

Design of technology-based pervasive gaming experiences: properties and degrees of pervasiveness

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Abstract

The current technological development has allowed the incorporation of new peripherals in game-based systems (GBS), allowing to offer experiences that were not possible before, such as: virtual reality through devices like Oculus glasses or Play Station VR, virtual assistants like Alexa or Google Assistant, motion sensors like Kinect and georeferenced location offered by mobile devices. This incorporation has generated new paradigms such as pervasiveness, which applied in the field of digital games allows the generation of pervasive game experiences, extending the game world from virtual to real, giving way to endless possibilities of implementation. These possibilities also incorporate new challenges and elements to consider in the design of these game experiences, besides producing confusions and misinterpretations in the pervasive context, reducing the efficiency and quality of the experiences made. To reduce this problem, the purpose of this paper is to identify the different properties that characterize pervasive gaming experiences according to their different expansions, and to create a means by which the degree of pervasiveness of a designed gaming experience can be determined.

Keywords¹

Pervasive, Game Experience, Game Based Systems, Pervasiveness, Player Experience

1. Introduction

The term "Pervasive" can be considered relatively new, because until recently the scientific community in general used the term "Ubiquitous" when referring to a set of small components such as sensors and computational devices integrated into the everyday life of people [1]. This was intended to provide access to computers at the physical and virtual level in a way that was invisible to the user, from any time and place [2], [3]. Currently, there is access to various devices with different sensors and a high level of processing such as smartphones or tablets, allowing to obtain various information through sensors such as: gyroscope, accelerometer, GPS or camera. There are also experiences based on new paradigms of interaction such as virtual assistants, virtual reality, augmented and mixed reality offering new experiences to navigate and communicate with other users or elements in a natural way, increasing the interaction between people and physical objects that are part of the context [4], [5]. The commercial and cultural popularity of devices that offer a high degree of portability has attracted the attention of many users, often switching from laptops and desktops to smartphones or tablets [6], which in turn offer better immersive experiences with real actions [7]. These characteristics have enabled the development of solutions in different fields such as education, health, industry and entertainment [8]–[10].

Pervasiveness has adopted a new approach, this being the field of entertainment in games. This is called "pervasive gaming" being defined by Arango et al. [11] as "one that provides the player with an

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enriched game experience through the evolution of dynamics, expanding the game space² according to the context where it is played, which allows breaking the limits of the game world³, breaking into reality and making the elements present in it influence during the experience” . This definition has been strongly influenced by previous established definitions such as the one defined by Montola [12], [13] which defines that pervasive games are "those that extend the boundaries of traditional computer games with respect to spatial, social and time dimensions". In this definition, it is established that pervasive games differ from traditional games when the first break the limits of the "magic circle" established by Huizinga [14]. A non-pervasive game (which is within the magic circle) is always played in a certain place, for a certain time and with certain people [15], [16], facilitated through current devices and technologies [17].

All of the above elements offer endless possibilities when designing and implementing pervasive gaming experiences, whether oriented to a general population or specific to particular needs. These game experiences should always seek to offer the best possible player experience (PX), understood as the individual experience that a player lives when interacting with a game-based system [18]. In addition, it should be understood that the simple fact of using technologies and devices that allow pervasiveness does not make the gaming experience pervasive.

For this reason, this paper presents a means by which the degree of pervasiveness of a game experience can be determined, in addition to offering a series of transversal considerations through the properties of pervasiveness identified in each of its expansions. The paper is structured as follows: Section 2 gives a brief description of the definition of pervasiveness, its implications and its components; Section 3 explains each of the expansions of pervasiveness, as well as the different properties proposed for each of them; Section 4 establishes the "pervasiveness pyramid" as a way by which the degree of pervasiveness of a technology-based gaming experience can be established; finally, Section 5 presents the discussion, conclusions and future lines of work.

