Classifying Pervasive Games: On Pervasive Computing and Mixed Reality

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Abstract. Pervasive Games have become popular in recent years. Their ambitious goal is to bring the computer into the world in order to augment existing games or to even come up with hitherto impossible or unthought-of forms of entertainment. This paper reflects on the various approaches to define what Pervasive Games consist of, how they relate to playing and games, and how different terms and views can be integrated. The paper contributes a unifying and integrating classification of the respective terms that relates different states of reality to the relevant dimensions and game elements.

Keywords: Pervasive Games, Mixed Reality Games, Play, Game, Entertainment, Classification, Augmented Reality.

1 Introduction

Playing games has been an essential part of mankind ever since. In contrast to most tasks that are performed for purposes such as surviving, earning money, etc., playing games is usually done voluntarily. Seeing games as a form of entertainment, the general purpose is simply to have fun. But playing does not only serve the purposes of recreation and amusement, it furthermore has a high social value: Quite often playing (a game) is the common ground for the participants to come together in the real world and converse, at least as far as sports and traditional games are concerned.

The beginning of the computer era introduced a new, hitherto unknown layer of existence: The virtual layer. Especially boosted by an enormously fast increase of computational power, it was soon possible to create virtual worlds. Computer or video games, however, by rather focusing on enhancing the players' experiences, abduct the players into a virtual world and let them explore worlds that are only limited by the players' and the creators' fantasy, while the social and the physical components are often neglected.

Pervasive Games or *Mixed Reality Games* offer a new concept that aims at combining the properties and advantages of these three worlds, the physical and the social on the one hand, as well as the virtual on the other hand. The term “Pervasive Games” has become very common and embraces the employment or application of Pervasive and Mobile Computing technologies either to augment traditional games or

to create new games that are impossible to realize with traditional media. Although being a rather new research area, Pervasive Games have received continuously increasing attention and have become a popular field of investigation.

This paper looks into the recent research on Pervasive Games and thoroughly investigates the terms, concepts, and definitions that have emerged within the last couple of years. We have three main goals or contributions: Firstly, we sort the "jungle of terms" that has grown in the wake of this research. Secondly, we come up with a classification of Pervasive Games that aims at providing researchers with feasible and lucid means to classify their projects. Thirdly, we explore the essential components and characteristics of Pervasive Games and discuss their practical realization and importance with regard to a thrilling mixed reality experience for the players.

This paper is structured as follows: Chapter 2 looks closer into the terms *play* and *game* and elaborates the difference between them. Afterwards, the terms *Pervasive Computing*, *Mixed Reality* and finally *Pervasive Games* are introduced and discussed, as we define them in the context of this paper. Chapter 3 deals with several classifications of the area of "interactive mixed reality entertainment"[1], which consequently are the basis for discussing how pervasive computing technology can and should be used for augmenting games. Finally, chapter 4 sums up our findings and contribution.

2 On Playing and Games

Truly defining or explaining the term *Pervasive Games* requires the separate and thorough analysis of both words. Contradictory to the order of the term, we first focus on *games*, and, in addition to that, on *play(ing)*, both of which are forms of entertainment. After that, we will investigate the "pervasive" part of *Pervasive Games*. In this context we will also discuss the terms *Pervasive Computing* and *Mobile Computing*, which are the very technological basis for Pervasive Games.

The terms *game* and *play* are not unambiguously defined and it might even be impossible to do so: Entertainment in general, and playing (games) in particular, are understood very differently throughout different cultures. Recreational activities in one country might not be considered recreational or even appropriate in another country and vice-versa.

Furthermore, *game* and *play(ing)* are very closely related, even so close that sometimes it is not possible to distinguish them. In fact, other languages, like German for example, do not even really differentiate between these terms: "To play" would be translated with "spielen" (verb) while "a game" would be translated with "ein Spiel" (substantive); so the expression "to play a game" would be translated with "ein spiel spielen", clearly indicating the close linguistic relation between the two words. Salen and Zimmermann even point out that *play* includes *game* and vice-versa [1]. There are, however, several differences that will be elaborated now.

[1] We apologize for this rather "buzz word"-like expression, but it will turn out to be the most accurate description in this case.

Playing. Playing is most inherent in human beings. Not only can playing be seen as an expression of joy and recreation, but it also plays an important role in building up and improving important psychomotoric skills and functions. Shwe lists eight different types (or rather, purposes) of play [2]:

- Discovering and exploring play,
- Hands-on active play,
- Problem-solving play,
- Fantasy play,
- Cooperative vs. competitive play,
- Child-directed play,
- Symbolic-representational skills (one thing can represent another thing), and
- Social play.

But what exactly is *playing*? Looking up the word "play" in the dictionary reveals the following definitions [3]:

- **noun 1** games and other activities engaged in for enjoyment. **2** the progress of a sporting match. **3** a move or manoeuvre in a sport or game. **4** the state of being active, operative, or effective: *luck came into play*. **5** a dramatic work for the stage or to be broadcast. [...]
- **verb 1** engage in games or other activities for enjoyment rather than for a serious or practical purpose. **2** take part in (a sport or contest). **3** compete against. **4** take a specified position in a sports team. **5** represent (a character) in a play or film. **6** perform on or have the skill to perform on (a musical instrument). **7** produce (notes) from a musical instrument; perform (a piece of music). **8** move (a piece) or display (a playing card) in one's turn in a game. [...]

