Sánchez de Francisco, M., Díaz, P., Onorati, T. et al. Connecting citizens with urban environments through an augmented reality pervasive game. Multimed Tools Appl 82, 12939–12955 (2023).

DOI: 10.1007/s11042-022-14055-9

Connecting citizens with urban environments through an Augmented Reality Pervasive Game

Mónica Sánchez de Francisco[1], Paloma Díaz[1], Teresa Onorati[1], Ignacio Aedo[1]

[1]*Department of Computer Science, Universidad Carlos III de Madrid*

email: mosanche@inf.uc3m.es, pdp@inf.uc3m.es, tonorati@inf.uc3m.es, aedo@ia.uc3m.es

Corresponding author: Teresa Onorati, tonorati@inf.uc3m.es

Abstract. The concept of Playable City situates games in public spaces to create connections between the citizens and the urban environment. To this end, Augmented Reality (AR) and pervasive technologies can provide additional information about urban objects or places and support innovative and engaging experiences to increase the user interest in the surrounding area. Understanding how these experiences affect the user interest is crucial for reaching a well-established connection between the people and the spaces around them. Our contribution is a preliminary framework to evaluate how being engaged in a playful activity improves interest and awareness in a specific urban area. The framework is based on the situated motivational affordances to establish a correlation among the users' motivations, the situation, and the employed technological artifact. We use an AR pervasive game to evaluate a playful historical experience as a technology probe. The results suggest that while playing the game, the citizens started to show a growing interest in the historical facts around them. At the same time, they began to raise concerns about other issues like sustainability, socio-environmental, and socioeconomic development.

Keywords: AR Pervasive Games, Playable Cities, User Engagement, User Interest, Situated Motivational Affordances

1. Introduction

The concept of Playable City emerges from the integration of playful experiences in the smart city to move from a sheer data-centric to a human-centric perspective aiming at making cities more enjoyable and humanized [1]. Since the concept was coined at the Pervasive Media Studio in Bristol to refer to artistic projects [2], many experiences have been proposed to improve urban spaces' knowledge and connect citizens amongst them or with the city itself [3–8]. Playable cities use the urban spaces as scenarios to play games to promote specific behaviors, attitudes, or interests. They provide an opportunity to experience urban environments differently from their routinary uses, meanings, and services [8] to provoke awareness about specific problems or attitudes. For instance, the application Gamifying the City [3]engages citizens in healthier habits and more ethical and collaborative behavior in society, mixing Augmented Reality (AR henceforth) and gamification elements. Similarly, Chronica Mobilis [9] brings attention to the effects of gentrification in downtown areas. As AR and pervasive technologies become more and more available thanks to the advances in affordable smartphones and powerful 5G networks, playable cities can effectively increase urban awareness and civic engagement.

Playful experiences with the city can impact how people perceive the urban spaces [10–12] , but the role of the underlying technologies in this impact is still an open issue. In this work, we are interested in understanding how to assess playable cities going beyond usability, user experience, or user engagement criteria to explore their effect on users' motivations. Hence, we introduce here the evaluation of a case study that has been performed under the lenses of the situated motivational affordances model [13]. This conceptual model roots in the relation of three key design constituents: the situation (in our case, the playable city), the affordances enabled by the employed artifacts (in our case, AR pervasive games), and the success of the interaction (in our case, raising user awareness on the city). However, this model only identifies a very abstract conceptual framework but does not establish any specific evaluation process nor defines any evaluation criteria or mechanism. In this work, we try to go a step further by proposing a preliminary evaluation framework that integrates the situated motivational affordances [13] along with the user engagement factors by O'Brien et al. [14] and the concept of Personal Urban Awareness [15] to assess how a pervasive AR game influences user interest and awareness. The framework follows a two steps method: first, the participants engage in a playable city that acts as a technology probe, and second, we collect qualitative and quantitative data about their experience. As a technology probe, we use the pervasive AR game introduced in [15]that recreates a historical fact in one of the university campus buildings. The place was an excuse to involve participants in a game that reminded the original use of the building, now forgotten in the hectic life of the city. We tested the evaluation framework with 20 participants and obtained some interesting results. They all considered the experience with the pervasive AR game as an effective way to improve the connection between them and the place. Specifically, in the user interest and awareness evaluation, there is a strong correlation between the situational motivational affordances and the user engagement after the interaction with the game. Based on this result, we can state that interacting with the pervasive AR game makes people more interested and aware of certain urban spots' historical, social, or environmental issues after the experience.

