (right).

5.3.3 Questionnaire

The following tables (see Table 27, Table 28, and Table 29) contain the different questions that will be presented to the participants before and after they take part in the experiment.

Table 27. General questions

	Question	**Answer choices**
Particulars	Sex?	Male / female
	Year of birth?	Number
Control questions	I regularly play computer games (incl. console)	Not at all – very little – somewhat – to a great extent
	Are you familiar with badge systems?	Not at all – very little – somewhat – to a great extent
	Which of these terms are you more familiar with?	Badge, achievement, trophy, none of the above

Table 28. First test's questionnaire

	Question	**Answer choices**
Cognitive load	How was your mental effort when solving the problems?	Very low – low – moderate – high – very high
	How were the given tasks?	Very easy – easy – average – difficult – very difficult
	When solving the tasks, I had to process many information simultaneously.	Strongly disagree – disagree – undecided – agree- strongly agree
	The design of the badges was inappropriate.	Strongly disagree – disagree – undecided – agree- strongly agree
Badges system design	Describe shortly what you understood or did not understand about the badge system. Did anything irritate you?	Free text
	How do you think the badge design could be optimized?	Free text

Table 29. Second test's questionnaire

	Question	Answer choices
Badge Perception	Was your mental effort in the 2nd test higher or lower than in the 1st one?	much lower – lower – comparable– higher – much higher
	Was the 2nd test easier or harder than the 1st one?	much easier – easier – comparable – more difficult – much more difficult
	When solving the tasks, I had to process more information simultaneously in the 2nd test than in the 1st one.	Strongly disagree – disagree – undecided – agree- strongly agree
	The presentation of the badges in the 2nd was better and more appropriate than in the 1st test.	Strongly disagree – disagree – undecided – agree- strongly agree
	Describe shortly what you have better (or worse) understood in the 2nd test.	Free text
	How do you think the badge presentation in the 2nd test could be optimized?	Free text

5.4 Conclusion & future work

In this paper, we emphasize on the importance of applying established design theories such as the signs theory in reducing the cognitive load caused by the implementation of gamification on top of existing systems. We thereby argue that badges, whose icon design takes consideration of the signs theory are better perceived than badges, whose design deploys generic icons.

To prove right our argument, we have prepared a quantitative study, to which different participants with different ages and backgrounds were invited to take part in. The participants should afterwards answer various weighted questions related to their perceptions of two different badge designs, namely a design using an appropriate graphical representation and a design using a general one.

Our next step is conducting the study and gathering the questionnaire answers for a further evaluation and validation of the proposed hypotheses.

6 Improving the Task of Gamification

Title	Augmenting the Task of Exercise Gamification: An Expert View on the Adoption of a New Technology for Deploying Existing Virtual Environments in Virtual Urban Exergames
Authors	Amir, Matallaoui, Technical University of Berlin, Straße des 17. Juni 135, 10623 Berlin, Germany, amirqphj@mailbox.tu-berlin.de Nizar, Ben Sassi, GT-ARC gemeinnützige GmbH Berlin, Germany nizar.ben-sassi@gt-arc.com Fikret, Sivrikaya, GT-ARC gemeinnützige GmbH Berlin, Germany, fikret.sivrikaya@gt-arc.com Rüdiger, Zarnekow, Technical University of Berlin, Straße des 17. Juni 135, 10623 Berlin, Germany, ruediger.zarnekow@tu-berlin.de
Published in	Proceedings of the 21st Pacific Asia Conference on Information Systems - (Matallaoui, Ben-Sassi, et al. 2017)
Abstract	Exergames commonly denote serious games and gamified systems that were developed for the sake of improving health and exercise adherence. One of the recent trends in exergaming are urban games. They are defined as "highly interdisciplinary digital games which root in such diverse fields as architecture and urban planning, healthcare sciences, and serious games research" (Knoell, et al. 2014). Besides having various 'physical benefits', such as promoting movement patterns, urban exergames have the core task of psychologically motivating players to exercise more and inspire them to be physically active. While offering an innovative and an immersive way to exercise, urban games come also with the typical drawbacks which outdoor exercising generally has (e.g. being dependent on good weather and intimidation problems for obese people). A possible solution would be simulating urban games for indoor exercise. On top of augmenting the sedentary game input to a motion-based one, designing and developing 3D environments for virtual urban games is not an obvious task and it takes a vast amount of knowledge, time and budget to create a realistic world with a "tremendous appeal and a powerful attraction". To bypass this challenge, we introduce in this work a new technology for accessing and gamifying existing game environments. Furthermore, we validate our approach by presenting the results of a qualitative research that we have conducted with the help of gamification experts and exergame designers.
Keywords	Exergames, Gamification, Serious games, Health, Virtual words, Immersion

6.1 Introduction

6.1.1 Background

In the recent years, many studies have been conducted on technological solutions aiming at enhancing the experience of exercising and physical activity (Singh et al. 2011; Finkelstein et al. 2011; Hossain, Hassan, and Alamri 2013). Exergaming, commonly defined as the use of video games in physical exercise, has gained in attention and acceptance and, with the release of various motion tracking-based technologies (e.g. Wii Mote, Microsoft Kinect, fitness trackers), an important number of exergames has been published (Wii Fit, Kinect Sports). These games are characterized by having body motion as input and game mechanic. Hence, they help decrease sedentariness, and enjoy physical activity.

While studies on exergaming have been carried out in the past years, a large number of them opted for the use of existing commercial consoles such as Nintendo Wii and Microsoft Xbox with the corresponding motion-based video games such as Wii Fit and Kinect Sports. Further works tried to convert existing sedentary games (e.g. games played using a normal gamepad or keyboard) into active ones by altering the input form static (e.g. button-based) to a motion-based one. The rest chose to exclusively develop an entire system for the study's purpose. (See *6.3.1* Methods for references and further details)

While augmenting game input by introducing body motion capture is an essential research field, we also believe that the task of designing and developing an immersive game experience is very crucial. Taking serious charge of this task would enrich the creation of challenging activities that trigger the users' skills and satisfy their common desires such as achievement and self-competition.

A fundamental challenge, however, in achieving the pursued immersive exergaming experience is the disposition of appealingly designed virtual worlds. The development of such environments is however quite difficult and delicate. Due to this time-consuming and costly design task, different studies on exergaming were bound to the deployment of existing open source worlds for their systems. These worlds though, were generally poorly designed and did not always satisfy the users' needs of enjoyment. One better alternative would be the use of high quality virtual worlds available in the majority commercial games. These are however typically not accessible and thus cannot be used.

6.1.2 Motivation

One of the recent trends in exergaming are urban games (see Figure 26). They are defined as a "highly interdisciplinary digital games which root in such diverse fields as architecture and urban planning, healthcare sciences, and serious games research." (Knoell et al. 2014)

Besides having various 'physical benefits', such as promoting movement patterns by dint of, amongst others, stairs and slopes, urban exergames have the core task of psychologically motivating players to exercise more and inspire them to be physically active. That is to say, urban exercise environments have emotional effects on players and are rather engaging and stimulating.

Although offering an innovative and an immersive way to exercise, urban games come also with the different drawbacks which outdoor exercising generally has (e.g. being dependent on good weather and intimidation problems for obese people, who do not necessarily feel well when they exercise outdoors. (Guixeres et al. 2012))

To bypass the above stated limitations, we introduce in this work a new technology for accessing and gamifying 3D game environments. We thereby start by presenting the state of the art, then we state the different challenges and motivations behind our work. Further, we introduce an architectural concept of our technology, which we validate at last by presenting the results of a qualitative research that we have carried out with exergame designers.

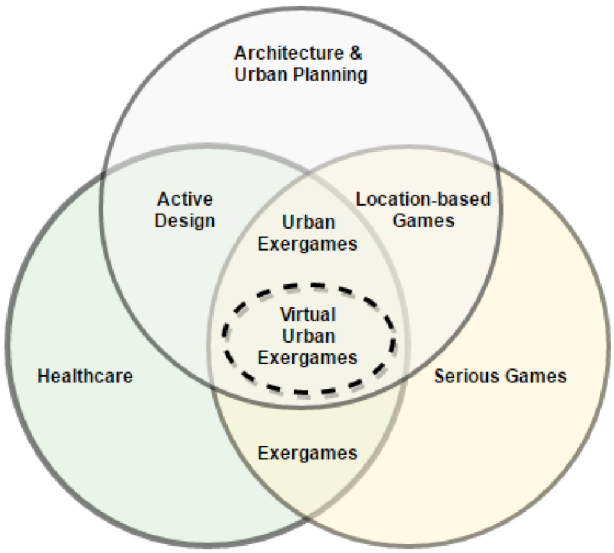

Figure 26. Relevant influences to the field of "Virtual Urban Exergames" – Adopted from (Knoell et al. 2014)

We would like at this point to emphasize again on the objectives of this work, which are on one hand presenting a new tool that would help gamification designers benefit from existing game worlds and use them in the intended serious contexts such as education and health promotion; one the other hand we give an evaluation of this tool with the help of a qualitative study conducted with gamification experts.

6.2 Related works

Different studies have tried augmenting the sedentary games to active ones. To the authors' knowledge, the only approach that the developers have come up with to gamify existing game environments (i.e. game scenes), was through modifying the corresponding source code. Since,

however, the source code of commercial games is typically not accessible, developers were left with open-source games. Converting these latter to motion-based ones was exclusively done through deploying the needed mechanics and behavior into the disposed source code.

Nguyen et al. (2012) have introduced a system which enables the users to explore virtual environments using a DDR Pad (a floor-based dance pad called so after Dance Dance Revolution). This system helps enhancing physical activity and reducing sedentariness through replacing the usual game controller by motion-based one. Exclusively for this purpose and the corresponding conducted study the authors have developed an exergame in which the player controls a character's movement and behavior by performing on the DDR.

In (Chowdhury et al. 2014) an implementation of a stimulating system for muscle conditioning activities has been presented. Using Game Maker Studio, a game engine, the authors have developed three games from scratch to be used in the given study. The common characteristic among these games is the fact that they are all played using only two buttons, namely the left and the right arrow buttons. To deploy these games in autism treatment, the authors have augmented the input method (button pressing) to a motion-based input using hand grippers.

Matallaoui, Herzig, and Zarnekow (2015) have introduced a model-driven serious game (and hence exergame) development. To validate the proposed approach, the authors have presented a use case in which they can be perceived to gamify an existing application. They therefore have integrated an achievement system on the top of the application main purpose. While the achievements' unlocking logics are defined outside the considered application, the achievement system's graphical representation is done through extending the available code with the corresponding plugin that was developed and provided by the authors.

To decrease sedentary playing and to drive forward active one, the authors in (Berkovsky, et al. 2010) have integrated new game mechanics into an open source game. In this game, players have to move a ball through a given course to a target point. The time parameter was the central game mechanic and had to be allocated to accomplish the game levels. To do so, an accelerometer was used to capture the physical activity of the players. This activity is then mapped into time that players could use to continue playing. While motion-based input was implemented, the source code of the game had to be modified in order to visualize the acquired amount of time.

Guo and Quarles (2013) presented an approach for deploying any genres of games, even those negligibly used as exergames, to enhance motivations and engagement for physical activity and exercise. They, therefore, presented a car racing game controlled by motion-based input. Thereby, an open source Unity3D game was modified in a way that the game car is steered using Kinect captured motions.

