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Heuristics to Improve Player Experience and Playability in Pervasive Games for Older Adults

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ABSTRACT

The adoption of advanced technologies by older adults faces significant challenges due to the technological gap, affecting their ability to fully enjoy innovations in their daily lives. This phenomenon is particularly evident in the realm of entertainment, where technological games can offer substantial benefits to those who venture to use them. Despite the growing interest of older adults in digital games, the complexity of these technologies can hinder their adaptation and effective use. Pervasive technological games, which integrate devices such as virtual assistants, mobile sensors, and virtual reality, represent an example of these innovations. This article explores the key factors for designing game experiences with some degree of pervasiveness that are adapted to the needs and characteristics of the older population, with the aim of improving the player experience and engagement.

1. Introduction

The unfamiliarity that older adults experience with technology prevents them from taking full advantage of the benefits it can offer. This limitation is evident in different situations, such as leisure and fun time. In this sense, it has been shown that technological games have a positive impact on the older adult population that has become familiar with them. Among the games that are particularly effective for this group are those that involve direct and natural interaction, stimulating multiple senses at simultaneously. Pervasive games, an emerging genre, have great potential to generate positive experiences and emotions in older adults [1]. These games can not only be entertaining, but also offer several benefits. They can be easily integrated into the daily routine, encouraging physical activity, cognitive training and socialization, which contributes to the overall well-being of this population group.

Some pervasive games incorporate physical locations, stories and social contexts into their game dynamics, which can be beneficial for older adults in terms of improving their quality of life, especially in physical aspects such as walking and specific exercises [2]. These games are characterized by being more relaxed, avoiding cognitive overload on

players and facilitating their learning and adaptation process. In addition, these games have the advantages of fostering social connections, increasing physical activity and improving mental well-being [3]. They also focus on providing flexible experiences for casual gamers, allowing seniors to learn at their own pace and participate according to their preferences.

In the case of older adults, the pervasiveness of games is not only used as a form of social interaction or generation of emotional well-being, but also as a means for rehabilitation processes and physical and cognitive training. When a pervasive game focuses on promoting exercise, increasing physical activity and is controlled by physical actions, it is known as “exergaming” [4,5]. These games often use virtual reality or motion sensors to create an engaging environment for the player, where physical actions performed can be captured and feedback provided, as well as encouraging light or vigorous physical activity in fun environments. Exergaming is well received by older adults, as they find it a fun and engaging way to be physically active both indoors and outdoors [5,6]. Several research studies have been conducted that focus on physical training through virtual reality for fall prevention [7,8], the use of motion sensors to promote physical activity [9], rehabilitation

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processes after a fall [10], and the impact of social relationships and performance when having these types of experiences in company [11–13].

The application of virtual reality with older adults in the context of pervasivity has been shown to be positive and relevant. Participants who have had previous interactions with virtual reality describe it as fun, engaging and beneficial [14]. Even those who initially have skepticism and lack of knowledge about virtual reality technology experience a change in their attitude after playing, finding it enjoyable and useful [7]. Virtual reality is not only used in exergaming (exercise games), but also in other contexts, such as social and cognitive training, through experiences such as urban adventures in a virtual city, shopping, buying fruit or going to a virtual cinema, where different mental exercises are presented [15].

In this study, an approach to design immersive experiences for older adults is presented, based on our previous published research [16]. This model has been formulated using specific heuristics and checklists, with the purpose of simplifying the creation of game systems based on the notion of "pervasiveness" and providing an enriching game experience, taking into consideration the needs of this demographic group. Unlike our previous publication, here we explain in detail the process applied for the definition and validation by experts of the set of heuristics established to guide not only a process of game experience design, but also a means by which it can be applied to evaluate and identify potential problems in pervasive game experiences oriented to the older adult population.

The text is structured as follows: In Section 2, the concept of pervasivity is contextualized and examples of its previous application in the older adult population are provided. It also reviews our base proposal of transversal elements that are essential to guarantee an optimal game experience by facilitating the interaction between the pervasive experience and older adults; In Section 3, the methodological process employed to define the transversal elements model and its conversion into applicable heuristics is detailed; In Section 4, an analysis of the results obtained is carried out. Finally, in Section 5 the conclusions of the study are presented, and possible directions for future research are raised.

2. Background

The concept of "pervasiveness" has found application in the field of entertainment, particularly in the context of pervasive games. Games of this kind are characterized by being playful experiences that merge with the tangible environment, thus eliminating the boundaries that have historically defined the game [17]. This means that the game is no longer limited to a specific place, time or number of players. Pervasive games transcend traditional space, social, contextual and temporal boundaries, expanding the game space and offering a richer, more

immersive game experience [18] (see Fig. 1).

Pervasive games are distinguished by their ability to combine game rules with elements of the real environment, such as geographical locations, individuals and tangible objects. This fusion generates a singular game experience that transcends the conventional barriers that usually separate the player from reality, generating a greater immersion in the game experience. Additionally, these games promote a robust social dimension, characterized by natural interactions ranging from voice communication to gestures, actions and the manipulation of physical objects. One of the primary benefits of pervasive games is their aptitude to address the challenges inherent in conventional digital games. These games promote both physical activity and social interaction, while linking the intrinsic motivation of the participants [20].

An important distinction of pervasive games compared to traditional games is that the evolution of the game is based on the actions of the participants, as not all players are directly involved in the game or play the same role, but each may have their own interests and motivations. This can generate uncertainty in the objectives of the game, which makes it flexible and dynamic in terms of its direction and development, as well as in the rules that can change for each player depending on their context and game experience.