2. Background

Any technology-based pervasive game is characterized by offering a set of game mechanics or rules combining aspects of the real world such as locations, people or objects with a virtual world, thus generating the game world. This breaks the limits of the magic circle that surrounds the player, generating a deeper and more attractive immersion, accompanied by a strong social component with natural interaction such as voice, tangible elements, gestures or actions. Pervasive games allow overcoming the problems generated by traditional digital games, as they allow increasing physical activity and social interaction while maintaining the intrinsic motivation of the players [19]. Another difference with traditional games is that the pervasive game evolves according to the actions of the participants, because not all players are directly part of the game or not all play the same game, since each player may have their own interests and motivations in the game. This can generate uncertainty in the objectives of the game, making it flexible and dynamic not only in the direction it will take, but also in the rules that guide the game, which can change according to the experience perceived by each player and the context in which that experience is being lived.

As established by Arango et al. [11] Pervasive games are characterized by offering different components that together allow the experimentation of pervasive experiences. These components include devices, game context, social interaction, time, space, multiple realities, crossmedia and pervasive narrative. Devices are all those technological elements used in a pervasive game that allow interaction, comfort and freedom in the real world to play with real-time access. Examples of these devices are cameras, motion sensors, virtual reality (VR), etc. Context refers to where the player is located, which influences variables such as ambient temperature, frequency of play and how the user can interact with the game. Due to this context, the game can present variations that allow the evolution and customization of the game experience.

Social interaction in pervasive games is the ability to be used with other people such as family and friends directly or indirectly depending on the type of game and the role of the player. This interaction

² Environment where the game takes place, both virtual and real.

³ This is the result of the union of the game space, its rules, the different axes of pervasiveness and the interaction between virtual and real elements [26].

can occur not only between people, but also with virtual elements such as avatars or real-world elements. In addition, another important factor in pervasive social interaction is the role of the observer, understood as the person who does not play directly but who can influence the dynamics of the game [20].

Time in pervasive games refers to their capacity to offer game experiences without being connected, that is to say, to their dimension and temporal expansion. This allows that there are no time restrictions to perform the activities of the game, as long as these are in the game world defined by its rules and allowing its integration to the daily life of the player [12]. Space is the ability of pervasive games to blend the real world with objects in the virtual world. This generates a better gaming experience and takes players to a new form of fun.

Multiple realities in pervasive games are given by covering the game world with tangible elements or with virtual, augmented or mixed reality experiences. These are not the same as a pervasive game, they are just ways of making a game pervasive. Crossmedia is the ability of pervasive games to be played across different media such as smartphones, tablets, television, newspapers and the internet. In addition, these gaming devices could use "media" such as flashlights, cameras, streetlights, public events, projections, movies, etc.

Finally, the pervasive narrative, which can be considered as one of the strongest components of the games, because it links all the other components through a coherent story, also allows the interaction of the players with the game. From the script, a sequence of events is generated to give the narrative expression and these collectively form the plot of the story, providing an order to the game experience and gives a logic to the player. For the design of the story it is important to consider the new narratives based on "emergent narratives" and "environmental narratives" where the story is created based on the interaction of the players with the GBS and that, in the pervasive context, can be affected by the context in which the game is being played [21].

3. Properties and dimensions of pervasiveness

In pervasive games different extensions are experienced over what is classically controlled by the so called "magic circle" and together with the game experience that the player lives, being this called "pervasive expansion" [12]. This expansion can be of space, social and temporal type on the magic circle, but there is also the expansion of context that involves the place of execution affecting the gameplay level, the game elements and the dynamics that emerge throughout the experience [22] (see Figure 1). Next, each of the pervasive expansions is analyzed and a set of properties that characterize that particular pervasivity is proposed and explained for its understanding.



Figure 1. Magic circle and its social, space, temporal and context expansion.