6.3 Exergame development

6.3.1 Methods

The development as well as the deployment of exergames and gamified systems can be categorized into three forms according to (Matallaoui, Koivisto, et al. 2017):

- The disposition of already available (commercial) consoles (e.g. Nintendo Wii, Xbox Kinect) with their corresponding physical activity-engaging games (e.g. Wii Fit, Kinect Sports); (e.g. (Guixeres et al. 2012; Hanneton and Varenne 2009; Monteiro et al. 2014))

- Augmenting sedentary systems to active ones by means of 'meta-games' (e.g. badges, ranking) to achieve and enhance a targeted physical behavior; (e.g. (S Berkovsky et al. 2010; Guo and Quarles 2013; Warburton et al. 2007))

- Exclusively developing exergames from scratch. (e.g. (Finkelstein et al. 2011; Mazzone et al. 2013; Snyder, Anderson-Hanley, and Arciero 2012))

6.3.2 Technical challenges

Figure 27 shows an abstraction of the common modules of exergames. These consist of 1) mainly, the game, on top of which the exercise is built, 2) an extended input, using motion and physical activity and lastly 3) the output, being extended to haptic (e.g. vibration), audio (e.g. applause) and visual feedback (e.g. badges)

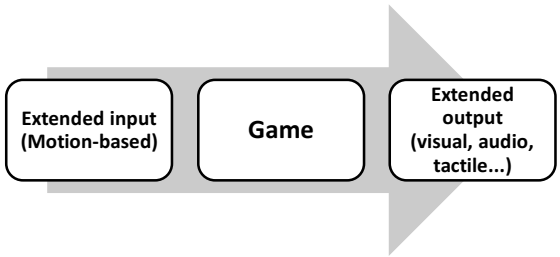

Figure 27. Exergame components

As noticeable in the afore listed related works and based on the depicted exergame components in Figure 27, it is clear that designing exergames is a concurrence of multiple tasks, namely:

1. the use of motion and health-related tracking devices and technologies, in order to collect the users' exercise-associated data,
2. the deployment of the gathered physical activity data as game input,
3. and the design of an immersive exergaming experience, typically following the different game design principles and behavior models such as the Flow theory (Csikszentmihalyi and LeFevre 1989) and the Motivation theory (Maslow 1943; Nevid 2007).

6.3.3 Challenges simulating urban environments for indoor exercise

Virtual urban games, being also an instance of serious games, inherit all the design and development challenges and hurdles these latter have. Besides augmenting the game input to a motion-based one, designing and developing 3D environments for virtual urban games is not an obvious task and it takes a vast amount of knowledge, time and budget to create a realistic world with a "tremendous appeal and a powerful attraction" (Weber 2015). Hence, gamification designers/developers who are intending to build their own 3D environment would face high risk and get distracted from their main task, which consists primarily in deploying gamification mechanics (e.g. levels, badges, and ranking) with the goal of enhancing exergame motivation and engagement.

In this work, we only focus on the exergame visual output (Figure 27 – extended output). The extension of the game input (Figure 27 – extended input) to meet exercising requirements will be treated separately in further works. In the next section, we present a conceptual depiction of the proposed technology and the underlying approach.

6.4 Technology concept

To overcome the afore mentioned limitations concerning the affordability of such 3D environments, we present in this section a technology (see Figure 28), by which exergame developers can take advantage of the commercial virtual worlds when designing and developing exergames.

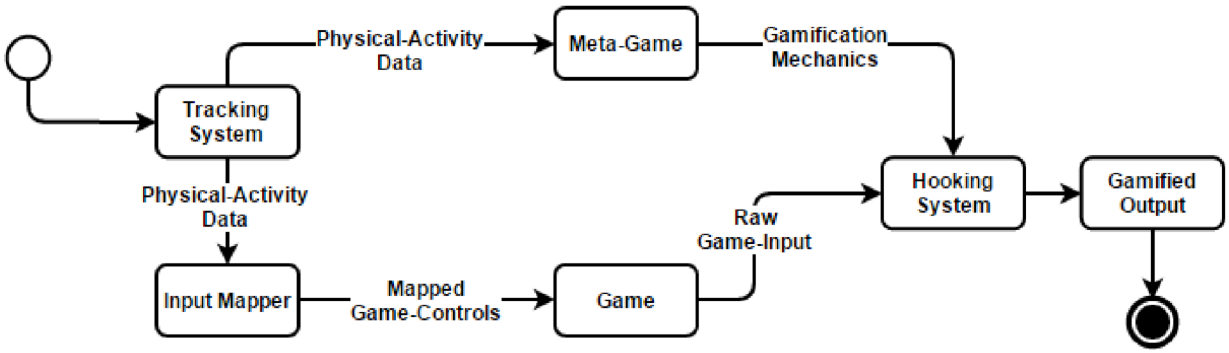

Figure 28. Data-Flow Concept

The ***Tracking System*** is responsible for gathering the physical activity data. Different devices (e.g. Kinect, tracking band, smart phones) and technologies (e.g. IR sensing, ANT+, Smart Bluetooth) have recently been deployed for this purpose. In exergames, tracking the users' motion and health-related data (e.g. speed, heart rate, steps count, and temperature) is cruical, since this data represents the base of the exergame input.

The task of the ***Input mapper*** is to transform the received physical activity data into game compatible inputs. For instance, a measured positive speed of a jogger is transformed by the

input mapper to the Up-Arrow command, which represents the actual game control for moving forward.

The *Game* component responds to the simulated input and updates the game scene. It contains the virtual environment on which the gamification takes place.

The *Meta-Game*, i.e. a game over the actual game, encloses the gamification design. This latter is responsible for the exergame flow.

The *Hooking System* is responsible for integrating the generated gamification mechanics into the raw game output in order to produce the final exergame scene (visual output). This technique takes control over a specified code chunk and manipulates with, amongst others, the purpose to extend its original behavior.

6.5 Technology review

6.5.1 Case study

To validate our approach, we have developed a use case scenario, in which we have used the introduced technology to add badges and real-time feedback on top of Grand Theft Auto 5 (GTA5), "an open world, action-adventure video game developed and published by Rockstar" (Wikipedia). We have picked GTA5 for our case study, as it disposes of an attractively designed open world. GTA5 offers a discovery mode, in which the game environment can be freely explored.

The use case goes as follows: after starting the meta-game application, the user cycles in front of a display connected to a PC on which the GTA5 game is running. The cycling characteristics are sensed using an ANT+ cadence sensor mounted on the bike. The sensor transmits the data to the exergame interface, which to its turn forwards it to the input mapper as well as the meta-game.

Figure 29. *(a) Raw-game output* *(b) Extended output.*

Figure 29 shows how the actual game (a) was extended (b) to visualize the tracked physical activity data (heart rate = 108bpm on the bottom right corner) and the gamification mechanics ("Cycling Pro!" badge unlocked for cycling 10Km on the top right).

6.5.2 Research methodology

In addition to having dominated acceptance research in information system technology (Choudrie and Dwivedi 2005; Lee and Baskerville 2003), quantitative research methods are very appropriate for evaluations focusing on impacts such as user satisfaction, system usage rates and effectiveness (Strauss and Corbin 2008). Since, in this work, our study issues cannot be simply subdivided into discrete ones and we are not examining the static characteristics of the presented technology, we have opted for a qualitative study. The followed qualitative approach was adopted from (Vogelsang, Steinhüser, and Hoppe 2013) and has been partially custom-tailored to meet some impediments (e.g. availability of gamification experts).

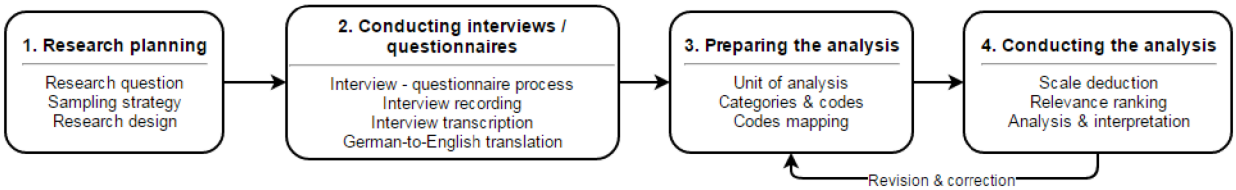

Figure 30. Applied research methodology adopted from (Vogelsang, Steinhüser, and Hoppe 2013)

6.5.3 Research planning

At the planning stage, according to the diagram in Figure 30, we agreed to conduct interviews with gamification experts and exergame designers. Contact acquisition was mainly initiated in-person at the HICSS (Hawaiian International Conference on System Sciences) and mutual projects with the departments of Agent Technologies and Human-Machine Systems of the Technical University of Berlin Germany through the presentation of the project intentions. Additional gamification experts and exergame designers were suggested by the already contacted ones. We further decided to also use a questionnaire for this qualitative research due to the fact that many experts, which we planned to interview, did not have the time for it and preferred the written form.

6.5.4 Conducting interviews & questionnaires

At the second stage, we conducted various interviews and questionnaires with 10 experts (see Table 30).

Table 30. Overview of conducted interviews and answers to the questionnaire

	Companies / Institutions		Interviewees / Participants (position)
	Industry / Field	Size (# of employees)	
P1	Internet of Things (IoT)	> 100	UX designer
P2	Psychology & Ergonomics	> 200	Gamification designer
P3	Fitness & E-health	> 10	Serious game designer

P4	Travel & Leisure	> 100	Head of marketing
P5	Information Technology	> 10	Software development
P6	Health	> 100	Serious game designer
P7	Mobility & Transport	> 10	Gamification designer
P8	Food Delivery	> 100	Head of marketing
P9	Consulting (IoT)	> 1k	Gamification consultant
P10	Serious Games	> 10	Game Developer

The interviews took place in-person and lasted 30-45 minutes. All experts had middle to senior executive positions and several years in the field of exergames and exercise gamification.

Table 31. Questionnaire / Basic interview guideline

Thematic aspects	Guiding questions
Interview context	Could you, please, detail on your expertise and knowledge in the field of gamification?
	What is your current occupation, with regards to gamification?
Thematic view	What is your understanding of "exergaming"?
	What type(s) of game environments do you think would fit with exercising (sports)?
	In your opinion, which characteristics should be available in a game environment in order to be suitable for exergaming?
	What do you think is the appropriate way to give feedback about the reached progress?
Technology adoption	How would the availability of such a technology affect the process of exergame design?
	What effects do you expect the presented technology to have on exergame designers?
	How do you evaluate the proposed technology? Innovation? Efficacy?
	What does such a technology mean for future projects in exergaming?
Further aspects	What do you think this study should further focus on (within "visual output")?

The questionnaire that is seen in Table 31 was sent as a google form to the corresponding interviewees and was answered per email. The interviews, after agreement with the experts, were audio-recorded for later transcription.

6.5.5 Preparing the analysis

Third, the transcripts that we generated from the recorded interviews and the additional questionnaires received per email formed the units of analysis for our study. Core statements as

well as complementary ones were extracted, segmented into discrete elements and sorted into different categories in order to enable insight, review and further development according to (Strauss and Corbin 2008).