An example of successful application of pervasive experiences in older adults is the game Pokémon Go [21], where an increase has been observed not only in physical activity through the need to walk, but also in social interaction, which can strengthen relationships between older adults and younger generations and reduce intergenerational gaps and ageism [22]. In many cases, older adults have assumed the role of supervisors of their grandchildren while interacting with strangers through play, which has strengthened their relationships and generated opportunities for intergenerational interaction. This approach has proven to be effective in improving the quality of life of older adults and promoting social integration in a gaming context.

There are a wide variety of examples like the one mentioned above aimed at the elderly population. Some notable examples include titles such as "Age Invaders" [23] and "The Fantastic Journey" [24]. In addition to games aimed at the general public, there are also specific initiatives for older adults. These include escape games such as "A Tale of Tales" [25] and location-based collection games in open spaces, such as "Life Chasing" [26] and "Shinpo" [1]. These games are mainly used to promote physical activity, cognitive training and social interaction in this demographic. Several exergaming-type game applications have been developed that target the older population. These applications include "Dancetown Fitness System" [27], "Smart Chair" [28], "Wii bowling", "Table tennis game" [29], "Basketball Genius", "Flying Eagle", "Ping Pong", "Escape Room" [30], "Safari Move" [31] and "SportWall" [32].

To design pervasive game experiences that are adapted to the needs of the older adult population, it is essential to consider the physical and cognitive particularities of this group. To achieve this, a previous systematic review was carried out [33] which examined the use of pervasive game experiences in older adults. This process provided detailed information on the different experiences offered through pervasive game-based systems (GBS) for this population. The review was conducted following the methodology established by Kitchenham and Charters [34], which establishes a series of tasks for the application of systematic reviews in the software field. A search string with logical operators and relevant words was used to efficiently filter the results obtained. In addition, inclusion and exclusion criteria were defined to select relevant papers and reduce the total number of articles to be treated in the proposal presented here (see Fig. 2).

3. Proposed model: pervasiveness pyramid

After conducting the exhaustive systematic review [35], identified a series of elements of primary consideration in the design of pervasive game experiences oriented towards the older adult population. These



Fig. 1. Pervasivity expansions [19].

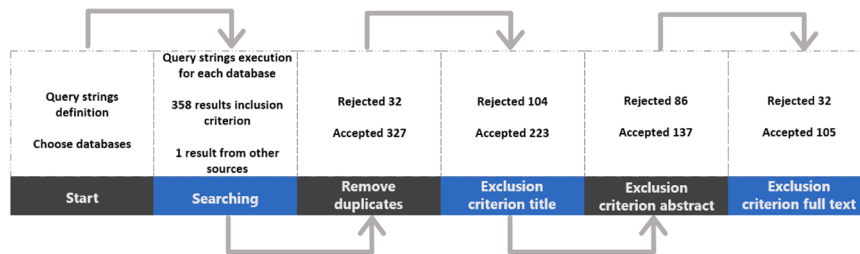


Fig. 2. Systematic literature review process [33].

findings were used to define a model called the "pervasiveness pyramid", which emerged as an effective means to evaluate the degree of pervasiveness provided by a game experience [19] (see Fig. 3). In addition, we identified a set of transversal elements that deserve special attention in the context of the older adult population. It is important to note that these elements can be easily adapted and extended to any type of pervasive game-based system and target population [36].

The "pervasiveness pyramid" presents a conceptual structure comprising three levels of integration in the context of pervasive game experiences. The initial level addresses the integration of physical and virtual environments using technologies in a specific context, which influences the game experience. The intermediate level focuses on the incorporation of space and social dimensions into the game environment. Finally, the advanced level encompasses the combination of all the above elements. However, up to this point, it has been outlined what aspects should be included in a pervasive experience in a general way, but no guidance has been provided on how to carry out such integration. The methodology to achieve this is based on the adaptation of the transversal elements identified, which must be adjusted according to the nature of the pervasive game system and its target audience, in this case, the older adult population. These identified elements focus on technology-based pervasive game systems, with the primary objective of offering an enriching game experience. The elements identified encompass aspects such as the technology employed, the game narrative, the aesthetics, the purpose of the game, the rules governing the game and, crucially, the ethical components guiding its development and application.

Ultimately, in the conceptualization of this model, it became necessary to specify different properties for the various expansions of pervasivity. These properties played a key role in the subsequent formulation of heuristics and checklists intended to provide a means by which they can be applied in the detection of potential design problems and in the evaluation of playability.

4. Materials and methods

To provide an exhaustive description of the generation of the explained "pervasiveness pyramid" model and the transversal elements

that should be considered to optimize the game experience in GBS with some degree of pervasiveness aimed at the elderly population, a rigorous search and definition process was carried out using a methodology designed to put the proposed theoretical model into practice. To achieve this purpose, the heuristic definition methodology proposed by Quiñonez et al. [37], which details a formal process of heuristic definition, was applied.

This proposal is composed of a total of 8 stages which direct the process with different inputs and outputs. The stages in question are the following: Exploratory, experimental, descriptive, correlational, selection, specification, validation and refinement stage (see Fig. 4). As result of the application of this methodology, a set of heuristics was developed and validated in the first instance through expert judgment, due to the desire to refine the proposed model through the opinion of different experts in the field, with previous experience in pervasive digital games or experience in the application of games in older adults.