According to the definition given above[2], *activity* and *doing this activity for enjoyment* are the two essential ingredients of playing: In contrast to work, *play* is primarily seen as an activity without explicit concepts or rules that is done for amusement and entertainment. The involved participants are usually called *players* or *actors*.

The verb "to play" is furthermore used to describe a player's active participation in a game (i.e., to play a game), which once more displays the close relation between *game* and *play*. We will now, however, focus on the distinctive characteristics between game and play, which brings us to the definition of "games". In contrast to *play*, there are considerably more definitions of games.

Games. Games can be designed and played for different purposes, including, for example, entertainment, learning, or training. In this paper we focus on games designed for entertainment. Analogous to "play", we will try to adumbrate the term "game": We will discuss several definitions and summarize the important aspects (cf. Table 1) that will be picked up again when we come to applying pervasive computing

[2] We will disregard using playing in the sense of acting, producing music or sports, though it could be interesting to investigate these issues with regard to Pervasive Computing.

technology (cf. Chapter 4). Again, we start with the definition given in the Oxford Dictionary [3]:

- **noun 1** an activity engaged in for amusement. **2** a form of competitive activity or sport played according to rules. **3** a complete episode or period of play, ending in a final result. **4** a single portion of play, forming a scoring unit within a game. **5** (games) a meeting for sporting contests. **6** the equipment used in playing a board game, computer game, etc. [...]
- **verb** play at games of chance for money.

We see that a game is "a form of competitive activity or sport played according to rules". In contrast to *play*, *game* is thus defined as being competitive (which *can* also be part of playing, cf. [4]) and applying certain rules. A game, moreover, is a "complete episode" while play usually rather refers to a single "move or manoeuvre" in a game. Finally, a game, or more accurately, the outcome of a game, must be measurable in some way, e.g., using "scoring units".

It is worth mentioning that there is no real verb "to game" (s.b.), which demonstrates that the emphasis is not on the activity itself, but rather on the event as a whole: According to the Oxford dictionary, the verb "to game" rather resembles "to gamble" which Lindley describes as "decisions of gain or loss made by chance within a framework of agreed rules" [5]. This also coincides with the third category of game given by Ball [6]:

- Game of skill,
- Game of strategy,
- Game of chance, and
- Games that combine two or even all three of the categories.

Starting from this official definition of "game", we will now discuss several definitions and extract the key elements. Salen and Zimmermann [1] describes a game as "an activity with some rules engaged in for an outcome" and they further define a game as a "system in which players engage in an artificial conflict, defined by rules, that result in a quantifiable outcome". The key elements in this description, and this definition, respectively, are:

- Activity with rules and an outcome,
- System,
- Artificial conflict, and
- Quantifiable outcome.

Again, as in the definition before, we see rules, an (artificial) conflict or competition, and a measurable outcome as central elements of games. This is also stated by Ellington [7]: "The activity must involve overt competition between individuals or teams, or between the individuals or teams, which are competing against 'nature'". 'Nature' in this case means that the players can also compete against an artificial opponent.

Additionally, there is another interesting aspect that we have seen before when discussing *play(ing)*: A game is also a (social) system, which inherently makes sense, since games are often considered a subset of play [1, 8]. Salen and Zimmermann differentiate between three systems: Formal systems, which are closed and where rules play an important role, experiential systems, which can either be open or closed and where the emphasis is on playing (no rules per se), and contextual systems, which are open and of cultural nature.

In this context, a game, in contrast to playing, is a closed system (everything is usually determined and set in the beginning and cannot or at least should not be changed during the ongoing game) with rules being the central element that converts and open system into a closed one (cf. Fig. 1). Although the range and strictness of applying the rules can admittedly vary very much; however, usually acting outside the rules is considered "cheating". Obviously, *rules* are a major element that turns play into a game.

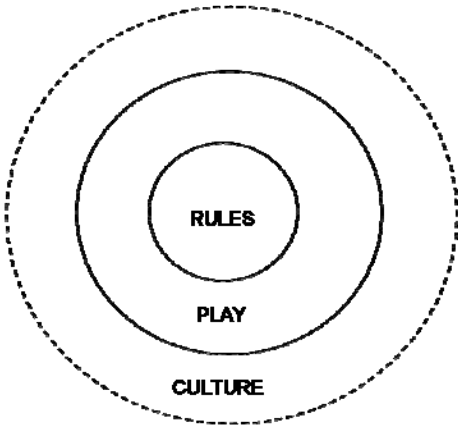

Fig. 1. The relation between rules, play and culture [1].

This aspect of "some sort of boundaries" in a game is also similarly described by Walther (cf. Fig. 2) [9]. According to him, in gaming "the distinctions that guide the form of play are not enough. In addition, one observes - and responds to - the very criteria of a specific game. At least, one has to be aware of these criteria in order to advance and, preferably, win the game."