The different steps of extracting, segmenting and sorting were reviewed by different persons to ensure objectivity and understandability. Data extraction and breakdown was supported by ATLAS.ti, a computer program used mostly in qualitative content analysis when dealing with unstructured data.

6.5.6 Conducting the analysis

At the final stage, we weighed the significance of each category based on the following two criteria, namely frequency (1) and relevance (2):

1 We counted the interviews and the questionnaires in which the category was mentioned or implicitly pointed to.

2 We assessed the relevance of the categories as follows: a) the category's corresponding feature is highlighted in the gathered data in particular (+2); b) the given feature is considered important but complementary (+1); c) the concept is principally considered not relevant (-1)

Hence, the conducted analysis gives a thorough portrait of the discussed categories as well as a classification of these categories based on the outcome of the weighed frequency and relevance all over the questionnaires and interviews.

6.6 Analysis outcome

We identified 12 features (see Table 32), which we have conceptually categorized under 1) Gamification technology characteristics, 2) Exergame environment characteristics and 3) Progress feedback.

Table 32. Feature frequency & relevance as identified in the expert interviews

Features	Freq.*	Rel.*	Proven?*
Gamification Technology Characteristics			
Guidance & assistance	4	7	-
Set of gamification components	5	8	-
Simplicity	6	9	+
Generic	4	8	+
Exergame Environment Characteristics			
Exercise-dependent	5	8	-
Immersive	8	14	+
Variable	4	6	+
Realistic	6	11	+

Progress Feedback			
Real-time feedback	9	15	+
Dashboard	5	7	-
Long-term goal tracking	5	8	-
Short-term goal tracking	7	11	+

*Rel: Relevance score - Freq: Frequency - Proven?: Is feature available in the presented technology.

6.6.1 Gamification technology

Gamification technologies (aka. software or platforms) are tools that enable the implementation of game mechanics into non-game contexts with the goal of boosting the motivation and enhancing the engagement with the given task. Whereas the focus in this work was on introducing a solution for exploiting available digital urban environments and not on offering a suitable user experience with the platform, the results of the study still show that interviewees found the presented technology *simple* and *generic*. These two characteristics had in fact relevance scores of (Rel.=9 & Rel.=8) and were respectively quite often mentioned (Freq.=6 & Freq.=9). Nevertheless, in order to improve the developer's experience with this technology, the implementation as well as the improvement of various features such as *design guidance* and providing ready-to-use customizable *gamification components* are essential and must-have features according to the experts. These factors were mentioned 4 and 5 times and had relevance scores of (Rel.=7 & Rel.=8) respectively.

6.6.2 Exergame environment

3D game environment present a stimuli for the players who can thus "experience a degree of presence" (Singhal and Zyda 1999). One of the important features that game environment should have is being immersive. This latter was mentioned quite many times in the interviews (Freq.=8) and has a relevance score of (Rel.=14). Besides providing a solution for deploying immersive game environments, the interviews outcomes show that the introduced technology also help using realistic worlds (Freq.=6 Rel.=11).

6.6.3 Progress feedback notification

According to (Nakamura and Csikszentmihalyi 2014; Schaffer and Fang 2015), "clear proximal goals, immediate progress feedback, and challenges that stretch skills" form three crucial conditions to reach a state of flow. We, in this work, have presented a gamification technology, which helps exergame designers integrate badges and game-related progress on top of an existing game.

Real-time progress feedback continuously informs the players about their evolvement in the certain activity, if any given adjustments are needed and how these latter could be carried out (Csikszentmihalyi, Abuhamdeh, and Nakamura 2005). With relevance scores of 15 and 11 based on statements found in 9 and 7 interviews respectively, it is reliable to state that real-time feedback and short-term goal tracking are fundamental as far as progress feedback is concerned.

In addition to these both important features, which are supported by the proposed gamification technology, the interviewed experts also mentioned that having a dashboard, in which long-term goals get tracked is also important for durable engagement. (relevance scores of 7 & 8)

6.7 Discussion & limitations

The analysis of the results show that the proposed technology proposes a solid solution for deploying existing game worlds in exergames. Despite its simplicity and support of real-time feedback, the technology however, lacks different crucial features such as designer guidance, long-term goal tracking and a set of predefined gamification components. Moreover, certain interviewees mentioned diverse issues that need to be further discussed and investigated regarding the intellectual property of the used worlds. Certain interviewees (P5, P6 & P8) suggested conducting further research on the design and the placement of graphics (e.g. badges) on top of the game screen. "This study should also focus on how and where the feedback should be placed on the screen" (P5). "The design of the badges should adapt the game content" (P6).

6.8 Conclusion

Serious game development in general, as well as exergame development in specific, steadily face major barriers. These include amongst others: 1) high development costs, which are in the case of serious games expanded due to the need of domain-experts (e.g. doctors, trainers, and psychologists), 2) the combination of both words "serious" and "games", which stimulates "the psychological barrier towards the use of entertainment technologies and methodologies for serious purposes" and finally 3) the fact that, nowadays, players have very high expectation with regards to the audio and visual quality of the game (Wortley 2014). To bypass this last challenge, we have, in this work, introduced a new technology for accessing and gamifying existing game environments. We, moreover, have validated our approach by presenting the results of a qualitative research that we have conducted with the help of gamification experts and exergame designers.

The relatively positive results of the study show that the presented technology, although lacking some important features, offers an adequate solution for deploying existing immersive game environments.

7 Model-Driven Implementation of Gamification

Title	Model-Driven Serious Game Development: Integration of the Gamification Modeling Language GaML with Unity
Authors	Amir, Matallaoui, Technical University of Berlin, Straße des 17. Juni 135, 10623 Berlin, Germany, amirqphj@mailbox.tu-berlin.de Philipp, Herzig, SAP SE, Konrad Zuse Ring 10, Potsdam, Germany philipp.herzig@sap.com Rüdiger, Zarnekow, Technical University of Berlin, Straße des 17. Juni 135, 10623 Berlin, Germany, ruediger.zarnekow@tu-berlin.de
Published in	Proceedings of the 48th Annual Hawaii International Conference on System Sciences - (Matallaoui, Herzig, and Zarnekow 2015)
Abstract	The development of gamification within non-game information systems as well as serious games has recently gained an important role in a variety of business fields due to promising behavioral or psychological improvements. However, industries still struggle with the high efforts of implementing gameful affordances in non-game systems. In order to decrease factors such as project costs, development cycles, and resource consumption as well as to improve the quality of products, the gamification modeling language has been proposed in prior research. However, the language is on a descriptive level only, i.e., cannot be used to automatically generate executable software artifacts. In this paper and based on this language, we introduce a model-driven architecture for designing as well as generating building blocks for serious games. Furthermore, we give a validation of our approach by going through the different steps of designing an achievement system in the context of an existing serious game.
Keywords	Gamification, Domain-specific languages, Model-driven implementation

7.1 Introduction

Gamification, defined as the use of game design elements in non-game context (Deterding et al. 2011), is an interdisciplinary approach, through which users are motivated to achieve certain behavioral or psychological outcomes (e.g., learn faster, complete profile, use specific platform daily). However, in industry, the majority of gamification concepts are never implemented after their conceptualization. One key issue is that the effort for the subsequent implementation of the concept requires high effort with regards to time and development resources on the one hand and to the fact that the desired outcomes of the gamification cannot be guaranteed on the other hand.

Therefore, it is necessary to simplify the overall implementation process of gamification. In order to improve the communication between domain and gamification experts as well as IT experts, the Gamification Modeling Language (GaML) has been proposed (Herzig et al. 2013). GaML defines a meta-model of game design elements based on the current consensus of game design elements in the gamification community. Besides its formal definition it has been shown that the language is highly understandable by both target groups (Herzig 2014). Therefore, domain experts are able to understand and modify existing formal gamification definitions.

So far the GaML is of descriptive nature only, i.e., it is possible to check whether a given specification is valid with regards to the meta-model and additional semantic properties. However, a valid specification cannot be used to automatically generate software artifacts that can be utilized to assemble a gamified system or parts thereof. Therefore, we aim at the generation of target code from the corresponding models by means of a given model-to-code transformation, i.e. models in GaML should be deployed to substitute code and to serve as input for code generators.

Through integrating GaML in the automated process of creating gamification and serious games, we argue that the efforts for implementing gamification artifacts can be significantly reduced. Furthermore, the language introduces a higher level of abstraction since the approach allows being independent from concrete technologies, platforms, or specific computational models. Furthermore, the approach helps to increase the overall quality of the gamified software since errors in the implementation can be already detected and fixed at design time which is not the case in current embodiments.

These facts, however, have not been proven and there is no published work showing a real case implementation of GaML. In this paper, we present our work, in which we have gone through the process of generating target code from the model and integrating it into a target application. We thereby argue that GaML can also be used in the implementation of serious games.

The paper is structured as follows. First, we present a model-driven approach for defining gamification and building blocks of serious games. We thereby also illustrate the importance of

adopting such an approach. Second, we present a model-driven architecture for developing achievement systems within serious games made in Unity. Third, we validate the given architecture by presenting a case study. The paper closes with a summary and an outlook to future work.

7.2 Model-driven serious game development

Model-driven software development (MDSD) is defined in (Stahl and Voelter 2006) as the deployment of domain-specific languages (DSLs) in order to create models that efficiently express the structure as well as the behavior of an application. These models are afterwards transformed into compilable code by means of predefined model-to-code transformations.

MDSD features various advantages if compared to conventional software development. On the one hand, it improves the integration of professional domain experts in the implementation of the application. This enhances the development process by increasing the communication between designers and developers. On the other hand, a better-quality control of the application's behaviors and rules is achieved by the designers themselves, since they are able to read and understand the language elements, as they were an active part during the development. Moreover, domain-experts are able to program in the DSL themselves, and may directly define the technical behavior of the application.

Being a special case of software, serious games development should also profit from the above stated advantages. It has already been mentioned that gamification concepts can be expressed using GaML (Herzig et al. 2013). Taking this in consideration, we next show that GaML can as well be used in developing special building blocks for serious games.

7.2.1 The gamification modeling language

The Gamification Modeling Language has been initially proposed as a formal language adhering to a context-free grammar (see 10.7.1 Grammar of the gamification modeling language GaML for the grammar in Backus-Naur form) and is based on the current consensus of game design elements that can be found in the gamification literature (e.g. (Hamari, Koivisto, and Sarsa 2014)) and is consistent with prior models and taxonomies (e.g. (Deterding et al. 2011)). Besides the formal definition of gamification concepts, it has been shown that the language's meta-model, i.e., the abstract syntax, is understandable and modifiable for domain experts, i.e., when they are confronted with a given instance (Herzig 2014). In addition, GaML has two concrete syntaxes, namely a textual and a graphical form-based one. It has been shown that understandability and modifiability is independent of the representation, however, the graphical is better suited when writing new instances (Schad 2014). For the remaining text we use the textual syntax for a compact visualization.