5. Exploratory and experimental stage

A systematic review was conducted as part of an exploratory process aimed at gathering insights into the gaming experiences of older adults, with a particular focus on pervasive games [33]. This review also examined current approaches to the application of gaming experiences, the level of acceptance among older adults, and the various mechanics and dynamics employed for this population [16]. The findings, which encompass theoretical and practical considerations, conducted to the development of a model featuring transversal elements to improve the experience of the older adult player in pervasive GBS.

It should be noted that, although different sets of playability, usability, player experience (PX), user experience (UX) and similar heuristics have been identified in the different stages of application of the methodology used as a guide, the objective of the heuristics sought to be defined is specifically focused on the evaluation of the game-based system and the experience it offers, taking into account its particularities. Although mentioned and used as a reference in the methodological process, and compared with previous proposals, the proposed heuristics presented will have their own nomenclature and specifications, in the hope that these will be the basis for extending the playability analysis

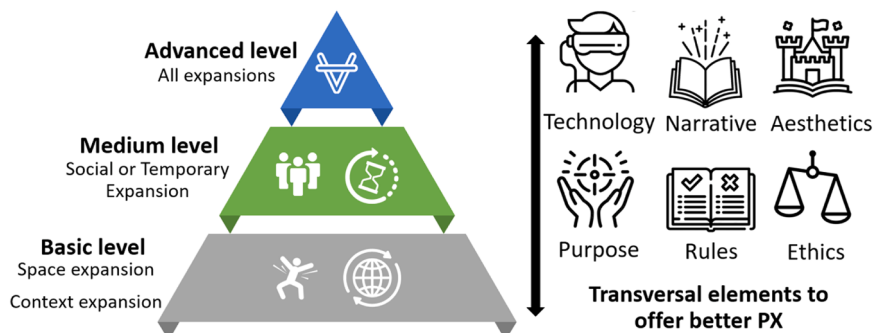


Fig. 3. Pervasiveness pyramid and its transversal elements [19].

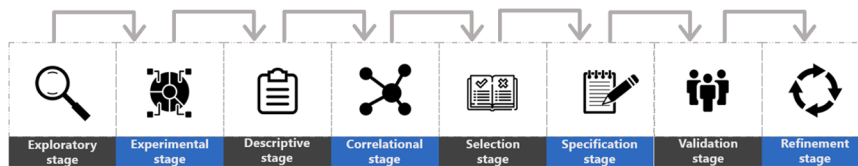


Fig. 4. Stages performed to establish pervasiveness heuristics [38].

proposed by Gonzales and Gutiérrez [39], which is currently the most complete and detailed proposal in terms of playability analysis at game and product level, as well as in the evaluation of player experience. It should be noted that the data corresponding to the experimental phase were obtained through a rigorous systematic review process, eliminating the need to carry out additional experiments to obtain the required information.

6. Descriptive stage

The systematic review focused on identifying pervasive game experiences in the older adult population [33]. The results indicated that these experiences are mainly applied for the promotion of physical and cognitive activity and the generation of feelings of wellbeing at a social and learning level. In addition, it was possible to identify characteristics and particularities of these pervasive game experiences that served as a basis for the definition of the considerations that should be considered for the design of pervasive experiences for this population. The results obtained by Rienzo and Cubillos were also considered [40], which conducted a similar systematic review but not applied to pervasive experiences, but rather game experiences in general. Both reviews found playability and PX heuristics, as well as usability and UX heuristics applied to GBS.

In relation to existing research on **pervasive game experiences specifically applied to the older adult population**, there are no models, specific recommendations or heuristics for the evaluation of playability specifically oriented to the older adult population, but there are cases of application of pervasive game experiences for commercial or therapeutic purposes [22].

For the design of game experiences that best suit the older adult population, the application of **dynamics** oriented to physical activity, cognitive training and the application of immersive and non-immersive experiences stand out, some of them being the work done by I. Awada [41], G. de Paula [42] and S. Merilampi [43]. With respect to the mechanics implemented, a high percentage of application is found in the use of challenges, the experiences offered, the obtaining of points to evaluate the performance of the participants, the findings and the thematic application to favor the experience lived by the older adults. Some of these works are those carried out by J. Fiorini [44], E. Seah [45] and M. Tabak [46].

Regarding heuristics specifically oriented to **playability** for the evaluation of the game as a product, we find the list proposed by Desurvire et al. [47] with 4 areas of evaluation but not oriented to the older adult population: gameplay, game history, mechanics and usability. Also noteworthy is the proposal made by Paavilainen et al. [48, 49] on social networks but also not oriented to this population. On **PX** oriented heuristics, there is the work done by Salgado et al. [50] oriented to older adults but only in applications for mobile devices. Regarding **playability properties**, the set of 7 properties defined by Gonzales and Gutiérrez was taken as follows [39] because these are the most complete, of greater reference at present and are aimed at both the evaluation of the game as a product and the evaluation of the player's experience.