The paper is organized as follows. Section 2 introduces the background of this research about situated motivational affordances, user engagement, user interest, and personal urban awareness. Section 3 describes the AR pervasive game used as a technology probe in the empirical study. Section 4 describes the evaluation framework, whose application and results are described in Section 5. The paper ends by pointing out lessons learned and limitations of the experiment in Section 6 and drawing some conclusions about the work in Section 7.

2. Related Works

Playable cities examples usually make use of pervasive and location-based games to combine the virtual and physical world by placing digital elements in the physical space and enabling interactions between both worlds [16, 17]. These games provide new ways to explore the city [18] and establish connections with the scenarios where they occur. The methods proposed to evaluate the experiences focus mainly on measuring factors like the number of participants, the active versus passive attitude during the game [8], the number of app launches, the number of game actions performed [19], as well as the duration of each gaming session and the personal motivations for playing the game [20, 21]. Still, it would be interesting to understand if such playful experiences can create emotional links, enhance the connection with the urban environment or impact the way people perceive it. Hamari et al. [22] have collected several empirical studies that analyze how the popular game Pokémon Go affects issues like sociability and social capital development. However, there are few contributions to the correlation between the physical space and the pervasive AR games and, more specifically, the impact on the users' perception and interest [23]. In this paper, we propose a preliminary evaluation framework that contributes to finding such correlations. To this scope, we review in this section relevant concepts needed to understand and assess playable cities, including situated motivational affordances, user engagement, user interest, and personal urban awareness.

2.1 Situated Motivational Affordances

James J. Gibson coined the term *affordances* in 1979 to describe the possibilities for action related to the properties of the environment or the objects and the actor's capabilities. For instance, the affordances represent how the actor is “equipped” to act about the objects or properties (e.g., a tree affords climbing to a monkey, yet not a zebra). Later, Donald Norman [24] appropriated the concept and introduced it to the discipline of Human-Computer Interaction as the perception of action possibilities, i.e., perceived affordances. The perceived affordances can guide the design of useful and effective technologies and objects that clearly indicate their functionality and purpose and allow users to naturally and intuitively use them. The concept has evolved hand-in-hand with the technology, adding new meanings and perspectives to interaction design studies. For instance, motivational affordances have been recently proposed to understand how interactive systems can motivate users to change attitudes, perspectives, or behaviors [25] . This new perspective of interaction design is strongly related to the goal of playable cities. A step further in this direction is the situated motivational affordances model [13], which conceptually defines the relationship between the artifact's characteristics, the use situation, and the users' abilities. As shown in Figure 1, this model has two main actors, the *situation* and the *artifact*, that provide salient motivational features to reach a (successful) interaction and, consequently, satisfy the users' motivational needs.

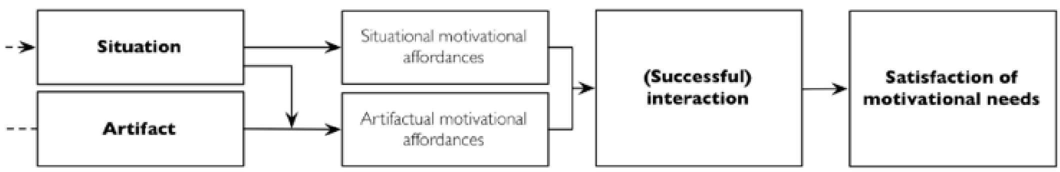

Figure 1. Situated motivational affordances conceptual model [13].

In this work, we root on the situated motivational affordances model to define an evaluation framework for the motivations generated by a playful experience. Based on this model, the context of the game is the situation, and the technologies used in the game become the artifact. In the following subsections, we review some concepts and tools that can help to define assessment mechanisms for this conceptual model.

2.2 User Engagement

Several definitions have been used to describe different aspects of User Engagement (UE henceforth). UE is usually defined as the emotional, cognitive, and behavioral connections generated when the users interact with a product [26]. It also focuses on why a specific technology appeals to people to use it [27]. O'Brien and Toms [28] establish a four-stage loop to explain how UE evolves: Point of Engagement, Period of Engagement, Disengagement, and Re-Engagement. Irrespective of the UE interpretation, there is a consensus that it is highly dependent on the technological affordances offered to the users [14, 26].