By using GaML we ensure one of the core features of MDA, which is portability. This means that models are designed platform-independently since they only describe abstract

concepts and are not related to any system's architecture. Further advantages of integrating GaML within serious games development include:

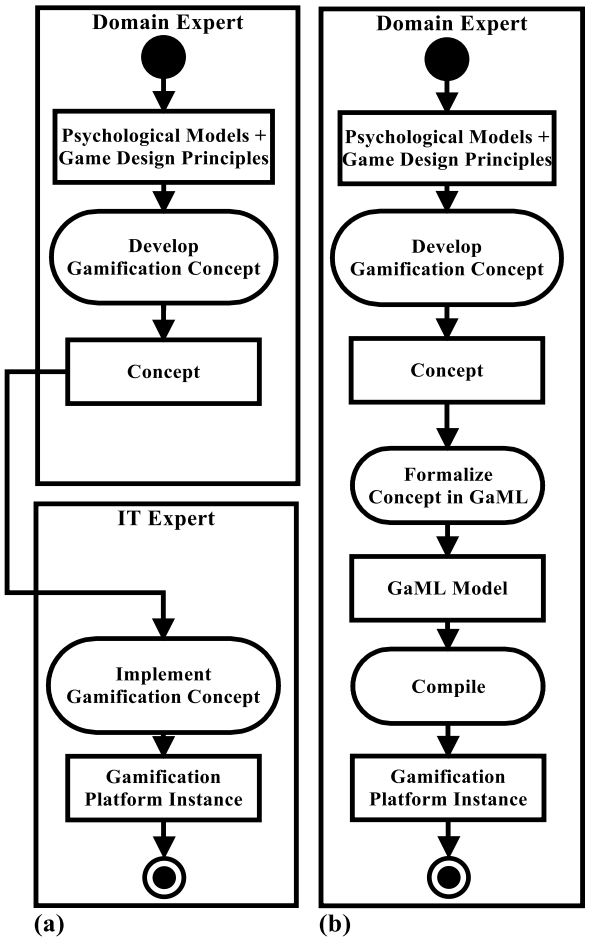

Figure 31. Current vs. model-driven gamification development approach (Herzig et al. 2013)

First, GaML models are expressed using textual input and this makes it easy to learn; by using text, we can describe any technical details of the developed application. Second, there exist diverse tools which support text input and textual artifacts. This can be very crucial, especially when considering the model's life cycle and its versioning. Third, gamification as well as serious game concepts could be defined by designers who do not need to know how application development is done using specific development environments (see Figure 31). This ensures a clear task separation. Furthermore, the consistency of the development is guaranteed, since designing tasks are done outside the used application development IDE.

GaML, the language used for the definition of achievements, ensures that all approved instances conform to the language's grammar and that these well-formed instances should compile to the target language (Herzig et al. 2013).

7.3 Model-driven achievement system design

7.3.1 Achievement system definition workflow

In this section, we show the model-driven process for creating an achievement system for serious games made in Unity (see Figure 32).

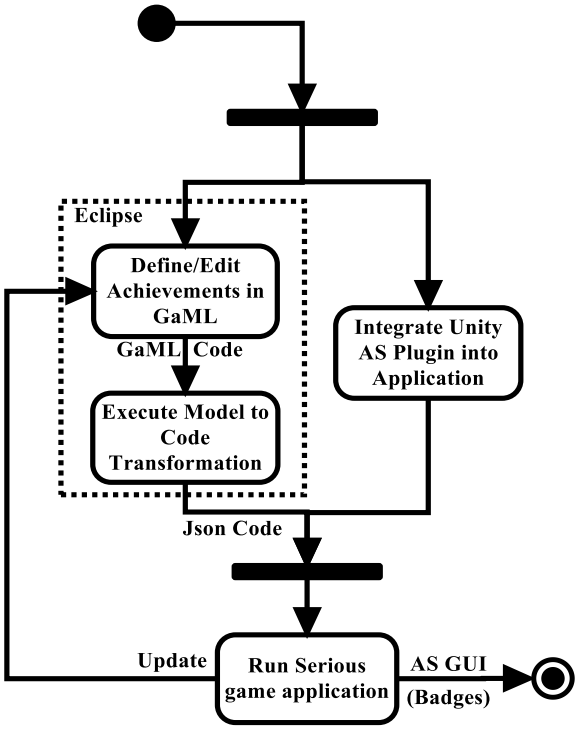

Figure 32. Achievement system model-driven implementation

Foremost and according to the GaML grammar, achievement designers write an instance of the GaML language, in which they define the desired achievements. Next, the achievements' definitions are checked for errors and a corresponding target code (in our case a JSON representation) is generated by means of the provided model to code transformation defined using Xtend. After building and running the game, the JSON file is parsed by the Unity achievement system plugin and achievements are then listed in the appropriate interface defined by the game designer.

The above-mentioned steps are described in more detail in the following text.

7.3.2 Achievement definition in GaML

At first place, a GaML instance is created, in which achievements are defined. As GaML was developed using Xtext, the definition of achievements is text based and is carried out within the Eclipse IDE.

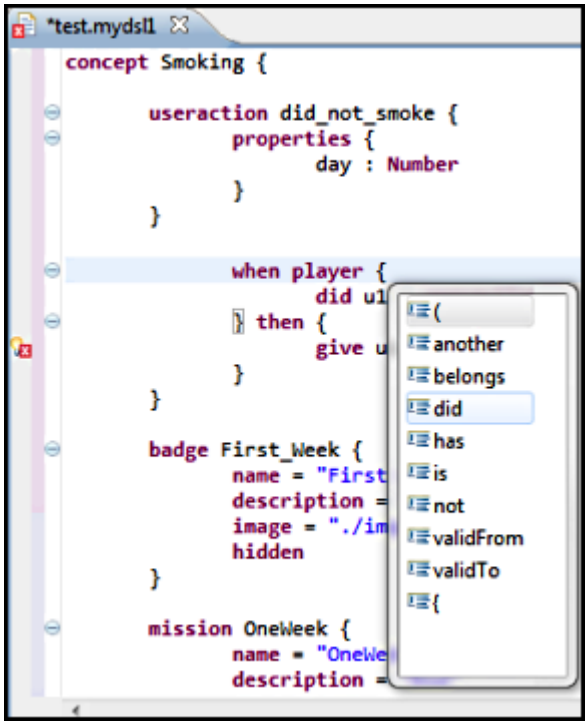

Figure 33. Xtext Framework (Eclipse-Foundation 2014b)

Xtext (Eclipse-Foundation 2014b) is an Eclipse plug-in that supports domain-specific language development. Due to this fact, many of Xtext functions are based on already established frameworks in Eclipse and on the features of Eclipse itself. The final outcome of a DSL development in Xtext is again available as an Eclipse plug-in. Hence, it does not only provide a compiler and a code generator but a complete development environment. Furthermore, this can be adjusted to any specific requirements of a particular DSL. The advantage here is that many developers are familiar with such a common environment like Eclipse. A possible disadvantage, however, could be that this tool is directed to a target group of programmers due to its considerable level of complexity. Another special feature of Xtext is the use of a text editor as an input medium. Hence, the DSL code (GaML code) is entered by the end-users as free text. They are thereby assisted by automatic code-completion of the inputs, syntax highlighting and other features (see Figure 33). A validation of their inputs is as well made using various criteria, which can be defined by the end-users themselves.

However, due to the entering of the GaML code in the form of a free text, Xtext should at first convert the user's input into a semantic model. Afterwards, validations and transformations (e.g., target code generation) are carried out based on the semantic model.

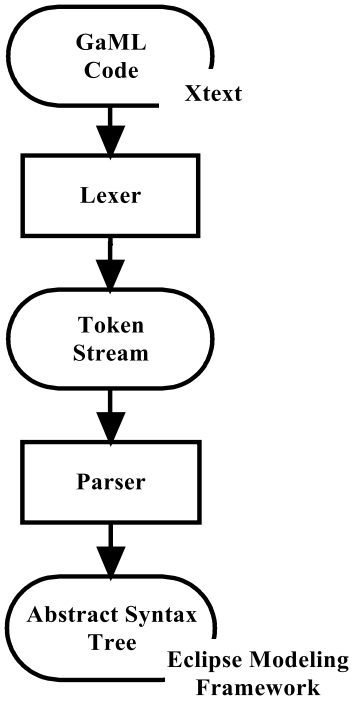

Figure 34. From code to semantic model

This conversion is performed with the help of a lexer (lexical analyzer) and a parser (see Figure 34). In the first instance and according to specific rules, the entered free text is decomposed by the lexer in individual related components; so-called tokens. Based on the lexer's outcome, the parser interprets the user's input and translates it into a semantic model (Abstract Syntax Tree) using the defined parser rules. For the projection of this model, the modeling constructs of the Eclipse Modeling Framework are used. Only when this transformation of the free text into a semantic model can be successfully finished, other transformations such as target code generation could be made.

7.3.3 Model to code transformation

The code generators were written using the Xtend language, which was specifically configured to enable programming based on text templates. The information provided by the semantic model is accessible within the Xtend program by using the Java classes, which represent the language's AST model. These classes are generated automatically via the Eclipse Modeling Framework.

Xtend (Eclipse-Foundation 2014a) is a statically typed programming language whose typing, however, is mostly done by type-inference (i.e., automatic deduction of the type of expressions). Therefore, types are rarely explicitly declared. The Xtend language was specifically designed to improve some of the existing Java concepts. Upon execution, Xtend is not directly translated into Byte-code but Java code. This makes Xtend programs deployable on arbitrary platforms. Moreover, this has the advantage that the programmer can trace the Java programming constructs, which result from his code. Within Xtext, Xtend is used as a code generator for the implemented DSLs.

The Xtend constructs that were especially intended to be used for code generation include *dispatch functions*, which are featured by Xtend, in addition to *normal* functions, whose use is done via a static binding through their parameter values. By using the keyword 'dispatch', various functions (having the same name) can be combined into a set of dispatch functions. Within these overloaded functions, it is decided through the type(s) of the input parameter(s), which function is called.

The code snippet below shows two dispatch functions having the same identifier "compile" but different input parameters (due to demonstration purposes, the snippet shows a possible way to generate Java code from the GaML model; though in this work JSON code is generated). The "compile" function instantiates an integer and sets its value to 0 if the construct is of type Point. If this latter is of type Badge then a string with the badge's name is created.

```
def dispatch compile (Point point) '''
public int «point.name» = 0 ;
'''
def dispatch compile (Badge badge) '''
public string «badge.name» = "";
'''
```

One of the main tasks of the code generation is to put together long strings. In order to make this task as simple as possible and obtain a readable code as well, Xtend offers 'rich strings'. To mark the use of such strings within the code, three single quotation marks are used at the opening and at the end (see code above). Within this template the objects' attributes can be accessed. It is also possible to call other (self-defined) functions and to use available features such as IF and FOR. To call such functions inside of the template, we need to put them between the signs '<<' and '>>'; everything within this signs is thus executed as code.

7.3.4 Code deployment

Depending on the target platform, the code that has been generated using the model to code transformation is then integrated in the application. This automatically generated code should not be modified. For instance, it would be inconvenient if after writing C and compiling it we needed to edit and revise the assembly language or machine code produced (Kelly and Tolvanen 2008). Similarly, the generated code form the GaML instance should not be modified or reworked.

7.4 Case study

In this section we present a real case study, in which we have defined achievements for an existing Unity application. For demonstration purposes, we use a "Stop Smoking" app. This latter is a Unity serious game that aims to help smokers quit smoking by offering simple and easy steps to follow. In order to enhance the motivation we have designed an achievement system, through which players are rewarded badges for accomplishing given tasks.