In addition, because PX is a particular case of UX, the facets defined by Morville will be considered [51] due to its high relevance as general knowledge base. The 10 Nielsen **usability** heuristics are also considered [52] for the same reason and its possible application to the field of

digital gaming [53]. Among the usability heuristics considered that are specifically oriented to older adults, the study carried out by Silva et al. [54] The results of this research are a set of 33 heuristics to find alternatives for the design of interfaces and interaction mechanisms with this population. Other relevant research on mobile devices oriented to older adults are those carried out by Lee et al. [55] and Santos et al. [56], which provide a set of rules and specific recommendations. These heuristics focus on identifying usability issues in this population, but only on mobile devices and not on pervasive experiences per se. Some initiatives focused on obtaining qualitative information from participants, oriented on aspects of location-based gaming experiences. In this regard, we find the work carried out by Fornasini et al. [57], learning assessment - satisfaction researched by Palacio et al. [58] and experiences of escape games as proposed by Doroudian et al. [25].

The following tables show a summary of the different elements considered for the correlation of the model defined on relevant aspects of technology-based pervasive game experiences in older adults (see Table 1), playability - usability (see Table 2), and PX - UX (see Table 3). The elements considered of high importance (rated 3), are those pervasive experiences that are applied to the context of older adults or that are the basis of knowledge of the specific area of games such as playability or PX. The documents that are considered of interest (rated 2), are those that either do not focus specifically on pervasive game experiences, but on game experiences applied to older adults, or that are knowledge base in related areas such as UX and usability. Finally, the papers considered unimportant (rated 1) are those that are based on theories already taken as a reference, which were not applied to older adult contexts or in pervasive game experiences. In addition, game experiences that, although pervasive and applied to older adults, did not offer relevant heuristics or specifications to be used as a basis for the construction of the proposed model, were categorized as unimportant.

7. Correlational stage

Several elements have been identified that should be considered in the design of pervasive game experiences for older adults. These elements include aspects related to the aesthetics of the game experience, the narrative, the purpose, the rules, the ethics, and the technology that will be used to facilitate the pervasive experience.

To verify that these elements cover the various characteristics of pervasiveness, correlations were carried out with each of the heuristic proposals and selected findings. These correlations have revealed that the proposed elements have sufficient scope to address the reference characteristics, in addition to addressing aspects that have not been considered in the existing definitions (see Table 4). The information with ID P03, P04 and PLP06 were excluded because it was information obtained properly for the generation of the identification of the transversal elements to be considered in the proposed model, being obtained through systematic reviews, which included application cases, but not heuristics. The information obtained with ID P01 and P02 was excluded because it was taken as a reference for the structuring and design of the proposed model. The information PLP07 was omitted because there are more current models, such as PLP01, which is based on this model. PLP08 was not considered because it was not applied to contexts of older adults or in pervasive game experiences. Finally, the information from PLP01 will be evaluated together with PXP01 because these models are from the same source of information but have different approaches.

Table 1

Prioritization of information obtained from relevant aspects in pervasive game experiences.

ID	Rating	Topic	Source
P01	3	Findings own systematic review	Salazar J. et al. (2022): Systematic review carried out in its own way [33].
P02	2	External systematic review findings	Rienzo A., Cubillos C. (2020): External systematic review [40].
P03	1	Case study of application of a pervasive experience	Fornasini et al. (2020): Using geocaching to promote active aging [57].
P04	1	Case study of application of a pervasive experience	Palacio et al. (2017): Perception of the usability of different video game devices in elderly users [58].

Table 2

Prioritization of information obtained from playability (product) - usability for pervasive contexts.

ID	Rating	Topic	Source
PLP01	3	Playability	González J., Gutiérrez F. (2010): Playability attributes oriented to the evaluation of the game as a product [39].
PLP02	2	Playability	Santos L. (2017): Design and evaluation of mobile games for older adults [56].
PLP03	2	Playability	Lee S.: Game design guidelines for mobile devices to improve the gaming experience for the older adult population [55].
PLP04	2	Usability	Nielsen J. (1994): Nielsen's heuristics as a knowledge base for the identification of potential problems in information systems, but with possible application in digital games [53].
PLP05	2	Usability	Silva et al. (2015): list of heuristics for evaluating smartphone apps for older adults: a study of apps aimed at promoting health and wellness [54].
PLP06	1	Playability in a practical case of application of a pervasive experience.	Doroudian et al. (2020): Designing an online escape game for older adults: The implications of playability testing sessions [25].
PLP07	1	Playability	Desurvire et al. (2004): Heuristics for assessing the playability in games [47].
PLP08	1	Playability	Paavilainen et al. (2015): Playability problems specific to social networking games [217].

8. Selection stage

No specific heuristic sets oriented to design specifications of pervasive game experiences oriented to older adults were found, but playability heuristics applied to game experiences on mobile devices for older adults were found. Playability heuristics were also found oriented to a general audience, i.e. to a general group of players, but not in pervasive experiences. User experience and usability heuristics were also found, but oriented to transactional systems.

Since no specific base heuristics were available, it was decided to build a new set, taking as a reference the findings previously described. This set is based on the following elements specified as relevant in the

design of pervasive experiences oriented to the older adult population (see Table 5). It should be noted that each defined pervasive element was classified based on the properties and specifications established [16] and based on the playability attributes defined by Gonzales and Gutiérrez [39] because it is the main source of knowledge, and it is expected to generate an extension of this model. Finally, in this classification process, no coincidence was found regarding playability attributes and the ethics that should be considered in the orientation of the game in older adults, this being an element not considered so far in any source obtained in the review process.