3.1. Space expansion

This type of expansion in pervasive games refers to the location where the players are located because it is not only limited to the real world⁴ but also to the virtual world⁵. This is achieved by integrating everyday places to make them part of the game, turning them into the playground or game zone where the different activities must be performed [23]. This process of space expansion also generates an increase in space awareness of the players, because it is important to know where the player and the other participants are really located. Some examples of mechanics used in this type of expansion are the proximity and distance between the different real places and the player, or between the other players, being measured with motion sensors, GPS, wireless networks, Beacons among others and used as elements of the game or as part of the challenges and puzzles designed. Another example is the integration of representative elements such as monuments in a city, making them part of the game. As stated by Arango et al [22] it is important to be clear that each action performed in the real world can have an effect on the game according to the type of pervasive game (real, virtual or mixed). Based on the aforementioned characteristics, a series of properties are proposed, which allow characterizing this type of expansion and which encompass it in a general way giving a better understanding of this dimension, being these properties the following ones (see Figure 2):

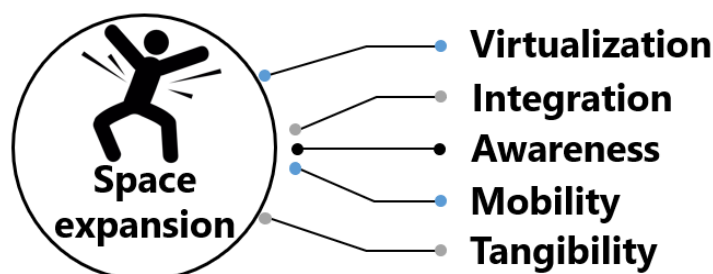


Figure 2. Space expansion properties

- **Virtualization:** This is an expanded perception of the game space based on a mixture of the real and virtual world, as well as mapping the virtual world based on the real world. This should not be confused with the typical immersion that depends solely on the mechanics of the game. For example, in a georeferenced game, the mapping is the map that you have in the real-world game which can be direct (for example, georeferenced using google maps) or using a fictitious representation but directly related to the playing surface.
- **Integration:** Integration is the expansion of the rules from the real to the virtual world, that is, it refers to the transfer of the rules that exist in the real world to the virtual world. For example, if in the real world it is not allowed to hit a policeman, in the virtual world it is not allowed either. Another example is the impossibility of crossing walls in the real world, or the opening hours of a certain place. There are rules of the real world that, although they are not defined in the game, they must still be followed. For example, if the game asks to go from point A to point B in the real world, although the game rules do not contemplate it, traffic, zebra crossings, etc. must be respected. All these elements and the previous ones in turn support immersion, considering that if the rules of the real world can be broken in the virtual one, it negatively affects the experience.
- **Awareness:** It is the knowledge that players have about the rules of the game, their own state and that of other players to make decisions. This can be given, for example, in knowing that they can hide behind a wall to avoid detection and thus not be shot at in a given game, positively affecting immersion and fun.

⁴ Physical space in which players find themselves during the game experience offering opportunities or constraints that drive their actions, interactions and varying the experience.

⁵ Artificial virtual space inspired or not in reality where users can interact.

- **Mobility:** It is the ability of the player to change their location in different physical places in the game space. It is important to take into account the relationship between physical and virtual displacements in the game world.
- **Tangibility:** Ability to interact with objects in the different game spaces, handling the interconnection and feedback between the different spaces. This can be given, for example, through a tabletop (tangible table), in which, if an object is moved in the real world then in the virtual world its state also changes.