Evaluating the level of UE of an interactive system can be carried out using questionnaires like the User Engagement Scale and its Short Form (UES-SF) [14]. This questionnaire is organized into four categories: (1) Focused Attention, that is, whether the user is cognitively absorbed during the interaction; (2) Aesthetic Appeal, which assesses the look and feel; (3) Perceived Usability, which refers to the degree of control and effort required; and, (4) Reward, that deals with the subjective impression of perceived utility, including willingness to recommend or use it in the future, and the level of enjoyment. UE covers facets of an interactive system that focus mainly on the relation between the user and the technological artifact. However, it does not analyze the users' perception of the context.

2.3 User Interest.

The user interest is usually applied to personalize applications, make better recommendations, or provide more accurate information [29, 30]. It is evaluated on websites by monitoring actions such as search results [29], clicks [31], the total time spent scrolling with the mouse, and user ranks [32]. This kind of studies focus mainly on the interest in the information provided by the system.

However, in this work, we seek ways to measure how the technology raises interest in the context where the interaction occurs. We need to shift the focus from designing the artifact to interacting with it and using the technology to establish a relationship between the users and the urban space.

2.4 Personal Urban Awareness

In [15], we have introduced the concept of Personal Urban Awareness (PUA) to refer to a person's connectedness and engagement to an urban area and measured it during an experiment where the users played a historical game. PUA is rooted in the notion of *awareness*, defined as a person's perception and feeling of the surrounding context [33]. It applies an environmental education approach to motivate citizens to interact with their environment if they are aware and educated [34]. Based on these definitions, we have pointed out three factors to evaluate the PUA after the interaction with the system: (i) the interest raised about the environment, (ii) the gained knowledge, and (iii) the connection with the surroundings.

It is worth mentioning that the PUA can recall the concept of placeness, introduced by Edward Relph (1976), which embodies all the things that have to do with a place, from qualities to identities, uses, experiences or interpretations. Recent studies to measure placeness focus on the intrinsic features of the spaces [35], including sociability, uses and activities, access and linkages, comfort, image, and place identity. These elements are not relevant in this work since the space is used as the game scenario, and changing it does not affect the experience. The PUA focuses mainly on representing how an informal process like playing can promote interest in an urban environment.

3. Case Study: Raising Interest and Awareness through a Pervasive AR Urban Game

In this paper, we are interested in exploring how a playable city experience could raise the interest in the urban environment and how this interest could impact the players' awareness of other issues related to the area. To this scope, we have carried out a case study using an already developed AR urban game introduced in [15, 36] as a technology probe. As explained in [37], technology probes are artifacts deployed in a specific setting not to evaluate their usability but to analyze other issues related to their usage. Our contribution employs the artifact to study the capability of the playful experience to raise awareness and interest. Indeed, we have already studied the game usability in [36].

The game is a pervasive AR experience that recreates a historical fact in a building on the university campus. The story takes place in 1808 during the Second of May Uprising by Madrid people against the French troops. In that period, the Sabatini building, currently part of the Universidad Carlos III de Madrid in Leganes, was a barrack where the French Hussar Regiment was settled. The game starts with a brief introduction to the historical context and the instructions to play it. The goal is to build a cannon to rescue some citizens confined in the guardroom. The players have to explore the campus using the AR view to look for the pieces of the cannon represented as virtual objects in the real world. As support, they have a map of the area to see the actual position of the pieces (see -a- in Figure 2). Once they reach an object, players have to answer a historical quiz about the area before collecting it in the inventory (see -b- in Figure 2). The game ends when the players have all the components and can assemble the cannon as a puzzle (see -c- in Figure 2). Finally, they can use it to fight against the enemies and liberate the prisoners (see -d- in Figure 2).

-a- -b- -c- -d-

Figure 2. Screens of the historical pervasive AR urban game. a- the main interface; b- the AR view; c- the cannon assembly; d- the shooting with the cannon.

Walking around the Sabatini building to reach the spots indicated on the map and answering the quizzes can help players learn interesting historical facts about the area. This knowledge can be of particular interest for people who daily attend the campus, like students, academics, passers-by, or city inhabitants. For this reason, the game aims at raising interest in an urban area that usually goes unnoticed. The next section introduces the framework designed to evaluate this experience and identify the factors that impact user interest and awareness of the urban space.