9. Specification stage

For each transversal element identified, it was structured according to the guiding methodology, resulting in the different heuristics that will be used as an evaluation instrument. For each one, an identification code was assigned to each heuristic generated. The heuristics were given a name, a priority and a basic definition. Then, the purpose of the heuristic was explained in detail, the characteristic of the pervasive experience it affects, an example of application was given, and the benefits of the heuristic for the older adult population were explained. Finally, possible interpretation problems of the heuristic were addressed, a guiding

Table 4

Correlation between proposed and existing pervasive design features.

ID	Motivating aspects not included in this background information	Focus of the base information and aspects included
PLP01 PXP01	Game experience ethics.	Although it is the most complete proposal available, it is not oriented to pervasivity or older adults.
PLP02	Ethics and narrative of the game experience.	Heuristics only oriented to game experiences on mobile devices.
PLP03	Ethics of the game experience.	Heuristics only oriented to game experiences on mobile devices.
PLP04	Narrative, purpose and ethics in the game experience.	Heuristics oriented to product quality and the detection of possible failures, but not specifically oriented to pervasiveness.
PLP05	Technology, narrative and the ethics of the game experience.	Heuristics only oriented to mobile device experiences.
PXP02	Ethics in the game experience	UX facets oriented to transactional systems, not pervasive game systems or older adults.
PXP03	Rules, narrative, purpose, ethics and sound aesthetics in the game experience.	Proposed heuristics for evaluating UX in mobile environments, oriented to older adults, but not in game environments.

Table 3

Prioritization of information obtained PX - UX for pervasive contexts.

ID	Rating	Topic	Source
PXP01	3	Player experience	González J., Gutiérrez F. (2010): Characterization of the player's experience in videogames [39].
PXP02	2	User Experience	Morville P. (2004): User experience facets [51].
PXP03	2	User Experience	Salgado F. et al. (2019): Heuristic definitions on mobile devices, applied as a practical guide on UX evaluation [50].

Table 5

Key transversal elements definition.

Proposed key element	Pervasive property covered	Justification
Aesthetics	Virtualization, awareness	The experience of the older adult population is optimized when an environment is created that is aesthetically appealing and facilitates interaction.
Narrative	Evolution, Integration	The expanded narrative in pervasivity generates dynamism in the game experience.
Technology	Mobility, tangibility, persistence, evolution, surveillance, transmediality	Technological devices for older adults should be designed with their specific needs and capabilities in consideration.
Purpose	Social experience, social interaction, mediation, participation.	The pervasive experience can serve a variety of purposes, such as entertainment, health improvement, promotion of learning or socialization.
Rules	Integration, pop-up playability	The dynamics and mechanics of the game must be adjusted to the particularities of the older adult population to offer a safe and adequate game space.
Ethics	Mobility, mediation	Games for older adults should ensure their physical and cognitive health, promote respect and culture, avoid negative emotional states and not be used for hidden purposes.

checklist for the heuristic is proposed, it was indicated to which transversal element of the defined model it corresponds to, the pervasive property addressed was associated and it was indicated to which playability attribute and playability dimension it corresponds to. It should be noted that, depending on the different technologies used in the pervasive experience, some elements defined in the checklists may not be applicable, and therefore should be omitted depending on the evaluation context. A total of 9 heuristics were defined from the 6 transversal elements identified, as follows (see [Table 6](#)).

10. Validation stage

With the proposed heuristics ready, an expert judgment evaluation is carried out to validate and refine them, so that these heuristics can be applied in a real environment through heuristic evolution and user testing. To achieve this, 9 evaluators were recruited who were interested in participating in the process, of which 5 evaluators had postgraduate training at master or doctoral level in the field of HCI, with previous experience in the application of this type of evaluations and in the field of GBS. The other 4 evaluators were involved in the process because of the need for insight from people with experience interacting with older adults, as well as specific social analysis between human and technology interaction. Of these, 2 of the evaluators had experience interacting with older adults and the other 2 evaluators were anthropologists with prior experience in technology and GBS. The latter 4 evaluators had no previous experience in the execution of heuristic evaluations, and prior training on this was necessary for them to execute an adequate and objective evaluation.

The questionnaire was structured in an electronic document that was sent to the evaluators explaining in detail the process to be carried out. The questionnaire included the dimensions of usefulness, clarity, ease of use and the need for a checklist as a complementary element, being structured in a total of 49 questions (Appendix A).

For each heuristic 4 questions were defined to evaluate them individually for each of the dimensions, using a 5-point Likert scale where a value of 1 indicates that the heuristic does not comply with its dimension and a value of 5 indicates that it complies completely. In addition, each

Table 6

Summary of defined heuristics.

ID	Heuristics	Definition
PH01	Aesthetically pleasing and minimalist visual environments	The pervasive game experience must offer simple, clear and attractive environments to facilitate interaction with the game and generate positive feelings.
PH02	Immersive sounds that represent the actions performed	A pervasive game experience that is effective for older adults should use immersive sounds that generate familiar memories and emotions. These sounds can help older adults feel connected to the game and understand their progress.
PH03	Secure and adjustable interaction	Immersive game experiences must be safe, appropriate and specific to the needs and characteristics of older adults.
PH04	Continued support and feedback to guide and instruct the older adult	The pervasive game experience should provide the older adult with clear, consistent guidance and opportunities for feedback. This will help ensure that older adults can enjoy the game experience without obstacles.
PH05	Provide purpose and highlight the benefits of the game experience	The pervasive game experience should offer the older adult an environment that generates well-being and positive feelings, as well as fun. The benefits of using this experience should be highlighted clearly and concisely.
PH06	Simple rules and balanced difficulty	Experiences should be offered that require short periods of time, with simple regulation, with balanced difficulty, and with the possibility of individual or social interaction.
PH07	Pleasant and easy-to-use pervasive technologies	To offer pervasive experiences, technological devices and peripherals must be direct and natural input, with few buttons, portable, effortless, immersive and easy to configure.
PH08	Extended narrative with meaning	The extended narrative should provide a clear and coherent context for the player's actions. It should also generate positive emotions, such as surprise, expectation and empathy. In addition, it should encourage curiosity and learning, and provide the player with a sense of recognition and usefulness for their actions.
PH09	Ethics and safety in the game experience	The pervasive game experience must provide the older adult with a safe and respectful environment, both physically and cognitively. This environment must protect their data and states of mind, avoiding any kind of exploitation or abuse.