He continues: "Thus, the organization of gaming lies in a third order complexity which, in logico-formalistic terms, can be explained as follows: First, a fundamental distinction occurs. Either one is in or one is out. [...] Next, a second transgression takes place. [...] The suppleness of play stems from the fact that it is open to the repetitive fabrication of rules. The flexibility of games is precisely that they are autonomous in respect to rules; instead, they are open for tactics. [...] Finally, the movement towards rule is a result of a form within a form within a form, i.e. a third-order complexity, a temporal displacement of two transcending acts - that of constituting the contingent modality of play and that of fixating the principles of a game's structure."

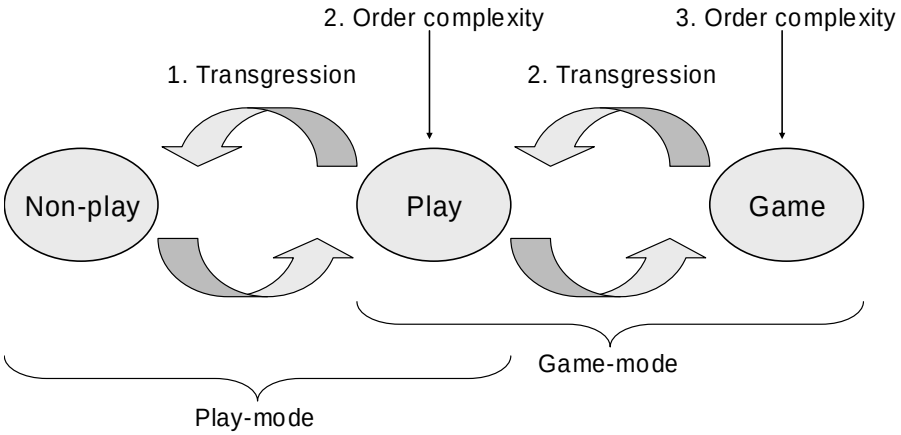

Fig. 2. Transgression and complexity in play and game [9].

Lindley gives a rather ludological definition of games: A game is "a goal-directed and competitive activity conducted within a framework of agreed rules" [5]. The elements listed by him coincide with the elements already gathered by us:

- Goal-directed,
- Competitive, and
- Framework of agreed rules.

Similar to Lindley, Klabbers [8] defines a game as "a contest (play) among adversaries (players) operating under constraints (rules) for an objective (winning, victory or payoff)". According to him, the difference between play and game are "constraints (rules)" and "an objective".

Juul's definition of game is built on six points ([10]):

- Games are rule-based,
- Games have variable, quantifiable outcomes,
- In games, value is assigned to possible outcomes,
- The player invests effort in order to influence the outcome,
- Player is emotionally attached to outcome, and
- It is optional whether a game has real-life consequences.

These points speak for themselves and will be added as such they are to our list of game elements. There is one aspect we have not discussed before which is the "emotional attachment" of players to a game based on personal values assigned to the game and the outcome. The emotional attachment, and thus the emotional experience, is an important trait and will be picked up again later.

Finally, we present a different approach taken by Costikyan [11]. He sees a game as "a form of art in which participants, termed players, make decisions in order to

manage resources through game tokens in the pursuit of a goal". Although the consideration of a game as a form of art is very interesting, we will not elaborate this aspect further, for it would exceed the scope of this paper; we focus on extracting the mentioned elements crucial for us:

- Decisions,
- Manage resources, and
- Pursuit of a goal.

Having discussed several definitions of game and having collected the central elements of each definition, we now try to group equal or similar elements. Tab. 1 lists the amalgamated elements of a game besides fun (actually, fun is a result of these factors if implemented well):

Table 1. The six essential elements of a *game.*

Element	***Synonyms***
Rules	Framework of agreed rules, constraints, rule-based
Competition	Competitive play, artificial conflict, competitive activity, contest among adversaries
Goals	Pursuit of a goal, goal-directed, objective
Outcome	Unit of scoring, quantifiable outcome, variable and quantifiable outcome
Decisions	Manage resources
Emotional Attachment	Value assigned to outcome, effort invested for influencing outcome

In addition to these key elements derived from the definitions above, we introduce a dichotomy by Crawford [12] (see Fig. 3). This classification does not only help us classifying different areas of entertainment that can be supported with or augmented by Pervasive Computing technologies, but also gives further insight of the nature of games.

Crawford starts his classification with entertainment. Adding the component of "interactivity" to entertainment results in "playthings", which is a rather vague and indistinct term. Playthings with goals are then called "challenges", while "toys" are playthings without goals. Challenges in turn are grouped into "puzzles" (a challenge without a competitor) and "conflicts" (where one or more competitors participate). Finally, Crawford differentiates between "competitions" (a challenge with a competitor but without attacks) and **"**games" (attacks allowed). Summarizing, Crawford defines a game as a form of **"**interactive entertainment with goals, competitors, and attacks".