The described workflow of Figure 32 has been followed for defining the achievements.

7.4.1 Unity

Unity is a cross-platform game engine with a built-in IDE developed by Unity Technologies. It is used to develop video games for web plugins, desktop platforms, consoles and mobile devices (Unity 2017).

The Unity game engine is also often used for making serious games. These latter take advantage of Unity's core features such as physics, networking, cross-compiling and other quite important features. The categories, under which these serious games generally appear, include:

- Education and instruction (e.g., Micro Plant, Surgical Anatomy of the Liver)
- Product demonstration and configuration (e.g., Bike configurator, Gun Construction)
- Architectural visualization (e.g., Insight 3D, Aura Tower)
- Exercise simulations (e.g., US Navy Virtual Training, I.R.I.S.)

7.4.2 Achievement systems

Achievement systems can be seen as "meta-tasks" (tasks over key-task), which provide further goals to the system users and are independent of the actual main goals. Hamari and Eranti (2011) define achievements as follows: "Achievements are *goals* in an *achievement/reward system* (different system than the core game) whose fulfilment is defined through activities and events in other systems (commonly in the core game)" (Hamari and Eranti 2011).

The below class diagram (see Figure 35) shows an adapted interpretation of a possible achievement's structure presented in (Hamari and Eranti 2011). Based on this diagram we can see that achievements consist mainly of three important parts, namely:

- An identifier, which to its turn consists of a name, through which the achievement is made unique, a description (hint) of the logic behind it and a badge, which encompasses its visualization.

- An achievement unlocking-logic, which entails:
  - A trigger: Could be either an action done by the user (e.g., eat an apple) or an external event (e.g., temperature rises by x degrees).
  - Conditions: Arbitrary other conditions under which the trigger is valid (e.g., a user has already another badge assigned).
  - Count: The number how often the action or the event has to be triggered.
  - Pre-requirements: are global requirements, which have generally nothing to do with the conditions mentioned above (e.g., complexity mode should be set to hard in order to achieve this task).

- A Reward, by which users are compensated for unlocking the achievement. This reward can whether be game-related (e.g., points), system-related (e.g., by unlocking achievement X you fulfill on of the condition for unlocking achievement Y) or application-external (e.g., users are rewarded a shopping coupon).

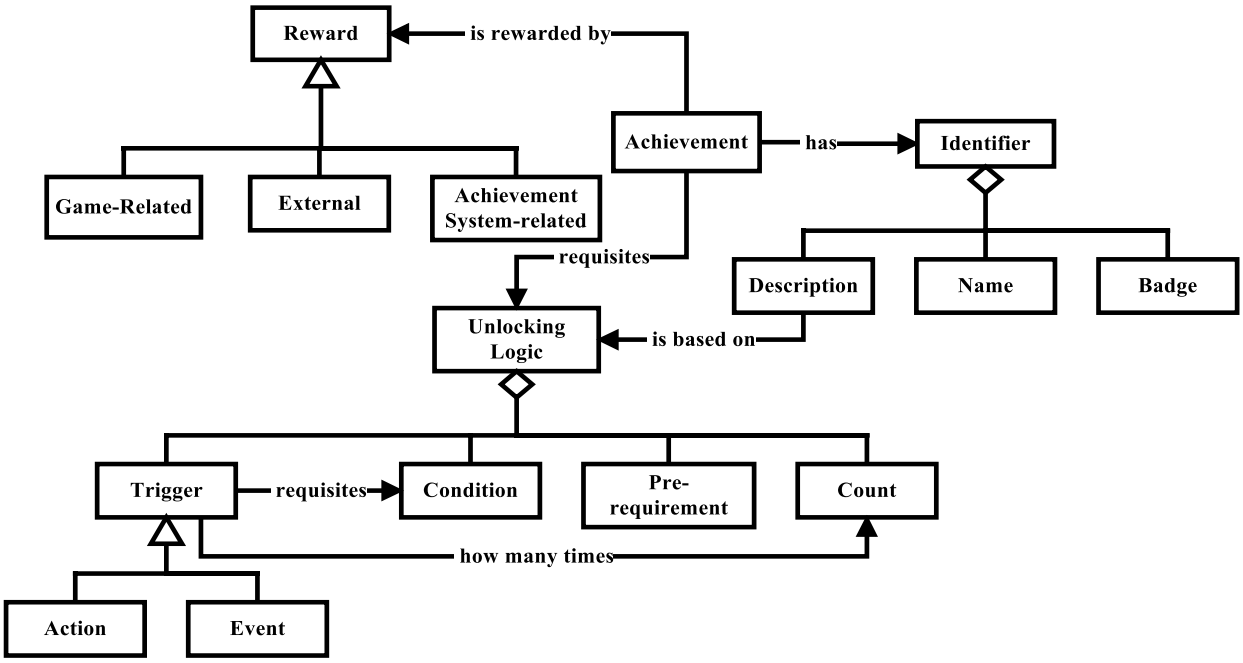

Figure 35. Achievement system class diagram

7.4.3 Unity achievement system plugin

The Unity plugin offers a generic achievement system that can simply be integrated in the application by importing it into the project folder. At this step, if we run the application just after integrating the plugin and without having defined achievements in GaML, the Unity inspector window shows an empty achievements list.

The screenshot in Figure 36 shows properties of such a list in a form-based way. This form is later filled in with properties that were parsed out the JSON file. These properties include the achievement's name, description, badge value, badge icon, target count, current count and if the achievement has already been earned or not.

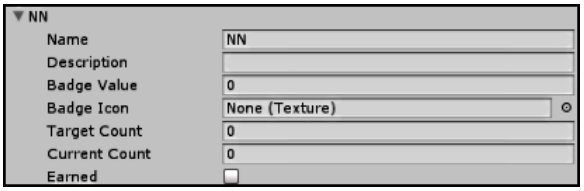

Figure 36. Unity inspector: achievement properties

7.4.4 Achievements definition in GaML

In the following text, an excerpt from the GaML specification of our use case is shown. The instance is introduced with the concept keyword followed by the concept's name, here *NonSmoking*. Furthermore, the concept defines one user action, namely the action that is triggered by the user if he or she hasn't smoked for a certain amount of days.

In addition, the concept defines two point metrics. First, *RewardPoints* that are assigned upon completion of specific missions and are visible to the user all the time. It is important to note that the point is declared of type *Advancing* which signified that these points cannot be lost. Second, *NonSmokingDaysPoints* which are used to track internally how many days the user has not smoked. Consequently, the point is of type *Auxiliary* which is used for the code generation at a later point in time. This point is not explicitly shown to the user but is used for tracking purposes only (e.g., to show them in a progress bar). This second point definition also covers a game rule that says every time users trigger the *did_not_smoke* event they get exactly the numbers of *NonSmokingDayPointsPoints* as specified in the *day* attribute of the user action.

Besides the point definitions, the specification also defines a badge concept as meta-data. In accordance with the achievement model provided before, the badge contains a name, description and a link to an icon as defining characteristics.

```
concept NonSmoking {

user action did_not_smoke {
   properties {
      day: Number
   }
}
point RewardPoints {
   name = "Reward Points",
   abbreviation = "RP",
   type = ADVANCING
}
point NonSmokingDayPoints {
   Name ="NonSmokeDay",
   abbreviation = "NSD",
   type = AUXILIARY

     when player {
         did u1: user action did_not_smoke
     } then {
         give u1.day NonSmokingDayPoints
     }
}
badge One_Week {
   name = "1st Week",
   description = "1 whole week without Smoking!",
   image = "./images/7free.png"
}
```

```
mission OneWeek {
   name = "One Week Smoking",
   description = "Mission is completed when player
   spends 7 days without smoking."

   when player {
      has point NonSmokingDayPoints, SUM=7
      } then {
       give badge First_Week,
       give 10 RewardPoints
      }
   }
}
```

Finally, the concept covers the notion of missions which represents explicit building blocks to define condition-action pairs based on the user interaction or state. In this simple example, the mission requires the user to have seven *NonSmokingDayPoint*. If collected, the mission assigns the previously defined badge as well as 10 additional *RewardPoints* to the user[3].

7.4.5 Model to code transformation

In order to generate code from our GaML model, we have defined a GaML to JSON transformation using the Xtend language. The Xtend code below shows the main part of the GaML-to-JSON transformation. Rich strings have been used to ensure the target format.

```
«FOR b:nonSmoking»
'''
{
    "Name": «b.getName»,
    "Description": «b.getDescription»,
    "Badge": {
        "Value": «b.getMission.getReward»,
        "Icon" :  «b.getIcon» ,
    },
    "Count": {
     "target": «b.getMission.when»,
     "current": 0,
    },
    "earned": false,
}
'''
«ENDFOR»
```

[3]Please note that this is an oversimplified example for demonstration purposes only. In order to correctly model temporal constraints such as one week, the definition has to be defined using time windows as explained in the official GaML documentation.

The code snippet below shows the corresponding fragment of the generated Json code.

```
{
    "Name": "1st week",
    "Description": "1 whole week without
            Smoking!",
    "Badge": {
        "Value": 10,
        "Icon": "./images/7free.png",
    },
    "Count": {
     "target": 7,
     "current": 0,
    },
    "earned": false,
}
```

7.4.6 Run application

Before running the application, we have to make sure that we have imported the Unity Achievement System plugin into our project. Then, when we run the application, the JSON code is parsed by the plugin and the inspector form is automatically filled in with the wished achievements as well as their corresponding properties.

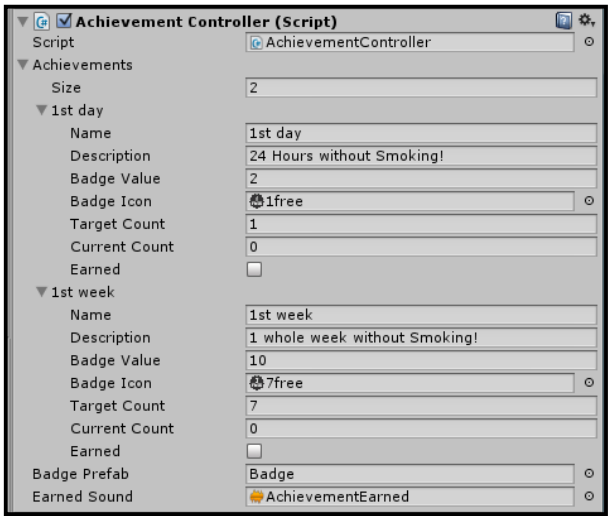

Figure 37. Automatically generated achievements

The screenshot in Figure 37 shows the application's achievement controller, which consists of an array of the defined achievements. The array contains two achievements (Size = 2). The first one has the identifier "1st day", is rewarded 2 points (badge value = 2) and is earned when the "player" stays one day (target count = 1) without smoking. The second one has the identifier "1st week", is rewarded 10 points (badge value = 10) and is earned when the "player" stays 7 days (target count = 7) without smoking. Both achievements are not earned yet.

Figure 38. Achievement graphical representation

Figure 38 shows the graphical representation of the achievement with the identifier "1st week". Most of the achievement properties can be seen except its icon. This latter is hidden by the description, which pops up on mouse hover.

The plugin offers also a locked version as well as an unlocked one for each badge (Figure 39).