3.2. Social expansion

This expansion can occur directly in games oriented to social interaction processes, or indirectly by making use of objects for mediation between people with similar interests. In this context it is possible to identify players who know they are playing and perform actions to continue in the game. There are also the conscious spectators, being the people who are involved in the game, but do not perform actions directly in it through the elements that the players have. However, spectators can alter in some way the development of the game and its participants. Finally, there are the unconscious spectators who do not know that they are part of the game, but can alter the development of the game by coming into contact with the players [20]. In the process of the social expansion of the game, spontaneous social interactions between players can occur, thus generating new relationships or unexpected changes in the narrative. All these characteristics of the social dimension mentioned above are represented by the following proposed properties (see Figure 3):

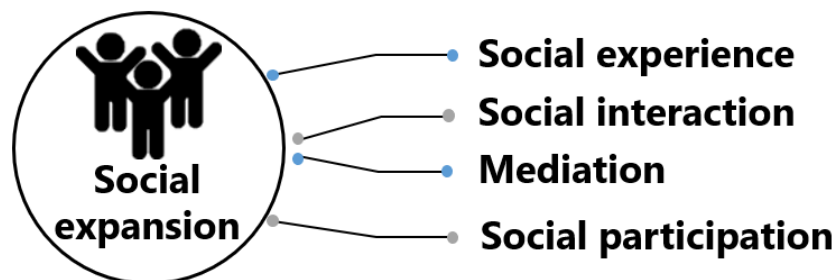


Figure 3. Social expansion properties.

- **Social experience:** Participants can share game experiences with other players based on the context offered in the game. The experience shared with other players in outdoor sites is not the same as indoors, and if other factors such as weather, time, available space and any additional variable that positively or negatively modifies the experience are considered, an endless number of possibilities are generated during the game.
- **Social interaction:** It is the direct or indirect interaction of the spectators who modify the development of the game and the participants. As indicated, spectators may or may not be aware that other people around them are experiencing a pervasive experience. These spectators can affect the experience by interacting with the participants, or by indirectly changing the game world and impacting the experience.
- **Mediation:** These are all objects that are used as mediators in processes of social participation, as in people with similar preferences. Here, the theme of the game is relevant, as it takes advantage of these similar preferences to bring people together. An example of this is the pervasive Pokémon Go game, which brought people with a preference for the franchise to the streets, gathering at specific points in the cities and generating new friendships.

- **Social participation:** These are all the participation processes generated through the game, which can be cooperative, collaborative, coactive or competitive. An example of this is also applied in the Pokémon Go game, which allowed the generation of teams, battle groups and coordination between unknown people, thus allowing them to collaborate with each other. In addition, competition among participants was then integrated, thus increasing the participation among them in the gaming experience.

3.3. Temporal expansion

It is understood as the ability of the game to continue its course without the need for the player to be connected, achieving the integration of the game during their daily life. This expansion can be offered in 3 ways, the first is that the player must be connected for the game to be executed, that is, if the player disconnects the game ends. The second way is that the game has the ability to continue its execution when the player disconnects, following its natural course and, therefore, when the player connects again will find modifications in it. Finally, it is possible to offer notifications to the player when a certain situation or structured event occurs in the game, allowing the player to know what is happening and make decisions at the best moment [22]. This temporal expansion allows the game to intertwine with the daily life of the players, combining actions with everyday life and evolving the game, even if the players are not present. All the above characteristics can be represented through the following proposed properties (see Figure 4):

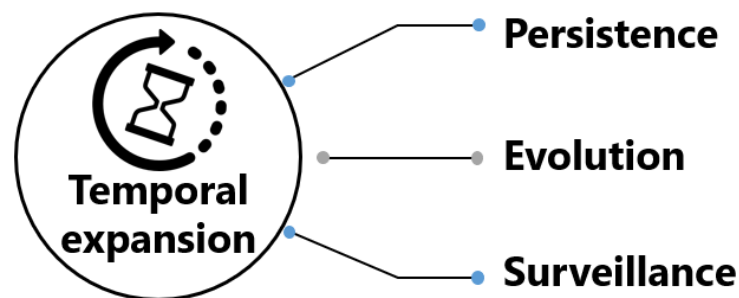


Figure 4. Temporal expansion properties.