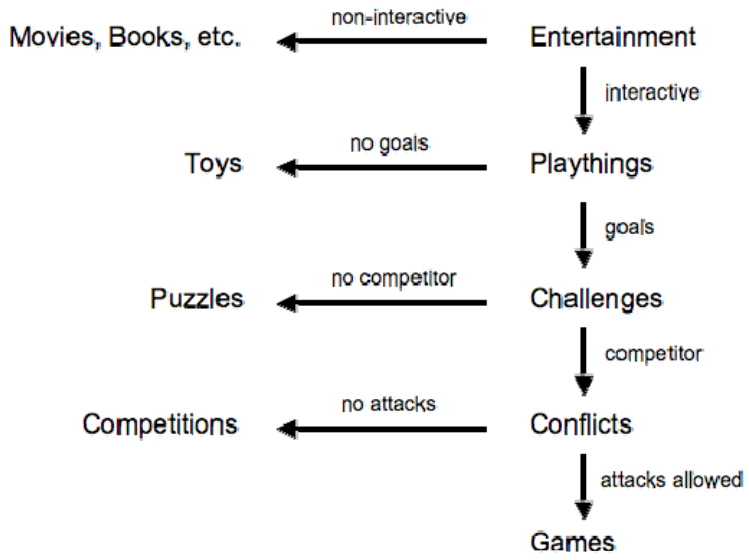

Fig. 3. Game as a form of entertainment: Crawford's classification [13].

The classification developed in this paper is mainly based on Crawford's classification. However, we extended this model by adding further categories and aspects that we consider relevant (see Fig. 4).

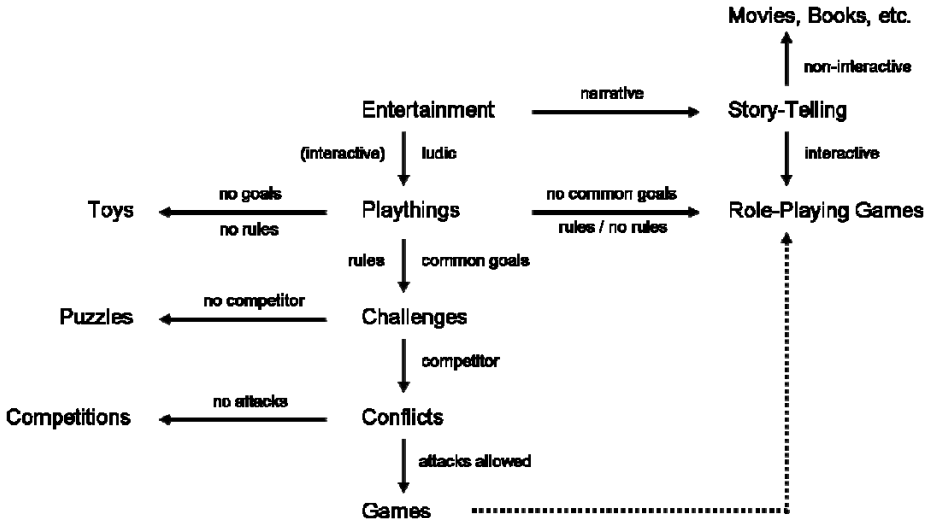

Fig. 4. Crawford's classification extended (cf. Fig. 3).

With regard to our findings on game elements (cf. Table 1), one important aspect that is missing in Crawford's definition of games are *rules*. But we also want to

include the narrative component [5, 14], especially Story-Telling and Role-Playing Games, that has not received much attention yet as far as Pervasive and Mobile Computing technologies are concerned. Most interesting is that role-playing games are usually seen as *games*, although they only partly satisfy the criteria of games (no common goals, rules are rather flexible, but certainly emotional attachment, etc.). This is also reflected by Lindley: "Stories and narratives can be defined as broadly as game: everything is a narrative/story" [5]. He moreover states that game designers should keep in mind that a better integration of the game play could be achieved by "continuously but unobtrusively reminding the player of the narrative context".

There is one final point to consider: The participants of a game, which, in contrast to play, can be either *active* (players or referees) or *passive* (spectators). Based on a classification by Barth, Klabbers sees a game as a representation of social systems, which is defined by three interconnected building blocks [8, 15]: *Actors*, *rules*, and *resources*. We agree with this view, which also coincides with the views of other authors. Nonetheless, we slightly extend this definition in order to integrate our findings. We elaborated six elements essential to games with one of them being rules; thus, we add the remaining five elements and call this block "elements of a game". Summing up, this results in *actors*, *elements of a game*, and *resources* (see Fig. 5).

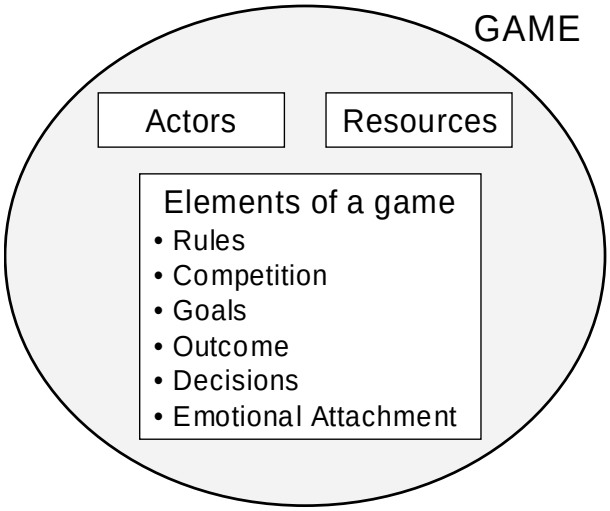

Fig. 5. The three building blocks of a game: Actors, resources, and the six elements of a game.