Figure 39. Locked & unlocked Badges

7.5 Related works

The state of the art in the field of model-driven development of gamification as well as serious games lacks a concrete approach that shows a complete MDA going through the whole framework and taking advantage of domain-specific languages.

In (Thillainathan, Hoffmann, and Leimeister 2013), a Serious Game Structure and Logic Modeling Language (GLiSMo) is introduced. The authors state that different serious game components could be modeled using GLiSMo. These include amongst others acts and scenes, objects, characters and inventories, user feedback and rewards. To demonstrate the use of the language, Shack City was designed. It represents a story based serious game, which playfully help learn about sanitation, heating and cooling. However, the game has been developed and implemented in a first version as a web application using HTML5. Thus, GLiSMo was only used for the sake of description and no automatic code generation was targeted.

In (Love et al. 2006), the game description language GDL is introduced. This language, although very expressive, is only used to describe and reason about the rules of general games with no intention of serving the further implementation of these rules by offering a model-to-code transformation.

Furtado and Santos (2006) present a visual domain-specific language named SharpLudus (SLGML). Although encompassing semantic validators and code generators in addition to the language, the proposed approach can be seen more like a game engine than a model-driven way for game development. Authors state also that some classes (e.g., CustomTriggers and CustomReactions) are not re-generated and specific methods should be added by the developers. This violates one of the most MDSD rules, namely generated code should not be modified. Moreover, the presented language is not suited for the development of serious games since, for example, no achievements, rewards or ranking systems can be modeled using it.

Another domain-specific visual language is introduced in (Marchiori et al. 2011). The DSVL makes it possible for game designer to design and run their own games by offering automatically compilable graphical game elements. Although easy to understand and to use, the games created by arranging these graphical elements are restricted to narrative educational games, which deploy exclusively the point-&-click genre.

In (Ribeiro and Almeida 2012), the authors present a prototype of a serious game, whose goal is to instruct people about fire drills. A virtual fire evacuation coach was therefore developed. It was namely made in Unity but no model-driven approach was adopted and no automatic code generation was conducted.

In (Tang et al. 2008), the authors describe the process of creating a domain-specific modeling language for serious games. They, however, suggest a model-driven framework for designing such games based on UML, which is in fact a general-purpose modeling language. This presented approach loses out on the benefits of domain-specific languages, of which model-driven serious game development should make use as demonstrated in our work.

7.6 Summary & Outlook

In this paper we have introduced a model-driven approach for developing serious games. We have thereby taken advantage of the Gamification Modeling Language GaML and hence have presented a model-driven architecture for the development of achievement systems within serious games made in Unity. As a validation of the proposed architecture, a case study has been presented.

Next, we are planning to conduct a quantitative evaluation of the proposed approach in order to demonstrate the potential and effectiveness of adopting such an approach in comparison to the conventional development methods.

8 Conclusion

Gamification has emerged to become an important medium for increasing user motivation, flow, and engagement. Its development within non-game information systems as well as serious games has recently gained an important role in a variety of business fields due to promising behavioral and psychological improvements. However, being generally deployed on top of existing systems, gamification usually entails an additional complexity layer to the actual task. This usually induces a cognitive overload and hinders the implemented gamification to be perceived. It has been demonstrated in this thesis that besides coming up with sophisticated gamification mechanics, applying proven design theories and taking account of the gamification aesthetics is of utmost importance in easing the induced cognitive load.

Through a systematic literature review (Matallaoui, Koivisto, et al. 2017), this research reveals that more effort should be put into gamification design to achieve the pursued engagement and motivation goals. The objectives of this thesis were therefore based on the current challenges faced by different industries struggling with 1) the effectiveness of integrating gamification affordances alongside 2) the associated high efforts and costs of the implementation.

8.1 Theoretical contribution

Our systematic review (Matallaoui, Koivisto, et al. 2017) has concretely shown that only "few studies (Finkelstein et al. 2011; Nguyen et al. 2012) have considered designing a game experience following the Flow theory (Csikszentmihalyi 1975) and none of the studies had investigated the type of their participants (e.g. according to Bartle's (1996) classification)." Moreover, most of the studies "did not focus on the gamification design principles and guidelines".

It has been in this dissertation emphasized on how crucial it is to consider recognized design theories when implementing gamification. For instance, it has been demonstrated that taking account of the multimedia design principles would result in a better perception and understanding of the implemented gamification. To validate this thesis, a quantitative study was conducted. It deployed a serious game, on top of which two badge systems were implemented, respectively taking account of the multimedia principles in the first one and omitting them in the second one. The evaluation of the outcomes showed that "the badges, whose design has implemented the multimedia principles were notably better perceived and understood compared to the other badges."

Likewise, and taking advantage of the same serious game, a further quantitative study has been designed, to which different participants with different ages and backgrounds were invited. The objective of this study is to validate our thesis stating that "badges, whose icon design takes consideration of the signs theory (semiotics) are better perceived than badges, whose design deploys generic icons". (Matallaoui 2018)

8.2 Practical contribution

Gamification as well as serious game development is increasingly encountering major challenges. The findings of our systematic review showed that more than 84% (16 out of 19) of the reviewed works have exclusively developed custom-tailored systems for the studies' purposes (Matallaoui, Koivisto, et al. 2017). In addition to the high costs related to the involvement of domain-experts (e.g. doctors, trainers, and psychologists) in the development cycle, it takes a vast amount of knowledge, time and budget to create game environments and rather gameful experiences with a "tremendous appeal and a powerful attraction". Users nowadays have actually "very high expectation with regards to the audio and visual quality" (Wortley 2014).

For instance, achieving an immersive exergaming experience requires the disposition of attractively designed virtual worlds. Designing such worlds is however quite challenging, costly, and time-consuming. Since high-quality virtual worlds are commonly found in commercial games, different studies on exergaming were bound to the use of accessible open source worlds. These latter though, "were generally poorly designed and did not always satisfy the users' needs of enjoyment" (Matallaoui, Ben-Sassi, et al. 2017).

To bypass this last challenge, a new technology for accessing and gamifying existing game environments has been introduced. This technology helps gamification designers benefit from these worlds and deploy them in the intended serious contexts such as education and health promotion. To evaluate the introduced tool, a qualitative study was conducted, in which different gamification experts with different backgrounds have taken part. The outcomes of the study have shown a broad welcome. Despite some drawbacks, the introduced technology was labeled as "robust, simple and generic".

Further in this dissertation, a model-driven approach for developing gamification and serious games has been presented. Our objective thereby, was to demonstrate the potential and effectiveness of adopting a model-driven approach in comparison to conventional development methods. For that, a model-driven architecture for the development of achievement systems within serious games has been introduced. To validate the proposed architecture, a case study was presented, for which a plugin for the Unity game engine had been developed (Unity 2017). Therefore a model-to-code transformation for the Gamification Modeling Language GaML (Herzig et al. 2013) was implemented. This made it feasible for gamification designers with no programming skills to implement runnable code.

8.3 Limitations and further research

Although this dissertation delivers useful theoretical as well as functional contributions to research and practice, it also has several limitations like any other research.

Although presenting, to the authors' knowledge, the first systematic review of the deployment of game-related motivational affordances in gamified exercise systems, the work presented in

"Chapter 3: Implementing Gamification: State of the Art" has several limitations. For example, in this review, only works that included hits for the keywords "virtual reality*" and "gam*" in addition to exercise-related terms were considered. The spectrum of this research could have been broadened and altered results could have been acquired if the search had included other keywords such as "interactive play" or simply "video game". Furthermore, a language bias might have occurred since only works reported in English were considered for inspection. Likewise, the exclusive use of Scopus in the research might have instigated a publication bias. While it is estimated that most of the applicable gamification studies can be found in this database, other databases like PubMed and Web of Knowledge could have also been considered.

Whilst it validates the proposed hypothesis, the quantitative empirical study carried out in "Chapter 4: Multimedia Design Principles for More Effective Gamification" also shows various shortcomings. For instance, the total number of participants in the study is 241 whereas the absolute number of participants in each separate test barely varied between 8 and 24. Although the overall outcomes speak in favor of the assumption, the partial results may not be considered very representative, due to the relatively low number of participants. The results of the study could however still offer a solid starting point to deploy different principles as well as completely further theories. This would give a different perspective on the subject and strengthen the embraced thesis.

Moreover, the theory-based research articles, namely "Chapter 5: Designing Better Perceivable Badges by Deploying Semiotics" and "Chapter 7: Model Driven Implementation of Gamification", are both based on conceptual or argumentative deductive analyses, thus relying on theoretical concepts from literature while lacking empirical evidence.

As for the evaluation of the introduced technology in "Chapter 6: Improving the Task of Gamification", controlling for gamification expert quality represents a shortcoming. Identifying gamification experts and ensuring a 'respectable' interviewee quality thereby was mainly based on the public profiles as well as cold calling and mailing. The outcomes of the study also show that the introduced technology is lacking "different crucial features such as designer guidance, long-term goal tracking and a set of predefined gamification components".

In addition to the research opportunities that would arise when considering the above limitations, various promising fields for future research are identified. For instance, theory-based studies, granularly examining the effectiveness of different gamification elements and mechanics in exergames, are needed. In addition, it is believed that more focus should be put on the effectiveness and the performance when implementing gamification. Promising fields such as virtual and augmented reality should be considered by future works for enhanced user engagement and motivation.

9 References

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10 Appendix

10.1 Chapter 1

Table 33. Contribution to publications

Title	Authors	Published in	Contribution of Amir Matallaoui
Introduction to Gamification: Foundation and Underlying Theories.	Amir Matallaoui Nicolai Hanner Rüdiger Zarnekow	Gamification - Using Game Elements in Serious Contexts (Sammelband). Springer - (Matallaoui, Hanner, and Zarnekow 2017)	70 %
How Effective Is "Exergamification"? A Systematic Review on the Effectiveness of Gamification Features in Exergames.	Amir Matallaoui Jonna Koivisto Juho Hamari Rüdiger Zarnekow	Proceedings of the 50th Annual Hawaii International Conference on System Sciences - (Matallaoui, Koivisto, et al. 2017)	70 %
Cognitive Load Matters, in Gamification Even More. An empirical Study on the Importance of Incorporating the Multimedia Principles into Gamification Design.	Amir Matallaoui Class Gnerlich Rüdiger Zarnekow.	*International Journal of Serious Games IJSG2018 (under review)*	50 %
Towards More Effective Gamification: *Does Deploying Semiotics Help Design Better Perceivable Badges?*	Amir Matallaoui	Proceedings of the International Conference on Computer and Technology Applications - (Matallaoui 2018)	100 %
Augmenting the Task of Exercise Gamification: An Expert View on the Adoption of a New Technology for Deploying Existing Virtual Environments in Virtual Urban Exergames.	Amir Matallaoui Nizar Ben Sassi Fikret Sivrikaya Rüdiger Zarnekow	Proceedings of the 21st Pacific Asia Conference on Information Systems - (Matallaoui, Ben-Sassi, et al. 2017)	85 %

Model-Driven Serious Game Development: Integration of the Gamification Modeling Language GaML with Unity3D	Amir Matallaoui Philipp Herzig Rüdiger Zarnekow	Proceedings of the 48th Annual Hawaii International Conference on System Sciences - (Matallaoui, Herzig, and Zarnekow 2015)	75 %