- **Persistence:** It is the ability of the game to store the player's states and actions permanently, therefore, if a player disconnects at any time the player's state is saved for later continuation.
- **Evolution:** Even if a player disconnects and saves their state, the game continues its course without the player's control, therefore, when the player reconnects will find slight or significant changes according to the events that occurred in their absence. This property allows to measure the degree to which the game is independent of the players and how there are mechanisms that make the evolution of the game not depend only on the actions of the players.
- **Surveillance:** Depending on the type of game, if significant events occur in the game, the player will be notified so that quickly access the game and make decisions. The mechanisms associated with this property are interesting to continuously involve the player with the game system. It is important to motivate the player to return to the game.

3.4. Context expansion

The place where the game is played has a great influence on the player's gaming experience, because the game world and the other players impact this experience directly through the rules of the game, its limits and structure. In addition, it affects the player's motivation and the way in which the objectives

are fulfilled, being able to offer them challenges according to their own perspective, thus achieving more pleasant and fun experiences. These pervasive game rules can be fixed or dynamic, where fixed rules arise because they are associated with constant values of reality such as rules and laws that limit the movement and interaction between players such as schedules and physical limits. Dynamic rules allow people to change their objectives and ways of playing, offering greater dynamism. An example of dynamic rules could be a game system in which throughout the experience, players decide to change some objective and the challenges associated with that objective.

Another aspect that is significantly affected by the context are the game elements, offered through the pervasive narrative⁶, involving the characters of the story not as players but as roles that play each of the tangible and intangible elements in each narrative level, changing the course of the story and therefore all the elements present in the game experience. Finally, the context also affects the pervasive dynamics generating different game experiences depending on the variables of the environment, according to the time, space and society where it is being developed, thus achieving different perceptions. This is reflected for example in the temperature depending on the time of the year, its location, altitude among others that directly affect the way in which the user experience is presented together with the game experience. The dynamics can evolve in different ways, either by modifying the existing ones, creating new dynamics without affecting the existing ones or replacing the existing ones with new ones. This evolution generates a change in the game context generating infinite and unpredictable experiences for the player in the same game situation [20]. The mentioned characteristics can be represented by the following proposed properties (see Figure 5):

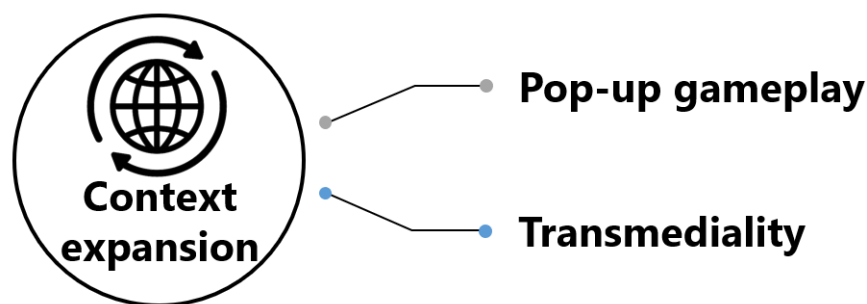


Figure 5. Context expansion properties.

- **Pop-up gameplay:** Gameplay experiences can emerge according to certain situations and interactions (weather, cultural rules, schedule). This can happen by including or modifying rules, changing narrative objectives or any other aspect in the game.
- **Transmediality:** It is the ability of the game to allow the player to access from different media and locations, for example, a player is on a certain device, stops playing and then connects from another device or medium to continue playing, and depending on the medium in which it is connected the experience perceived by the player may change. It is important to reflect that one aspect of transmediality is that the perceived experience is different depending on the medium through which it is viewed. It may even change if it is perceived using several media at the same time. It may, for example, be that some medium offers more information that may change the perception of some aspect of the game.

4. Pervasivity degrees

When designing pervasive experiences, use can be made of a wide variety of elements offered by the different expansions of pervasivity, at the space, social, temporal and contextual levels. But when can a game experience really be considered pervasive? This question arises because, although a game makes use of technologies that enable pervasiveness such as Kinect, motion sensors, VR, among others,

⁶ Story that is intertwined with the proposed objectives of the game.

these alone do not make a game genuinely pervasive. This is why the "Pervasiveness Pyramid" is proposed, which establishes in different degrees the level of pervasiveness of a game experience, according to the different elements that are integrated in the design of the game and in the experience it offers.