heuristic had an optional open-ended question to obtain qualitative information from the evaluator. Subsequently, the evaluator would find 3 additional questions to evaluate the heuristics together from its ease, intention to use and completeness being structured also with the Likert scale. Finally, the evaluator would find 1 optional question to obtain any other type of additional information that the evaluator would like to provide.

For each heuristic, the dimensions evaluated from D1 to D4 are described below. The questions focused on evaluating the heuristics as a group from Q1 to Q3. The question available for each heuristic to obtain qualitative information from H1 to H9. Finally, the question set to obtain qualitative information about additional heuristics is included in C1:

- **D1:** How useful are heuristics as a motivating factor in older adults to interact with game-based systems?

- **D2:** How clear are the heuristics to be applied in the design of game-based systems oriented to older adults?
- **D3:** How easily do you think this heuristic can be implemented in the design of game-based systems targeted at older adults?
- **D4:** How necessary is it to supplement the heuristics with a checklist?
- **H1–9:** What elements do you think are missing or should be included in this heuristic?
- **Q1:** How easy was it to perform this heuristic evaluation?
- **Q2:** Would you use this set of heuristics for the design of pervasiveness game-based systems targeted to older adults?
- **Q3:** Do you think that the set of heuristics presented covers all the aspects that can motivate older adults with respect to their participation in pervasiveness game-based systems?
- **C1:** Do you think that more heuristics should be included to those already defined and for what purpose?

11. Results

Responses were obtained from the 9 experts who participated in the process (see Table 7). The results of the responses are as follows, focusing on the individual analysis of the heuristics with respect to the usefulness, ease, clarity and necessity of a checklist. The results of D1 - Usefulness, show that the mean of this is the highest of all dimensions (4.70). Heuristics 5 and 4 are considered by unanimity of the evaluators as the most important to implement, thus highlighting the visual aesthetics of the game and the support. The overall standard deviation is low (its range is 0–0.53). All this indicates that the heuristics presented, evaluated individually, are useful for the design and evaluation of pervasive game experiences applied to older adults.

As for the results of D2 - Clarity, its mean is also high (4.65), with a range between 4.44 and 4.78 where heuristics 1, 3 and 4 are the clearest of all. Its standard deviation is also low, being the minimum value (0.44) in several heuristics. In addition, it is remarkable that the 2 heuristics rated as the most useful are also rated as the clearest and most detailed. As for the results of D3 - Ease, although the mean is the lowest of all, it is still an acceptable value (3.64). Heuristics 5 and 9 are the least easy to use (3.33 and 3.22 respectively) and heuristics 4 and 6 are the easiest. Their variation is one of the most significant with a range of 3.22–4.11. Their lowest standard deviation is with heuristic 4 (0.33).

Finally, regarding the need for a checklist to obtain more details, it is very high (4.51), which is understandable due to the results obtained in ease, this being a point to improve to approach the ease of use of the heuristics. All heuristics achieved a high average value with a minimum value of (4.11). In addition, heuristics 1, 6 and 9 are the highest scores with 4.67, being directly proportional to its ease, being these same heuristics rated as “acceptable” in this aspect. Heuristic 8 is characterized by having a high standard deviation with a value of (1.17). The experts’ perceptions are similar for all dimensions, except for the ease of use in multiple heuristics.

This contrariety, evidenced by the standard deviation obtained in the

evaluation of the ease of use in the heuristics that had an “acceptable” rating, may be due to the participation of some evaluators with no experience in this type of process, but their appreciation of their experience and suitability in the social field was also necessary. To generate a set of heuristics that fit as many fields as possible, the heuristics were reviewed to make them easily applicable, through checklists, recommendations and possible interpretation problems (Appendix B).

The overall perception of heuristics with respect to ease, completeness and intention to use can be seen in Table 8. The perception of the intention to use the heuristics was the highest rated item with a mean of 4.78, which makes the application of the set of heuristics presented attractive to the evaluators. For both easiness of use and completeness of the heuristics, positive results were obtained with a mean of 4.11 and 4.22 respectively, and a standard deviation of 0.33–0.44. All the above reflects a completely positive result with respect to the heuristics presented as a whole, although as will be seen in the qualitative results there are elements that can be improved.

In relation to the questions optionally asked for each of the heuristics, additional information was obtained with respect to heuristics 2, 3 and 9. The comments made, and actions taken based on these can be seen below in Table 9.