10.3 Chapter 3

Table 34. Summary table of reviewed works

paper	Used system	Targeted activity	Motivational affordance	Psychological outcomes	Behavioral& quasi-medical outcomes	N	Type of study	Reported results
(S Berkovsky et al. 2010)	gamifying an existing system: adding physical activity to an existing game	fun sport active playing	Rewards time virtual goods	competition enjoyment	decreasing sedentary playing & increasing active playing	284	quant.	partially positive
(Chowdhury et al. 2014)	excl. dev. sys. 3 new games played using hand grippers	Endurance muscle conditioning	points	achievement competition	treating autism through playing video games	29	quant.	positive
(Cui et al. 2009)	excl. dev. sys. camera-based tracking (image processing)	aerobics balance	avatars social interaction	self-expression (avatars) status (female audience) altruism (exercise sharing)	enjoying exercising through avatar personalize-tion	30	quant.	Partially positive
(Finkelstein et al. 2011)	excl. dev. sys. motion capture system with VR projection	balance aerobics strategy speed	points score multiplier score freeze	self-expression competition enjoyment	full body exercising while playing	30	mixed	positive
(Guixeres et al. 2012)	1st: Wii Fit on pc 2nd: excl. dev. sys. VR system + motion capture via smart shirt	balance jogging fun sport	points levels	achievement status (fighting obesity)	combatting obesity & sedentariness by exergaming	1st: 87 2nd: 126	quant.	positive
(Guo and Quarles 2013)	gamifying an existing system: car racing and controlling using Kinect motion capture	fun sport endurance speed	levels time progress challenge	competition achievement	converting sedentary games to exergames	24	qual.	partially positive
(Hanneton and	existing system: Wii Fit	balance	levels progress	competition achievement	physical activity	4	qual.	partially positive

Varenne 2009)	Wii balance board			status (female audience)	assisted by video game			
(Higuchi, Ueno, and Rekimoto 2014)	excl. dev. sys. heart rate & temperature sensors + Kinect motion capture + screen	speed balance	avatars coins collecting	self-expression self-control	self-competition through avatar representation	6	mixed	positive
(Hossain, Hassan, and Alamri 2013)	excl .dev. sys. a new game developed for Wii and uses the Wii-mote	running speed	avatars levels story	status self-competition enjoyment	obesity monitoring through exergaming	12	mixed	positive
(Hsieh et al. 2014)	excl. dev. sys. Kinect based motion capture	balance	points	status (elderly)	monitoring balance for older adults using games	8	quant.	positive
(Landry and Pares 2014)	excl. dev. sys. playground slide (4x3m) + IR-based motion capture	fun sport precision strategy speed	virtual goods levels team work	competition achievement enjoyment	enhancing physical activity through tempo raising	1st: 248 2nd: 178	quant.	1.study positive 2.study partially positive
(Le et al. 2012)	excl. dev. sys. camera-based motion capture + screen	jogging walking	avatar	enjoyment	enjoying indoor jogging	20	quant.	n/a
(C.-Y. Lin and Chang 2015)	excl. dev. sys. PC-webcam-based VR game	fun sport	n/a	self-competition	enhancing physical activity for children with disabilities	3	qual.	positive
(J. J. Lin et al. 2006)	excl. dev. sys. PC-based game + pedometer (step counter)	walking running	avatar progress levels social interaction ranking	self-competition achievement enjoyment	encouraging physical and social activity through exergaming	19	mixed	partially positive
(Mazzone et al. 2013)	excl. dev. sys. Kinect-based game	water sport muscle conditioning Rehabilitation	avatar	status self-competition	shoulder muscle activation through exergaming	5	quant.	partially positive
(Monteiro et al. 2014)	existing system: Wii Free Run game	jogging	avatar progress social interaction	status (female audience) achievement enjoyment	controlling body weight by exergaming for women	25	quant.	positive
(Nguyen et al. 2012)	excl. dev. sys. DDR-(dancing pad) based game	aerobics coordination	avatar virtual goods	competition enjoyment	enhancing physical activity through active virtual world exploration	17	quant.	positive
(Pasch et al. 2009)	existing system: Wii Sports	fun sport	avatar points progress	competition enjoyment	enhancing physical activity through immersive experience	4	qual.	partially positive
(Plante et al. 2003)	existing system:	cycling endurance	avatar time points	social interaction enjoyment	promoting psychological benefits of	88	quant.	partially positive

	PC-based biking game + ergometer				aerobic exercise			
(Singh et al. 2011)	existing system: Wii Fit Wii Balance	balance fun sport	avatar points progress rewards	status (old female audience) self-competition	reducing risk and fear of falls among older women through VR playing	38	quant.	partially positive
(Snyder, Anderson-Hanley, and Arciero 2012)	excl. dev. sys. stationary bike + cybercycle sensors + cycling game	cycling endurance	avatar progress social interaction	status competition	moderating exercise intensity through VR-based competitive-ness	23	quant.	positive
(Van Schaik et al. 2008)	excl. dev. sys. exercise bicycle + sensors + three different video games	precision balance cycling	n/a	achievement self-competition	encouraging physical activity for older adults through virtual augmented exercise	22	quant.	partially positive
(Warburton et al. 2007)	Gamifying an existing system: PlayStation 2 games (not exergames) + Biking Game	cycling	n/a	immersion	attendance in training; physical fitness outcomes	14	quant.	partially positive
(Wi, Kang, and Jang 2013)	existing system: exergames using Xbox 360 Kinect sensors	fun sport	n/a	status	relieving depression in older women with osteoarthritis	40	quant.	positive
(Zhang et al. 2012)	excl. dev. sys.: exergame (Virtual Network Marathon) developed by the authors	cycling	Virtual world avatar feedback social interaction levels ranking	immersion perceived effectiveness perceived competitiveness	learning about Chinese culture	20	quant.	positive

10.4 Chapter 4

Table 35. General questions

	#	Question	Answer choices
Particulars	P1	Sex?	Male / female
	P2	Year of birth?	Number
Knowledge about badge systems	P3	Do you know the concept of badge / achievement systems?	Yes / no
	P4	Which of these terms are you more familiar with?	Badge, achievement, trophy, none of the above

	P5	In your opinion, where are badges commonly displayed?	Top-left, top-right, bottom-left, bottom-right, center
Player type	P6	I would rather play games, in which I can outplay other players, dominate them and be on top of the ranking.	0 to 10 scale
	P7	My main goal when playing games is winning all trophies and unlocking all badges.	0 to 10 scale
	P8	When playing, I always try to explore every corner in the game and investigate all its elements.	0 to 10 scale
	P9	I like to collaborate with other players and share my achievements with them as well as with my friends.	0 to 10 scale
Control questions on badge understanding	P10	I regularly play computer games (incl. console)	Not at all – very little – somewhat – to a great extent
	P11	I am familiar with badges and know how they work.	Definitely not – probably not – possibly – probably – very probably – definitely

Table 36. First test's Questionnaire

	#	Question	Answer choices
Cognitive load	Q1	How was your mental effort when solving the problems?	Very low – low – moderate – high – very high
	Q2	How did you find the given tasks?	Very easy – easy – average – difficult – very difficult
	Q3	Did you have fun solving the problems?	Not at all – very little – somewhat – much – to a great extent
	Q4	When solving the tasks I had to process many information simultaneously.	Strongly disagree – disagree – undecided – agree- strongly agree
	Q5	I was highly pressed for time.	Strongly disagree – disagree – undecided – agree- strongly agree
Badges system design	Q6	I have well noticed the unlocked badges.	Not at all – very little – somewhat – much – to a great extent

	Q7	I understood why I had received the badges.	Strongly disagree – disagree – undecided – agree- strongly agree
	Q8	The presentation of the badges was inappropriate.	Strongly disagree – disagree – undecided – agree- strongly agree
	Q9	Describe shortly what you have understood or did not understood about the badges system. Did anything irritate you?	Free text
	Q10	How do you think the badge presentation could be optimized?	Free text

Table 37. Second test's questionnaire

	#	**Question**	**Answer choices**
Cognitive load	Q11	Was your mental effort in the 2nd test higher or lower than in the 1st one?	much lower – lower – comparable– higher – much higher
	Q12	Was the 2nd test easier or harder than the 1st one?	much easier – easier – comparable – more difficult – much more difficult
	Q13	Did you have more fun solving the problems in the 2nd test than in the 1st one?	Not at all – very little – somewhat – much – to a great extent
	Q14	When solving the tasks I had to process more information simultaneously in the 2nd test than in the 1st one.	Strongly disagree – disagree – undecided – agree- strongly agree
	Q15	I was more pressed for time in the 2nd test than in the 1st one.	Strongly disagree – disagree – undecided – agree- strongly agree
Badges system design	Q16	I have better noticed the unlocked badges in the 2nd test than in the 1st one.	Not at all – very little – somewhat – much – to a great extent
	Q17	I understood better why I had received the badges in the 2nd test than in the 1st one.	Strongly disagree – disagree – undecided – agree- strongly agree
	Q18	The presentation of the badges in the 2nd was better and more appropriate than in the 1st test.	Strongly disagree – disagree – undecided – agree- strongly agree
	Q19	Describe shortly what you have better (or worse) understood in the 2nd test.	Free text
	Q20	How do you think the badge presentation in the 2nd test could be optimized?	Free text