The Pervasiveness Pyramid (see Figure 6) establishes different levels that determine the degree of completeness of the pervasiveness applied in the game, divided into 3 levels called basic, medium and advanced. In addition, a set of transversal elements are established that should be considered when designing a pervasive experience, in order to offer an adequate experience to the player. This proposal arises as a way to analyze the degree of pervasiveness of a game experience, and can be applied to any type of pervasive experience oriented to any type of target audience. For this, it is necessary to adjust the respective transversal elements according to the target audience, such as, for example, the elderly, children with autism or any type of population, in which specific adjustments must be made in order to offer the best PX.

It is important to mention that the transversal elements established can exist in both pervasive and non-pervasive GBS, but these must be adjusted in order to enhance the pervasive experience offered and generate the highest possible engagement. An example of this is the application of pervasive GBS for specific application in serious game learning contexts for older adults [24]. Here, each element must be adjusted according to different particularities that must be considered in order to offer the best possible PX.

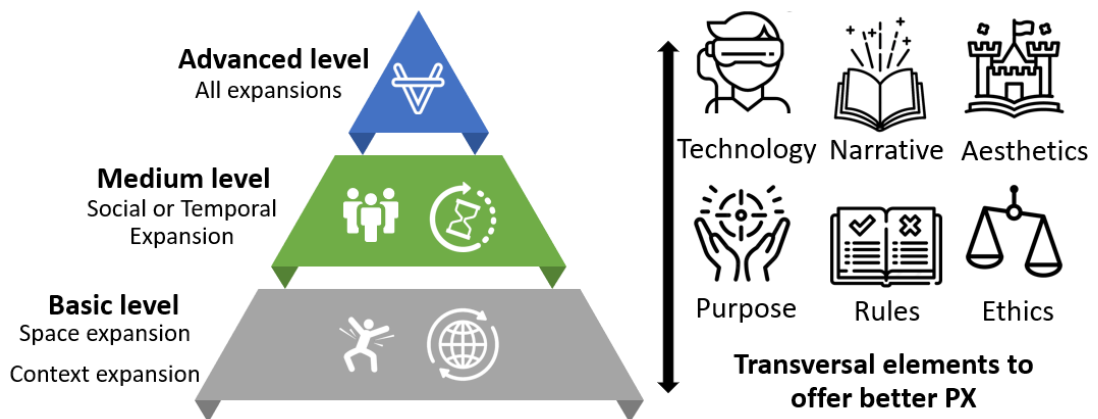


Figure 6. Pervasiveness Pyramid

4.1. Basic level

A characteristic and necessary element of any technology-based pervasive game is the integration of the real-world space and the virtual game world. This is achieved through different technologies such as virtual, augmented or mixed reality, as well as the integration of devices oriented to the detection of movement, voice, location, etc. Although these devices are key, by themselves they do not achieve pervasiveness, they must be accompanied by additional elements such as the context where the game experience is executed, its execution must have a purpose and a minimum narrative that structures the experience. A basic example of these are exergames, which require movements in the real world for their control, but also have a purpose such as the promotion of physical activity or a rehabilitation process. Also, it can be accompanied by a virtual instructor, messages or informative guides that orient the player during the game experience.

Another characteristic element of any pervasive game is the context, which has a strong influence on the game experience of the players through the rules, limits and structure. This context also affects the way in which the objectives must be fulfilled, through fixed or dynamic rules. This is why it is necessary to provide safe spaces for play, where their physical presence is not required at times or places where players can get hurt. Cultural aspects that are integrated into the game should also be considered,

so that there are no problems in the player's environment when the game needs to be played in open or closed spaces (see Figure 7).