Finally, the answers obtained in the final question on the heuristic or missing elements presented by the experts made some observations. Table 1 shows these observations made and specifies whether to accept them for the revision of the heuristics as appropriate. It should be noted that one of the expert evaluators was satisfied with the completeness of the elements contemplated in the heuristics. Table 10

Based on all the comments and results of the evaluations carried out, a refinement was made in the process of specifying the heuristics according to the base methodology. The heuristic specifications contain different elements such as its nomenclature, its name, its priority, its definition, its detailed explanation, the characteristics of the serious game it affects, the benefits of its application and its possible interpretation problems. The priority of these was established at three levels: (1) useful, (2) important, (3) critical. A heuristic set as (1) indicates that the heuristic, although useful, can be improved. Ranking (2) indicates that the heuristic is important and should be considered but is not mandatory because it depends on the context of the application. Finally, priority (3) establishes a key heuristic that must always be satisfied. The whole set of heuristic specifications can be found in Appendix B.

It is important to highlight the fact that from the whole process of refinement of the heuristics and in search of greater ease of application

Table 8
Survey results for questions Q1, Q2, and Q3.

	Q1 Easiness	Q2 Intention of future use	Q3 Completeness
Mean	4,11	4,78	4,22
Std. dev.	0,33	0,44	0,44

Table 7
Survey results for dimensions D1, D2, D3 and D4.

	D1 Useful		D2 Clarity		D3 Easily		D4 Checklist	
	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.
Heuristic 1	5	0,00	4,78	0,44	3,78	1,20	4,67	0,50
Heuristic 2	4,44	0,53	4,67	0,50	3,78	0,83	4,44	0,53
Heuristic 3	4,78	0,44	4,78	0,44	3,44	1,01	4,56	0,53
Heuristic 4	5	0,00	4,78	0,44	4,11	0,33	4,56	0,53
Heuristic 5	4,67	0,50	4,44	0,53	3,33	1,12	4,56	0,53
Heuristic 6	4,78	0,44	4,67	0,50	4	0,87	4,67	0,50
Heuristic 7	4,67	0,50	4,67	0,50	3,56	1,13	4,33	0,87
Heuristic 8	4,44	0,53	4,56	0,53	3,56	1,01	4,11	1,17
Heuristic 9	4,56	0,53	4,56	0,53	3,22	0,97	4,67	0,50
Mean	4,70		4,66		3,64		4,51	

Table 9
Individual heuristic comments.

Heuristic	Evaluator's comment	Action taken
Heuristic #2	What if the older adult has problems and does not hear sound well, is it supplemented with something?	In the heuristic specifications it was clarified that, as far as possible, sound should be used as a complement to other media to deliver information such as images, videos, etc. In addition, a checklist was generated including this recommendation.
Heuristic #3	Heuristics 3 and 9 are similar, it is important to specify that one is focused on the safety of the elderly at a physical and cognitive level and 9 only on the protection of their personal data, otherwise they must be the same, considering the narrative in its description.	In the heuristic specifications, in the interpretation problems sections, it is clarified that heuristic #3 approaches security from a game-based system interaction point of view, while heuristic #9 approaches security from a strictly ethical point of view, these 2 elements being different.
Heuristic #9	As a heuristic that discusses legal issues and value judgments, I suggest supplementing the explanation so as not to give rise to misunderstandings. I suggest expanding the examples of the heuristic.	Application examples were defined to provide a better understanding of this section. In addition, it was complemented with a set of checklists to guide the evaluator in its application.

Table 10
Heuristics group comments.

Evaluator's comment	Action taken
It is necessary to generate or establish those limits between the real and the virtual, because older adults will face a whole experience that can affect them cognitively and physically, which can generate shocks, anguish or fail to understand that reality, the senses are deceived and can play for or against, at that point, what mechanisms will be taken into account so that players keep in mind that it is only a game that will help them cognitively, physically and in their social interactions.	It was made clear to the evaluator that all these elements are incorporated transversally in the set of heuristics presented. To generate greater clarity on this, each heuristic presented was refined with different elements so that the definition of this was clear and oriented to the safety of the elderly.
All the proposals are in accordance with the purpose and practical, bio-healthy and social fulfillment of the proposal. I would propose an organization by categories of heuristics.	It was made clear to the evaluator that this set of heuristics comes from a previously defined model of pervasiveness, where these heuristics are found in higher level categories. To demonstrate this, an additional field called "Associated transversal element" was defined in the set of heuristic specifications, in which it is established to which transversal category of the pervasive aspects it belongs.

regardless of the area of expertise of those who make use of them, a detailed set of checklists was generated for each proposed heuristic, with a total of 99 different recommendations, which are found in the specification forms located in Appendix B (see [Table 11](#)).

Finally, based on the set of heuristics specified, the PL/PX web platform [59] has been defined for the design and evaluation of game experiences aimed at the older adult population, where the pervasive component is very important (see [Fig. 5](#)).

12. Conclusions and future work

Technology-based pervasive GBS offer numerous opportunities for the older adult population, but its design and implementation must consider their particularities. To achieve this, it is essential to fully

Table 11
Total checklist items generated.

ID	Heuristics	Checklist items
PH01	Aesthetically pleasing and minimalist visual environments	18
PH02	Immersive sounds that represent the actions performed	6
PH03	Secure and adjustable interaction	11
PH04	Continued support and feedback to guide and instruct the older adult	12
PH05	Provide purpose and highlight the benefits of the game experience	8
PH06	Simple rules and balanced difficulty	14
PH07	Pleasant and easy-to-use pervasive technologies	7
PH08	Extended narrative with meaning	11
PH09	Ethics and safety in the game experience	12
		99

understand the possibilities offered by pervasivity in terms of dimensions, features and key elements such as narrative, aesthetics, technology used, game rules, purpose and ethics. These elements make it possible to offer more immersive and meaningful gaming experiences for participants, moving the game from the virtual world to the real world, with interesting themes, deep narrative and fluid interaction with the game.