10.7 Chapter 7

10.7.1 Grammar of the gamification modeling language GaML

```
grammar org.xtext.example.mydsl.MyDsl with
org.eclipse.xtext.common.Terminals
generate mydsl "http://www.sap.com/gamification/GamL"
import "http://www.eclipse.org/emf/2002/Ecore" as ecore

Model: 'concept' name=ID '{' (type+=Element)* '}';
Element: GameLevel | Point | Skill | Mission | Role | Leaderboard | Level |
Good | Badge | Event;

GameLevel: 'gameLevel' name = ID '{'
              'name' '=' dName = STRING ',' 'completed' condition=When
              (',' clearOpenMissions ?= 'completeOpenMissions')?
              (',' 'followUpGameLevel' '=' followUpGameLevel =
[GameLevel])?
              (',' 'description' '=' description = STRING)?
(type+=Element)* '}';

Event: class=EventClass name=ID (body=EventBody)?;
EventClass: 'useraction' | 'internalevent' | 'externalevent';
EventBody: '{' data=EventData (inverseEvent = InverseEvent)? '}';
EventData: 'properties' '{' name += Field (',' name+=Field)* '}';
InverseEvent: 'inverseEvent' '{' 'name' '=' name = ID ',' 'joins on' '='
field=[Field] '}';

Field: name = ID ':' dType=DATATYPE;
Badge: 'badge' name = ID '{' ('name' '=' dName = STRING)
            (',' 'description' '=' description = STRING)? (',' 'image' '='
image = STRING)
            (',' ^hidden ?= 'hidden')? rules+=When? '}';
Point: 'point' name = ID '{'
            default ?= 'default'? ('name' '=' dName = STRING)
            (',' 'description' '=' description = STRING)?
            (',' 'abbreviation' '=' abbreviation = STRING)?
            (',' internal ?= 'internal')? (',' 'type' '=' type=POINTTYPE)?
            (rules+=Rule)* '}';
POINTTYPE: name = ('ADVANCING' | 'REDEEMABLE' | 'KARMA' | 'SKILLPOINT' |
'AUXILIARY') | (name = 'REPUTATION' '[' repFrom=INT ',' repTo=INT ']');
Mission: 'mission' name = ID '{'
            ('name' '=' dName = STRING) (',' 'description' '=' description
= STRING)
            (',' 'available' condition=When)?
            ((',' 'initiatedBy' '=' ('rule' | 'user')))?
            (('not')? rules+=Rule (('or' | 'not')? rules+=Rule)*) '}';
//MissionExpression:  'not'? parentMission+=[Mission] ('strong' | 'weak')?
((('and' | 'or') parentMission+=[Mission] ('strong' | 'weak')?) | (('and' |
'or')  'not' parentMission+=[Mission]))*;
Skill: 'skill' name = ID '{'
            ('name' '=' dName = STRING)
            (',' 'description' '=' description = STRING)
```

```
            (',' 'image' '=' image = STRING)
            (',' 'benefit' '=' benefit = STRING)
            (',' 'point' '=' point=[Point])
            ((',' 'available' 'for' time=TIME)?) '}';
            //(',' conditions+=When)* '}';
Level: 'level' name = ID '{' 'name' '=' dName = STRING ','
            'threshold' '=' threshold=(NUMERICOPERAND) point=[Point]
            (',' 'image' '=' imagePath = STRING)? '}';
Good: 'good' name = ID '{'
          'name' '=' dName = STRING (',' 'description' '=' description =
STRING)
          (',' 'image' '=' image = STRING) (',' goodType=GoodType)?
          (',' 'price' '=' price=NUMERICOPERAND point = [Point])? '}';
GoodType: 'type' '=' name = ('REAL' | 'VIRTUAL');
Role: 'role' name = ID '{''name' '=' dName = STRING ','
          (('skills' '{' skills += [Skill] ((',' skills+=[Skill])*) '}')?)
          ('description' '=' description = STRING)?
          ('image' '=' image = STRING)? '}';
Leaderboard: 'leaderboard' name = ID '{'
            'name' '=' dName = STRING ',' 'point' '=' point=[Point]
            ',' 'aggregation' '=' aggregation=AGGREGATION
            ',' 'order' '=' order=('ascending' | 'descending')
            (',' 'assembles' '=' ('player' | 'team'))? '}';
Rule: when=When then=Then;
When: 'when' ((entity=PlayerEntity '{' ('validFrom' '=' date+=DATE)?
                        ('validTo' '=' date+=DATE)?   boolExp=PlayerOr
                  '}') | (TeamEntity '{' ('validFrom' '=' date+=DATE)?
                  ('validTo' '=' date+=DATE)?   boolExp=TeamOr '}'));
PlayerEntity: name='player' var=EntityVariable?;
TeamEntity: name='team' var=EntityVariable?;
EntityVariable: name=ID;
Then: 'then' '{' (consequences+=Consequence) ((','
consequences+=Consequence)*) '}';
Consequence: consequences+=EventRefCons | consequences+=GeneralRefCons |
consequences+=PointRefCons | consequences+=Notification |
consequences+=Narration;
PlayerOr returns Expression: PlayerAnd ({PlayerOr.left = current} op='or'
right=PlayerAnd)*;
PlayerAnd returns Expression: PlayerTopElem ({PlayerAnd.left = current}
op='and' right=PlayerTopElem)*;
PlayerTopElem returns Expression: PlayerAtom | '(' PlayerOr ')' |
PlayerNegation;
PlayerNegation returns Expression: 'not' not=PlayerTopElem;
PlayerAtom returns Expression: atom=PlayerCondition;
TeamOr returns Expression: TeamAnd ({TeamOr.left = current} op='or'
right=TeamAnd)*;
TeamAnd returns Expression:   TeamTopElem ({TeamAnd.left = current}
op='and' right=TeamTopElem)*;
TeamTopElem returns Expression: TeamAtom | '(' TeamOr ')' | TeamNegation;
TeamNegation returns Expression:    'not' not=TeamTopElem ;
TeamAtom returns Expression: atom=TeamCondition ;
TeamCondition returns Condition: condition = Condition | ('has' entity =
PlayerEntity 'who' '{' condition = PlayerOr '}');
PlayerCondition returns Condition: condition = Condition | ('has'
condition=RoleRefs) | ('did' condition=EventDef) | ('belongs' 'to' entity =
```

```
TeamEntity 'which' '{' condition = TeamOr '}') | ('another' 'player' 'did'
condition=EventDef);
Condition: ('has' (BadgeRefs | PointRefs | LevelRefs | ItemRefs | SkillRefs
| MissionRefs)) | ('has' (BadgeRef | PointRef | LevelRef | ItemRef |
SkillRef | MissionRef)) | ('has' Luck) | ('is' Leader) | ('is' 'at'
LocationDef);
EventDef: (name = ID ':')? eventCond=EventCondition;
EventCondition:   ec=EventClass (type=[Event]) (',' 'lastsFor'
lastsFor=TIME)?
      (',' (field+=[Field] | 'player') rightTerm+=RIGHTTERM )*
      (',' 'this' temp+=TEMPORAL (var+=[EventDef] | date+=DATE))*
      ((',' ((agg=AGGREGATION '(' field+=[Field] ')' | aggr='COUNT' '('
event=[EventDef] ')')
      comp+=COMPARATOR numExpr=NUMEXPR)?
      ('within' within=TIME)?)?);
//(',' 'occurs' comp+=COMPARATOR occurs=INT)?
Luck: 'luck' 'P(' prob = NUMEXPR ')';
MissionRefs: 'missions' '{'   missions += MissionItem (','
missions+=MissionItem)* '}';
MissionRef: 'mission' MissionItem;
MissionItem: mission = [Mission] ('available' | 'completed')?;
LevelRefs: 'levels' '{' levels += [Level] (',' levels+=[Level])* '}';
LevelRef: 'level' level = [Level];
SkillRefs: 'skills' '{' skills += SkillItem (',' skills+=SkillItem)* '}';
SkillRef: 'skill' SkillItem;
SkillItem: skill=[Skill] ('level' '=' level=INT)? ('active')?;
ItemRefs: 'goods' '{' items += [Good] (',' items+=[Good])* '}';
ItemRef: 'good' item = [Good];
RoleRefs: 'roles' '{' roles += [Role] (',' roles+=[Role])* '}';
RoleRef: 'role' role = [Role];
BadgeRefs: 'badges' '{' badges += [Badge] (',' badges+=[Badge])* '}';
BadgeRef: 'badge' badge = [Badge];
PointRefs: 'points' '{'       points += [PointRefsElem] (',' points +=
[PointRefsElem] )*      '}';
PointRefsElem: point = [Point] ',' agg = AGGREGATION comp = COMPARATOR exp
= NUMEXPR;
PointRef: 'point' point = [Point] ',' agg = AGGREGATION comp = COMPARATOR
exp = NUMEXPR;
LocationDef: 'location' '(' 'lat' latComp=COMPARATOR lat=NUMEXPR ','
                                        'long' longComp=COMPARATOR
long=NUMEXPR ')';
Leader: 'top' '(' 'to' '=' to=NUMEXPR (',' 'from' '=' from=NUMEXPR)?
                    (',' 'leaderboard' '=' leaderboard=[Leaderboard]) ')';
/*
 * CONSEQUENCES
 */
EventRefCons: ('create' | 'delete') 'event' type=[Event]
                  ('('  fields+=[Field] '=' refs+=(NUMEXPR |
EQUALITYTYPES)
                              ((',' fields+=[Field] '=' refs+=(NUMEXPR |
EQUALITYTYPES))*) ')')?
                  ('for' who=EntityCond)?;
GeneralRefCons:   (action='give'
ref=(BadgeRefCons|MissionRefCons|GoodRefCons|SkillRefCons) ('to'
who=EntityCond)?) | (action='delete'
```

```
ref=(BadgeRefCons|MissionRefCons|GoodRefCons|SkillRefCons) ('from'
who=EntityCond)?);
BadgeRefCons: 'badge' badge=[Badge];
MissionRefCons: 'mission' mission=[Mission];
GoodRefCons: 'good' good=[Good];
SkillRefCons: 'skill' skill=[Skill];
PointRefCons: (action='give' points=NUMEXPR point=[Point]? ('to'
who=EntityCond)?) | (action='remove' points=NUMEXPR point=[Point]? ('from'
who=EntityCond)?) | (action='set' points=NUMEXPR  point=[Point]? ('for'
who=EntityCond)?);
Notification: ('notify' msg=STRING) ('to' who=EntityCond)? | ('notify' '('
      ('message' '=' msg=STRING) (',' 'title' '=' title=STRING)
                    (',' 'image' '=' STRING )?
                    (',' 'type' '=' ( 'information' | 'corrective'))?
                    ('to' who=EntityCond)? ')');
EntityCond: entityID = [EntityVariable];
Narration: ('narration' '(' ('name' '=' dName=STRING ',' 'description' '='
description=STRING)
                        (',' 'recipient' '=' who=EntityCond)? (',' 'image'
'=' icon=STRING )?
                        (',' 'video' '=' video=STRING )? (',' 'audio' '='
audio=STRING )? ')');
RefOp: eventRef= [EventDef] '.' (var=[Field] | 'player');
RIGHTTERM: ((comp=COMPARATOR (numop=NUMERICOPERAND | timeop=TIMEOPERAND)) |
      ('=' value=EQUALITYTYPES));
EQUALITYTYPES:    string=STRING | bool = ('true' | 'false' );
NUMERICOPERAND:  int=INT | d=DOUBLE | refOp=RefOp;
TIMEOPERAND: now='NOW' | t=TIME;
OPERATOR: '+' | '-' | '/' | '*' | '^' | '%';
NUMEXPR: (operand1=NUMERICOPERAND (operator=OPERATOR operand2=NUMEXPR)?) |
( '(' innerOperand1=NUMERICOPERAND (innerOperator=OPERATOR
innerOperand2=NUMEXPR)? ')'
             (operator=OPERATOR operand2=NUMEXPR)?);
TEMPORAL: name = ('before' | 'after' | 'coincidences' | 'during' |
'finishes' | 'finished by' | 'includes' | 'meets' | 'met by' | 'overlaps' |
'overlapped by' | 'starts' | 'started by');
TIME: value=INT name = ('h' | 'min' | 's');
COMPARATOR: name = ('>' | '<' | '<=' | '=' | '>=' | '<>');
AGGREGATION: name = ('SUM' | 'MAX' | 'MIN');
terminal DATE: '"' ('0'..'9') ('0'..'9') ('0'..'9') ('0'..'9') '-'
('0'|'1') ('0'..'9') '-' ('0'..'3') ('0'..'9') ('T' ('0'..'2') ('0'..'9')
':' ('0'..'5') ('0'..'9') (':'('0'..'5') ('0'..'9'))? ('.'('0'..'9')+)?
('Z'|(('+'|'-')('0'..'2') ('0'..'9') ':' ('0'..'5') ('0'..'9')?)))? '"';
DATETYPE: ('Date' | 'Time');
NUMTYPE: ('Number' | 'Decimal');
DATATYPE: ('Boolean' | 'Text') | DATETYPE | NUMTYPE;
terminal DOUBLE returns ecore::EDouble: ('0'..'9')+ '.' ('0'..'9')
```