Summing up, we have come up with two models that will serve as a basis for the remainder of this article:

- The extended dichotomy based on Crawford's classification, and
- The model of the three building blocks of a game which especially includes the compiled elements of a game deriving from several definitions of games.

3 On Mixed Reality and Pervasive Games

After having examined the terms “game” and “play” and elaborated the differences between them, we can shift our focus to the part that makes a game “pervasive”. Or, in other words, knowing what games are, the question is, what are *Pervasive Games*?

According to Benford et al., “Pervasive games extend the gaming experience out into the real world” while “the game player becomes unchained from the console and experiences a game that is interwoven with the real world and is potentially available at any place and any time.” [16]. Walther gives a more technical definition: “Pervasive Gaming implies the construction and enacting of augmented and/or embedded game worlds that reside on the threshold between tangible and immaterial space, which may further include adaptronics, embedded software, and information systems in order to facilitate a ‘natural’ environment for game play that ensures the explicitness of computational procedures in a post-screen setting” [17]. A good overview of further definitions and descriptions can be found in [18].

To begin with, the general idea of a Pervasive Game is to employ Pervasive and Mobile Computing technology in order to

- Support (i.e., a part of a traditional game is replaced by pervasive computing technology to simplify this part from the users' perspective),
- Augment (i.e., pervasive computing technology is employed to add a (virtual) component that was not there or even possible before) and/or
- Realize (i.e., completely new games are possible) the game itself.

The term “Pervasive Computing” was introduced by IBM in 1998 and describes a paradigm that deals with the integration of computers in our surroundings. A probably even more popular but very related term is “Ubiquitous Computing”, though the latter one is not very common in the gaming community. Mattern describes the difference as follows: “While [Marc] Weiser uses the term ‘Ubiquitous Computing’ rather in an academic-idealistic way, describing an unobtrusive, human-centric vision of technology, the term ‘Pervasive Computing’ has been coined by the industry with a slightly different emphasis: This term also centres around the idea of permeating and omnipresent information processing, but with the specific short-term goal of utilizing it in e-commerce scenarios and web-based business processes.”[3]

Despite these rather minor differences (also cf. [18]) we do not differentiate between “Pervasive Computing” and “Ubiquitous Computing” in this paper, but stick to the already established term “Pervasive Games” (and thus to “Pervasive Computing”).

The central vision is to bring the computers into the world, and embed and weave them into the fabric of our surrounding in such a way that they are indistinguishable from it [21]. By doing so, we can add a virtual layer to the physical world. This aspect is also referred to as “Augmented Reality”, which in contrast to “Virtual Reality” describes the paradigm of bringing the computer into the world, instead of bringing the world into the computer [20-23] (cf. Fig. 5).

[3] Translated from [19].

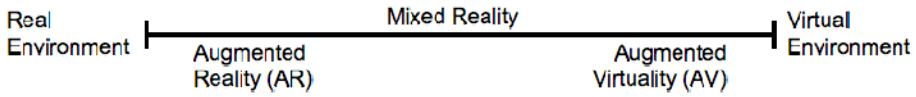

Fig. 6. The mixed reality continuum [20].

The Real Environment is the physical world we live in. A Virtual Environment is an artificially generated world that is either based on someone's imagination and fantasy, on the real environment (a projection, called "Augmented Virtuality"), or on a combination of both. The beauty of such Virtual Environments is that, on the one hand, there is no limit as far as the imagination and fantasy of the creators and the users are concerned; and, on the other hand, the possible number of virtual worlds (in contrast to the real world) is potentially infinite.

Stapleton et al. introduced the model of compelling mixed reality, which adds the component *imagination* (which in turn can be the basis for *a* virtual world) to real and virtual environments:

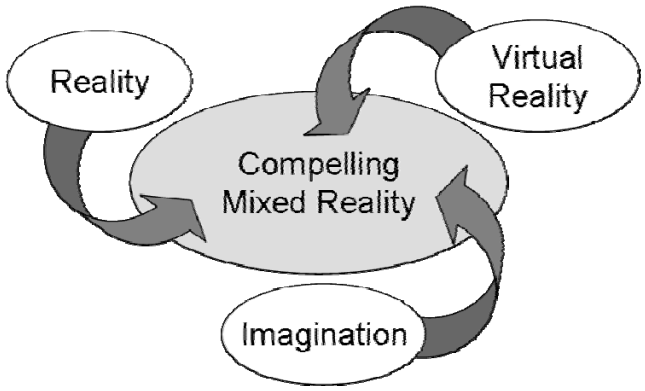

Fig. 7. Compelling Mixed Reality [24, 25].