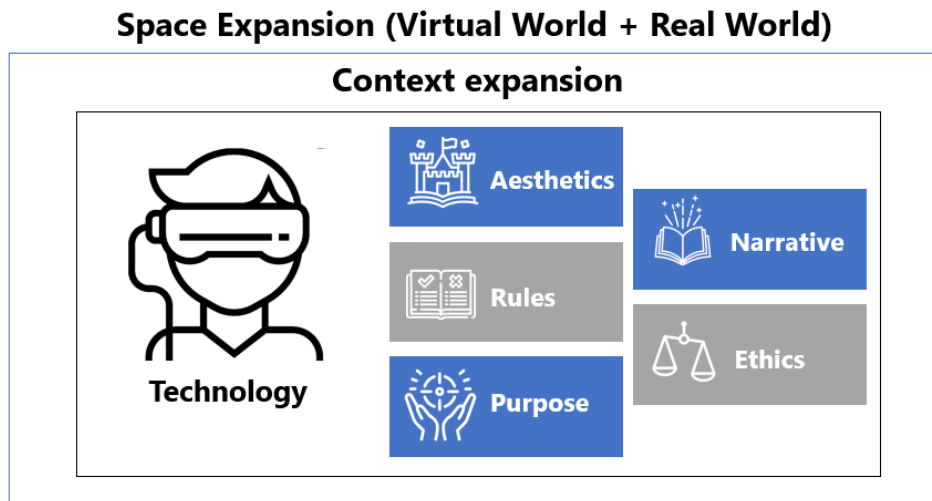


Figure 7. Basic level of pervasive gaming experiences.

The basic level of pervasiveness is sufficient to be considered pervasive, but to a very low degree. Here, the most basic and characteristic elements available for pervasive experiences are offered. At this point, the differentiating elements between a basic pervasive experience and a non-pervasive one focus on its transversal elements such as game aesthetics, rules, purpose, pervasive narrative and ethics. These elements together provide a differentiating factor between the fine line of a low-level pervasive game to a non-pervasive game.

4.2. Medium level

The two remaining dimensions at this point of pervasiveness are social and temporal expansion. If the game experience achieves to integrate to the game context and space, characteristics that allow social interaction between players, or on the other hand, it achieves to integrate the possibilities offered by the temporal expansion of pervasivity, this is considered a pervasive game of medium level. This process of scalar integration allows the consolidation of the game, enriching the experiences lived by the players and deepening the pervasiveness.

At the social level, pervasiveness should focus not only on allowing interaction between players, but also, if possible, on finding mechanisms to connect with others or on ways to help other players. To achieve this, mechanisms can be identified to connect people with similar interests in order to exchange experiences in the same challenge [25].

Finally, at a temporal level, the basic inclusion of game saving should be considered, or in an ideal state, the continuity of this, even if the player is not present. In addition, it is not advisable to force the player to wait a long time for another player to take turns and perform a certain action. This is why this type of conditions should be avoided, generating freedom in the game on the part of each player without having to wait for others (ver Figure 8). It is important the idea that the game has an "own life", it is not a game session of one player or the sum of the game sessions of all the players, but it is something more. The "game" is the place where players live their pervasive experiences.

Space Expansion (Virtual World + Real World) and Context Expansion

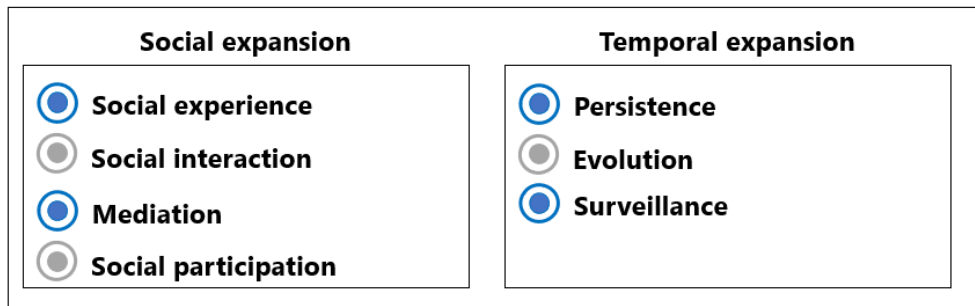


Figure 8. Medium level of pervasive gaming experiences.