4. An Evaluation Framework to Assess Interest and Awareness Raised by Playable City Experiences.

The situated motivational affordances conceptual model proposed by Deterdingn [13] states that motivational needs can be satisfied through the successful interaction with an artifact. The motivations are related to both the technological artifact and the situation where the interaction occurs. In this work, we apply this model to link the different criteria that influence the success of a playful experience. In Figure 3, the bold labels represent the dimensions of Deterding's model, while the italic ones are the criteria extracted from the case study considered in this work. The evaluation framework focuses on three dimensions of the model (see the dotted line area in Figure 3): situational motivational affordances, artifactual motivational affordances, and (successful) interaction.

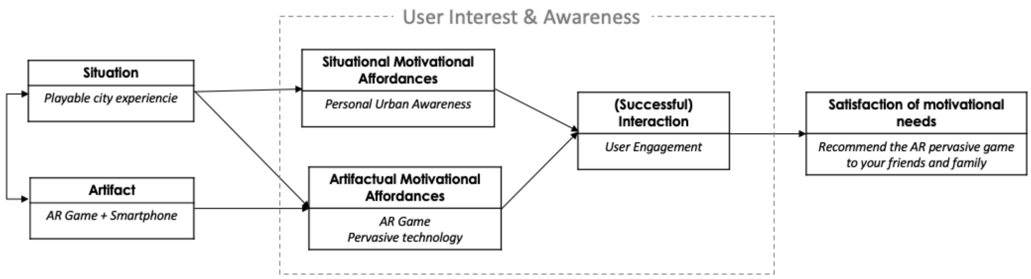

Figure 3. The preliminary evaluation framework for the user interest and awareness of a pervasive AR game in a playable city experience.

The **situational motivational affordances** dimension of the proposed pervasive AR game corresponds to the *PUA* concept as the connection established between people and their urban environment. We consider the following three factors to measure this dimension [34].

1. The *interest raised about the environment*, as the playable experience encourages users to know more about the context. In the game, users walk around the place collecting AR pieces in specific GPS positions and answering contextual historical questions. In this way, they get to explore and observe the area to answer correctly.
2. The *gained knowledge* considering that the playable experience helps users acquire knowledge about several aspects of the context. To advance in the game, users have to answer questions about historical facts that happened in

specific locations around the university campus. As a result, they can discover interesting and curious details that otherwise remain unknown.

3. The *connection with the surroundings*, where the playable experience helps create emotional links with the area explored. Following the game flow, the users walk around the building, collect AR pieces and answer questions. All these activities generate a positive experience to recall the next time they visit the same place.

The **artifactual motivational affordances** dimension aims at assessing how users perceive the technological artifact. Considering that we use a *pervasive AR game* played with a smartphone, in this section, we ask users some open-ended questions about their relationship with the technology and whether the smartphone is appropriate as an AR device.

(Successful) interaction refers to building an experience where the users solve their needs satisfyingly. Considering the characteristics of the case study, we evaluate the UE generated by the interaction with the AR game, including the 12 items from the UES-SF questionnaire [14] and its factors as criteria: Focused Attention, Perceived Usability, Aesthetic Appeal, and Reward.

Based on the application of Deterding's model, we build a questionnaire to assess user interest and awareness. The questionnaire has 13 closed-ended items answered by a 5-point Likert scale (1=strongly disagree, 5=strongly agree) and six open-ended questions that let participants describe their own experiences, opinions, motivations, or suggestions. Table 1 contains the complete list of questions organized by dimension and criteria, where the dimensions are from Deterding's model, and the criteria refer to the case study.

Table 1. The questionnaire items organized by Dimension > Evaluation Criteria, where the questions marked with a star are open-ended.

No.	*Question*
Situational Motivational affordances > Interest in the surroundings	
Q1	After playing this game, would you like to learn more about the area (and its surroundings)?

Q3	Would you like to use this application to learn more information about other artifacts and cultural spaces around you (buildings, fountains, statues, etc.)
Q11	To what degree do you think your interest about your surroundings has increased?
Q16	After interacting with the application, do you feel more concerned about certain aspects (e.g., socioeconomic, cultural, historical) of the urban context?
Q19	Would you like to play other augmented reality pervasive games on your phone to learn more about different contexts and surroundings of your city?
Situational Motivational affordances > Usefulness for gaining knowledge about several aspects of the context (history, sustainability, ...)	
Q2	Do you think this game has helped you to learn more about certain aspects (e.g., socioeconomic, cultural, historical) of the urban environment you're in?
Q4	Do you think these types of games are useful tools for learning more about certain aspects (e.g., socioeconomic, cultural, historical) and spaces?
Q5	Would you recommend this type of game to your friends and family to show them certain aspects (e.g., socioeconomic, cultural, historical) of places?
Q9	As you were playing, to what extent do you think you learned about certain aspects (e.g., socioeconomic, cultural, historical) of the surroundings?
Q15*	Do you think the application should contain other topics? Please indicate which one.
Artifactual motivational affordances > Pervasive Technology	