Mixed Reality describes a reality somewhere on the continuous spectrum between the real and the virtual environments. Mixed Reality is combination of two worlds, the real and the physical (also sometimes referred to as a hybrid world. The proportion of real and virtual components is dynamic and usually difficult to determine. Therefore, in the realm of games, it suffices to roughly differentiate between these three categories:

- Real World Games (i.e., traditional games),
- Virtual Reality Games (i.e., computer games), and
- Mixed Reality Games[4].

[4] Mixed Reality Games may not be confused with *Alternate Reality Games*, which describe a surrealistic game setting.

It is important to notice that *Mixed Reality Games* (or, "Hybrid Games" [26]) are not the same as Pervasive Games! For example, "EyeToy" for Sony Playstation is a Mixed Reality Game (since it combines physical and virtual components) but does not utilize Pervasive Computing technologies. Thus, Pervasive Games are a subset of Mixed Reality Games. This distinction brings us to another interesting question, that is, whether games that mainly use mobile devices are Pervasive Games. Usually, those games are more or less device-based which to some degree contradicts the vision of the disappearing and unobtrusive computers weaved into the fabric of our everyday lives, as it is the fundamental concept of Pervasive Computing.

Admittedly, the discrimination of Pervasive Computing and Mobile Computing is neither simple nor exact: While Saha and Mukherjee see Mobile Computing as a subset of Pervasive Computing [27], Roth argues for the opposite [28]. Mobile Computing rather encompasses issues of "mobility" such as mobile communication, mobile devices, and mobile applications [28], while "pervasive" means omnipresent and permeative.

This would actually lead to a new definition of "Pervasive Games": Games that can be played (physically) everywhere. And, even more, we can carry this to the extreme: Mobile Games would then be games that can be played while being mobile (games that are explicitly designed for, or can at least be used for, travelling, e.g., games on a mobile phone, a portable play station, etc); but both definitions per se also include traditional games such as "Hide and Seek" (pervasive game) and "Four-in-a-row" (mobile game).

For reasons of clarity, it would seem reasonable to (re-)integrate the term "computing", resulting in "Pervasive Computing Games" and "Mobile Computing Games"; they unambiguously reflect that the game is based on Pervasive Computing and Mobile Computing technologies, respectively. This, in turn, would mean that the term "Pervasive Games" is not totally correct. But since this term has become dominant in the respective research community, we will continue using it and furthermore use is as generic term encompassing Pervasive Computing Games and Mobile Computing Games.

Having introduced and thoroughly examined several terms in the context of this research field (such as Pervasive Games, Mixed Reality Games, Hybrid Games, Pervasive Computing Games, Mobile Computing Games; we could further add Augmented Games), we summarize our findings on Pervasive Games:

> *Pervasive Games are a ludic form of mixed reality entertainment with goals, rules, competition, and attacks, based on the utilization of Mobile Computing and/or Pervasive Computing technologies.*

Tab. 2, by combining the entertainment categories (see Fig. 4) and the different realities, reflects this definition.

Table 2. The entertainment categories combined with different levels of reality

	Physical Reality	*Mixed Reality*	*Virtual Reality*
Toys	Dolls (e.g., Barbie Dolls)	*Augmented Toys*	Virtual Pets (e.g., Tamagotchi)
Puzzles	Jigsaw Puzzles	*Augmented Puzzles*	Virtual Puzzles (e.g., Solitaire)
Competition	"Four-in-a-row"	*Mixed Reality Competitions*	Virtual Competitions (e.g., Mario Kart 64)
Games	Tabletop Games (e.g., Chess)	***Pervasive Games***	Computer games (e.g., Warcraft)
Interactive Story-Telling	Role-Playing Games (RPG)	*Mixed Reality Role-Playing Games or Story-Telling*	Virtual RPGs (e.g., World of Warcraft or Speculative Vision[5]

Some of the cells in the physical and the virtual reality columns hold a *sub*category (e.g., "Jigsaw Puzzles" in the *Puzzles*/*Physical Reality* cell) and some hold a concrete example or commercially available product that represents this category (e.g., "Four-in-a-row" in the *Competition*/*Physical Reality* cell), but most cells holds both (e.g., "Computer Games" as the subcategory (of virtual reality games) and "Warcraft" as a particular example in the *Games*/*Virtual Reality* cell). The purpose of these descriptions is to give the reader a better understanding of what each combination in this matrix actually means. In contrast to this, the terms used in the mixed reality column rather describe the whole category. Henceforth, the focus mainly is on Pervasive Games, though most aspects discussed below, possibly with minor adjustments, can be applied to the other mixed reality categories as well.

The different worlds of reality provide the environment in which the players will perceive, move and act. In computer games, for example, the worlds created and played in are often fantastically designed and presented to the player, creating an immersive environment that usually holds the user captive for some time: Players can explore places far away, places that are not yet reachable to humans in the real world, places long lost; there is no constraint regarding time and space! However, during all these virtual journeys the players usually never leave their physical space (i.e., sitting in front of a computer screen), and do not even move for hours while still descent in the virtual world. The main benefits of traditional games, namely amusement and social interaction, are thus only partly realized in virtual games.

We will now introduce four different dimensions that primarily contribute to the players' experiences and thus to their emotional attachment to the game, which in turn determines the success of a game:

- Physical experience or challenge,
- Mental / intellectual experience or challenge,
- Social experience, and
- Immersion into the game.