The proposed model of transversal elements was subjected to evaluation through a process of expert judgment. Different evaluators with expertise in the fields of HCI, digital games and interaction with older adults, with profiles including engineering, social and anthropological aspects, participated in the evaluation. The results of this evaluation showed that the proposed model, represented through a set of heuristics, was easy to use, useful and aroused interest and intention of use in their respective professional fields. The results obtained were consistent in both qualitative and quantitative terms. Based on these results, a process of improvement of the set of heuristics presented was carried out, adjusting their specifications, addressing possible interpretation problems, providing examples of application and generating a complete checklist covering the different heuristics proposed.

The use of a standardized methodology for the definition and objective evaluation of the heuristics has allowed a clear definition of the proposed approach. It has been observed that there is a discrepancy of opinions regarding the need for checklists as a complementary element in some heuristics during the design and implementation process of pervasive GBS. This discrepancy is due to the different profiles of those involved, such as people with experience in interacting with older adults and anthropologists, who had no previous experience with the concept of heuristics.

Although a practical validation process has not been carried out with end users, specifically older adults, through a pervasive prototype, the advances achieved will be of great use as design guidelines for future developments. It is expected that these future products will be designed with the unique characteristics of the older adult population in mind, which will allow for a more fluid interaction with GBS and significantly improve the player's experience. In future work, we seek to achieve a seamless integration between the characteristics of the gaming experience and the motivations of older adults, using specific playability evaluation instruments such as those developed on the PL/PX web platform, being simple, intuitive and enjoyable, with the objective of evaluating the game as a product and the fun experienced by the participants.

CRedit authorship contribution statement

Gutiérrez Vela Francisco Luis: Writing – review & editing, Writing – original draft, Methodology, Investigation, Conceptualization. **Salazar Cardona Johnny:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Conceptualization. **Moreira Fernando:**

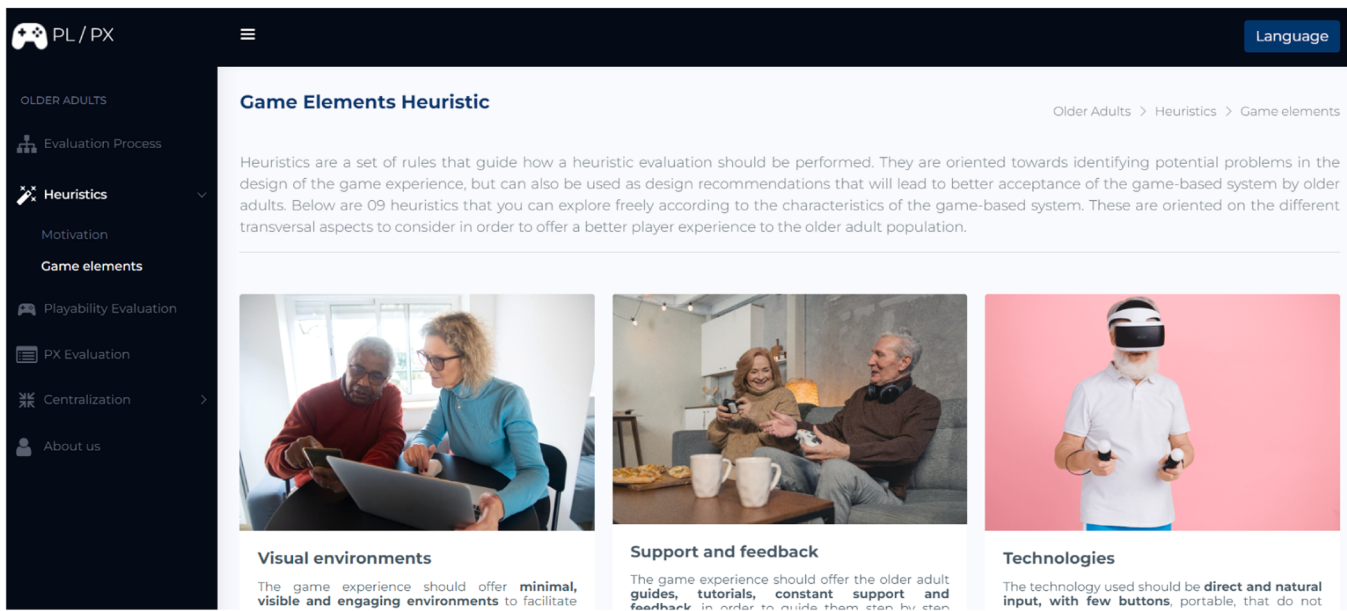


Fig. 5. PL/PX Platform developed [59].

Writing – review & editing, Writing – original draft, Methodology, Investigation, Conceptualization. **Arango Lopez Jefferson:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Conceptualization.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Fernando Moreira reports financial support was provided by Foundation for Science and Technology. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A

Evaluation form is available at: https://1drv.ms/x/s!AkaBCG8z281SgeEMFBr1kHbBQP_3nQ?e=wntaLB

Appendix B

Heuristics specifications is available in: <https://1drv.ms/b/s!AkaBCG8z281SgeEOByt1JQEb7jxTpQ?e=58MmUw>

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