Q6	Do you think that the mobile phone is an appropriate piece of technology to learn more about certain aspects (e.g., socioeconomic, cultural, historical) around you?
Q7*	If you think that mobile phones are adequate to learn more about certain aspects (e.g., socioeconomic, cultural, historical) around you, please justify the answer.
Q8*	Do you think that mobile phone technology has any advantages over other types of AR technology such as HoloLens glasses? justify your answer.
Situational Motivational affordances > Connect with some context	
Q10	To what extent do you think that learning about certain aspects (e.g., socioeconomic, cultural, historical) of this environment has made you more aware of the history of this area?
Q14	To what extent do you think your perspective of this area has changed after playing this game?
Q17*	If you think that this pervasive game could be used in another context. Please indicate in with ones
Artifactual motivational affordances > AR pervasive games for exploring urban context	
Q12	Do you think this application could have other uses in a different context that isn't related to this topic?
Q13*	If you think that this application could be used in other contexts. Please indicate in which ones.
Q18*	What kind of information do you think could be shown in this type of game?

5. Experimental Study

To evaluate the impact of the historical AR pervasive game on the players' concerns about the surroundings, we have applied the proposed framework by adapting the questionnaire to the specific aspects of this case. The questionnaire included an initial demographics section to gather data about users. The Ethics Committee of our institution validates the whole process.

5.1 Participants

We recruited 20 volunteers to participate in the experiment through a university mailing list. Participants were university students and academics between 18 and 45 years old (65% from 18 to 24, 20% from 25 to 34, 15% from 35 to 44). Considering that participants' gender may be fluid and impermanent, at the time of the experiment, we collected half responses of the participants who defined themselves as male, forty percent of the responses of female option, and ten percent of participants who preferred not to state a gender.

5.2 Apparatus

The game is an Android application (version Android 8.0 Oreo) implemented in Unity using the Vuforia2 library for AR interactions. It also uses GPS to track the players' position and the compass to orient them on the map.

5.3 Material

In this experiment, we have adapted the original questionnaire to reflect the specific aspects of the playful historical experience proposed in this study. In particular, the questions have been revised to include the pervasive AR urban game as the artifact used to reach the aim of learning the historical facts that happened in the Sabatini building. For example, the generic expression "learning about certain aspects […] of this environment" included in question Q10 (see Table 1) has been rewritten as "learning about the history of the Sabatini building". In the same way, question Q16 (see Table 1) has been changed to "After interacting with the game, do you feel more concerned about preserving this area's cultural legacy?".

5.4 Procedure

Before starting the session, we asked participants to sign an informed consent describing their participation. Afterward, the participant filled out the questionnaire's demographic part and received a brief explanation of the game mechanics and a smartphone with the game. All participants started to play from the same physical spot and walked around the building, gathering AR cannon pieces spread out around the area. In the end, when all pieces have been collected, they can mount the cannon, shoot and finish the game. The participants played the game individually. Next, they answered the user interest & awareness questionnaire. It is worth mentioning that all data were anonymized and only used for research purposes, following the ethics committee's recommendations.

5.5 Results for User Interest & Awareness Dimensions

A. Situational Motivational Affordances (PUA)

The situational motivational affordances dimension includes 11 items scored by a 5-points Likert scale and 2 open-ended questions. Running the Cronbach's
to estimate the internal consistency of the 11 items answered by the 20 participants, we have obtained a $\alpha = 0.777$, a value that is normally considered good [38]. The items and questions are distributed into three criteria related to the PUA: (i) usefulness for gaining knowledge, (ii) interest in the surroundings, and (iii) connection with some context. Table 3 shows the detailed scores for each one of them. The first criterion has obtained the highest score, 4.4 out of 5 (SD = 0.74), as the players consider the pervasive game a helpful instrument for learning more about the history of the building. For the second criterion, the participants gave a value of 4.15 out of 5 (SD = 0.76), indicating that the player's curiosity to know more about the area where the game took place increased after the interaction. The third criterion was scored a 3.90 out of 5 (SD = 0.84), representing how the participants perceived the relevance of the place they visited while playing. Overall, we can conclude that the players positively evaluated the game as an instrument to change a person's perception of an area.