[5] http://www.speculativevision.com

First, we have the physical dimension, which describes the sensation experienced by players when (inter-)acting with tangible objects and real persons in the physical reality. Second, we have the mental experience that is stimulated by mental or intellectual challenges such as riddles. Third, we have the social dimension, which reflects the interaction and communication with other players. This is a very important aspect that has received much attention lately since computer games have been criticized to not support or even possibly diminish social skills of the players (e.g., [29, 30]).

Finally, there is the immersive dimension, which means the immersion of the players into a game. This aspect is rather difficult to realize and evaluate, but certainly contributes very much, maybe even the most, to the entertainment induced by a game. Tab. 3 summarizes these four dimensions with regard to the three different realities discussed before. The number of stars displays how well a specific dimension can be realized in each reality (i.e., the potential). Three stars mean high potential, two medium potential, and one star low potential.

Table 3. The dimensions of experience combined with different levels of reality.

		Reality		
		Physical	Mixed	Virtual
Dimension	Physical	✘✘✘	✘✘	✘
	Mental / Intellectual	✘✘	✘✘	✘✘✘
	Social	✘✘✘	✘✘	✘
	Immersion	✘	✘✘✘	✘✘

The physical experience can certainly be realized best in the physical reality while in the virtual reality there are almost no possibilities to bring the sensation of tangible user interfaces to the players. The same applies to the social dimension: Coming physically together for playing provides more social stimuli than doing the same virtually. In both dimensions, the physical and the social, mixed reality entertainment is somewhere in between.

In the case of the mental / intellectual dimension, the situation is fairly different: To provide the players with challenges and experiences regarding mind and brain is quite possible in all realities. In the virtual reality, however, there are more powerful concepts possible, for example, riddles or tasks that adjust themselves to the players' capabilities and thus optimize the experience or challenge.

The fourth dimension describes in how far a player can be immersed into a game. Virtual reality games, in contrast to traditional games in the physical world, can usually contribute more to the players' immersion into the game. Nonetheless, it is our opinion that mixed reality games are able to contribute even more potentially, since they are not limited to audio-visual output only and users are not limited to be sitting in front of a screen: These games ”are situated and played in a real environment, much in the same sense as traditional games, their game play is augmented […] by computational services, to enhance and leverage the overall gaming experience” [31].

Obviously, with regard to the four dimensions of player experience, Mixed Reality Games hold the potential to diminish or even eliminate the disadvantages that both worlds inherently entail: The disadvantage of the physical reality, that is the potential of immersion, on the one hand, and the disadvantages of the virtual reality, that is the poor support of social and physical (i.e., tangible) experiences, are to some degree obliterated in the mixed reality.

Augmented Toys (e.g., [2, 32]), for example, "combine the best of two worlds - traditional toys and the power of computers and electronic chips -" [4] while also enticing imagination and supporting social experience (playing with friends) and immersion due the high degree of freedom. However, we argued before that the transition from the physical to the virtual world is continuous, which makes it potentially hard to realize a mixed reality environment where all dimensions are equally met.

And, as pointed out before, the major goal of game design certainly is to create a compelling and entertaining experience for the players and the success of a game depends on how much the players enjoy playing the game and how strong they become emotionally attached to it. Thus, by merging the virtual and the physical worlds we aim at providing the players with an adequate and well-balanced mixture of the aforementioned four dimensions of experience in order to maximize the entertainment factor. Consequently, the central question is: How can Pervasive and Mobile Computing technologies contribute to this goal?

We now investigate how Pervasive and Mobile Computing technologies can support a smooth entering of the "magic circle" of the game and the players' experiences when they are in the "magic circle" [1, 33, 34]. A first good approach is presented by Jegers [35] who discusses the "Pervasive Gameflow" which is based on [36]. The game flow consists of eight aspects, which partly overlap with the six elements of games introduced by us before (cf. Tab. 1):

- Concentration,
- Challenge,
- Skills,
- Control,
- Clear goal(s),
- Feedback,
- Immersion, and
- Social.

Jegers adds three further aspects with regard to Pervasive Computing:

- Mobile / platform-independent game play,
- Social interaction between players, and
- Integration of the physical and virtual world.

He then describes how Pervasive Computing can or even should support the original aspects (there is no special entry in Jeger's table for "Feedback" regarding Pervasive Computing):

Table 4: Pervasive Computing and Games, based on [35].

Aspect	***Support through Pervasive Computing***
Concentration	Pervasive games should support the players in the process of switching between in-game tasks and surrounding factors of importance.
Challenge	Pervasive games should stimulate and support the players in their own creation of game scenarios and pacing. Pervasive games should help the players in keeping a balance in the creation of paths and developments in the game world, but not put too much control or constraints on the pacing and challenge evolving.
Player Skills	Pervasive games should be very flexible and enable the players' skills to be developed in a pace set by the players.
Control	Pervasive games should enable the players to easily pick up game play in a constantly ongoing game and quickly get a picture of the current status in the game world (in order to assess how the state of the game has evolved since the player last visited the game world).
Clear Goals	Pervasive games should support the players in forming and communicating their own intermediate goals.
Immersion	Pervasive games should support a seamless transition between different everyday contexts, and not only imply or require player actions that might result in a violation of normal social norms in everyday contexts. Pervasive games should enable the player to shift focus between the virtual and physical parts of the game without losing too much of the feeling of immersion.
Social Interaction	Pervasive games should support and enable possibilities for game oriented, meaningful and purposeful social interaction within the gaming system. Pervasive games should incorporate triggers and structures (e.g., quests and events, factions, guilds, or gangs) that motivate the players to communicate and interact socially.