4.3. Advanced level

Finally, when a game integrates all dimensions of pervasiveness (context, space, social and temporal) together with transversal elements such as technology, aesthetics, rules, purpose, narrative and ethics, it is considered a game with a high level of pervasiveness (see Figure 9). This set of elements allows a greater immersion in the game, increasing the level of the pervasive experience offered. Each transversal element should be adjusted according to the target audience of the game, as well as the type of game that is being offered.

By considering all the above elements, it is possible to achieve complete, unpredictable and immersive pervasive experiences that totally break with the magic circle, incorporating the particularities of the place where it is played and changing the experience according to the device from which it is accessed.

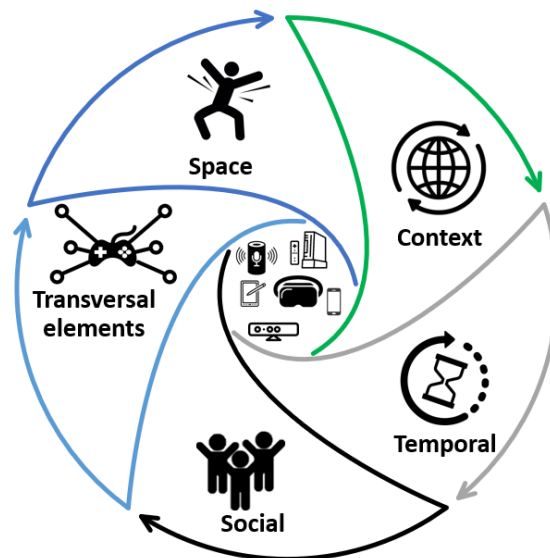


Figure 9. Advanced level of pervasive gaming experiences.

5. Conclusions

The design and implementation of games that offer pervasive experiences provides a world of possibilities for the player, but demands new challenges and considerations to offer a product that adjusts to the target population. Pervasiveness offers an interesting approach that allows the real world to be integrated into the virtual world, allowing it to be implemented not only for entertainment purposes, but also for deeper meanings such as physical activity, rehabilitation and learning. To achieve

this, it is necessary to understand the possibilities that pervasiveness allows, its expansions, its properties and a way by which the degree of pervasiveness of a game experience can be determined.

In this context, it is also necessary to consider different transversal elements that must be adjusted according to the target population, such as narrative, aesthetics, technology used, game rules, purpose and ethics. These elements must be adjusted according to the focus of implementation, being necessary to make adjustments in these elements in a game experience specifically focused on a population. A specific focus of application can be found, for example, for the elderly population where the objective is to promote active aging, or, for example, if it is desired to design and implement an experience for children with autism where the intention is to improve the social interaction of the participants. Each of these population groups, as well as others, has its own particularities and needs, and it is necessary to adjust the game to offer the best possible experience.

This is why this article identifies the different properties that exist in each of the expansions of pervasivity, such as space, social, temporal and context. This allows an understanding and design of pervasive experiences that truly address these particularities. In addition, it provides a way by which the degree of pervasiveness of a game experience can be determined, this being achieved through the "Pervasiveness Pyramid" where different levels are proposed according to the pervasive expansions addressed. Finally, the transversal elements to be adjusted according to the target audience and the context of the game were indicated.

Future extensions of this research should include context-specific applications, as well as the approaches applied to each of the transversal elements. In addition, a case of application of the use of the pervasiveness pyramid on a pervasive gaming experience should be provided. All this will provide a basis through which better gaming experiences can be generated, thus improving the entertainment and engagement of players, dedicating more time to them and obtaining better final products.

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