A truly compelling gaming experience must support all these aspects. Similar to this approach, we can use our definitions and classifications to analyze what designers of Pervasive Games should keep in mind to maximize the players' entertainment and amusement.

As pointed out before, a game consists of actors, resources, and the six gaming elements, namely rules, competition, goals, (quantifiable) outcome, decisions, and emotional attachment. It is difficult to give any suggestions on how to support or improve actors and resources since this strongly depends on the game (in sports, for example, the support of actors could be possible, probably in the sense of wearable computing). Therefore, we will concentrate on the six elements of a game.

Table 5: The six elements of a game with regard to Pervasive Computing.

Element	***Support through Pervasive Computing***
Rules	Pervasive Games should unobtrusively but continuously monitor the game, observe the rules, and always be aware of the current game state. The game state must be accessible to the players at all times and violations of rules should be immediately reported in an adequate way.
Competition	Pervasive Games should provide means to the players for a smooth engagement in a fair competition.
Goals	See Tab. 4
(Quantifiable) Outcome	Pervasive Games should always keep score of the game. It must be possible for the players to always inquire the current score.
Decisions	Pervasive Games must allow the player to make decisions anytime. For this reason, it would be desirable to collect / observe the players' decisions or input in an unobtrusive way. Also, important in this context is immediate feedback by suitable means.
Emotional Attachment	Pervasive Games should provide a compelling experience for the players that seamlessly combines (well-chosen) several different media ("cross-media entertainment"), multimodal devices, etc to realize physical, intellectual, and social experiences and challenges as well as a good immersion into the game.

In this context, it is also important to notice that designers should not focus on pursuing the technology-driven approach, but rather aim at maximizing the benefits from the users' perspective: "The design and development of applications tend to follow the technologically oriented path, where every interaction form and function is dictated by the platform, devices and software architecture. This often leads to systems that are not harnessing the true potential of interpersonal interaction. The problem can be explained by two factors. First, technologically oriented development is usually governed by the restrictions and conventions of contemporary systems. Secondly, the limitations of user interfaces, especially in the mobile context, are often said to cause the downscale in interactional degrees-of-freedom" [37].

Interactivity is an important aspect in this context: *Play* implies interactivity, implying that the "*play* does not just come from the game itself but the way that players interact" [1]. This is not limited to interaction with a "system", on the contrary; it especially refers to interaction between the participants, the actors, which can also be seen as the basis for the social component.

4 Conclusions

In this article we thoroughly discussed the origin and nature of Mixed Reality Entertainment, and especially Pervasive Games, a research field that has received a lot of attention in recent years. We gave a definition and overview of what Pervasive Games and related topics such as Augmented Toys are and how they can be classified. Furthermore, we looked into the different dimensions that contribute to the entertainment experience of the players and set them in relation to the three types of reality. We especially discussed Mixed Reality Entertainment, which combines the virtual and physical worlds and thus coalesces the advantages of both worlds.

We then looked into how Pervasive Games are able to, and even supposed to, support the players with their playing and gaming activities and contribute to the immersion into the game. But what is the long-term goal of Mixed Reality Entertainment in general and Pervasive Games in particular? What should designers try to accomplish and what would be a perfect gaming experience?

Imagine you could move freely in the physical world of your choice (e.g., western theme, futuristic theme, etc) that looks and feels totally real: You can grab tangible objects, you can interact with other persons just like you are used to, and you can do whatever you want in accordance with the game (rules), for example, fire weapons, restart the game, maybe even fly. And everything seems to be absolutely real and you could get injured or killed if you want to and thus experience the real thrill.

This scenario, which admittedly very much resembles the Holodeck from Star Trek[6], might represent the ultimate challenge and experience for human beings: By combining virtual and physical realities (actually, by materializing virtual worlds) users are totally immersed into this simulation and the entertainment factor and the emotional attachment certainly are at their highest.

Though Pervasive Games are far from providing such a perfectly thrilling and compelling experience, the nature of these games certainly is one step closer into this direction: Pervasive Computing Games aim at enhancing and augmenting the players' experience by adding new layers of entertainment and fun through a more challenging and interesting and immersive game.

Assuming that the trend of constant miniaturization and steadily increasing sensing and computing power will continue, Pervasive Games are likely to enter the commercial market soon. And they could have a similarly significant influence on how people play in the near future like the emergence of computer games in the 80s.

[6] A Holodeck is a simulated reality facility using replicated matter, tractor beams, force fields, and holographic images from the Star Trek fictional universe (e.g., http://www.startrek.com).

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