Table 3. Mean scores and standard deviation for the criteria in the situational motivational affordances dimension

Situational motivational affordances (PUA)	**Mean**	**Std Dev.**

Usefulness for gaining knowledge	4.40	0.74
Interest in the surroundings	4.15	0.76
Connect with some context	3.90	0.84

B. Artefactual Motivational Affordances (AR Game; Pervasive Technology)

For the artifactual motivational affordances, we asked 2 Likert items and 4 open-ended questions concerning two criteria: AR games for urban context and pervasive technology. The Cronbach's Alpha reaches a α = 0.655 that for an exploratory study could be considered an acceptable level according to [39–41], especially considering that in this case, we have a low number of items [42]. Table 4 lists the mean and the standard deviation for the two criteria in this dimension.

Table 4. Mean scores and standard deviation for the criteria in the artefactual motivational affordances dimension

Artefactual motivational affordances (AR games; pervasive technology)	**Mean**	**Std Dev.**
AR games for urban context	4.85	0.37
Pervasive Technology	4.80	0.41

The participants scored the usage of AR games for exploring the urban context with a 4.85 out of 5 (SD = 0.37), meaning that the players were enthusiastic about the experience, and they were willing to try similar games in other domains, like sustainability or emergency. The score for the pervasive technology criterion is similar to the previous one (M = 4.80 out of 5, SD = 0.41) as the users found smartphones an appropriate technology to learn more about what is around them. These results follow the same trend as those obtained for the gaining knowledge criterion in the situational motivational affordances dimension.

To analyze the open-ended questions, we followed a methodology based on the grounded theory to extract relevant arguments and concerns from the collected answers [43]. It involves three experts in human-computer interaction to collaborate in a two-step procedure. During the first step, the experts have worked individually, reading all the answers and coding them with the argument they defend and the type of contribution. Whereas the arguments depend on the study domain, we have used the axial coding paradigm by Strauss and Corbin [43] to tag the contributions as limited to objectives OBJ, outcomes OUT, consequences CON, and strategy &

actions STR. The objectives represent the causal conditions that generate the phenomenon to analyze (i.e., the AR pervasive game). The consequences and outcomes are the negative and positive aspects of the AR pervasive game over the context. The strategy & actions code collects suggestions about other scenarios where to use the AR pervasive game. The second step consists of combining the analysis of the three experts using triangulation to extract a unique list of coded arguments. In this methodology, triangulation is crucial to compare different points of view and balance them. The result found four main arguments: participation, affordable technology, context of use, and contextual information. Table 5 shows the results obtained from the triangulation, with the four arguments and the coded facts pointed out by the participants.

Table 5. Qualitative results from the open-ended questions.

Argument	*Code*	*Facts*
Pervasive Technology		
Participation	OBJ	Geolocation services make the experience more realistic, strengthening knowledge and creating new concerns.
	OUT	The smartphone is an element that everyone has, and it can boost social motivation.
		The smartphone allows access to historical information on streets, monuments, buildings, etc., around you.
		It is easy to recommend these types of games to family and friends.
	STR	It is much more impressive to read the history and curious facts about something you have in front of you (and that you can browse or gossip about).
Affordable technology	OBJ	It would be necessary to choose an understandable and eye-catching representation of the information.
	OUT	The smartphone can be used by everybody anywhere and at any time.
		Considering the high frequency of smartphone use, the users would have the app more at hand and use it more.

		The smartphone has the necessary sensors and capabilities to perform the tasks enjoyably included in the app.
		The smartphone is less expensive, more portable, comfortable, and intuitive than AR/VR glasses.
	CON	The HoloLens glasses can get you more into the proposed reality.
Context of Use	OUT	The smartphone allows mobility.
	OUT	The app shows the real surroundings with overlapping digital objects, making it safer to be on the street.
	STR	The app can be easily accessed and used in any other environment.
	CON	Using the smartphone for AR experiences has a deficiency in interaction, reduced to one hand. HMDs like HoloLens provide more freedom with incremental attention to gesture-based interaction.
		Considering that the AR paradigm is based on visual feedback, accessibility is difficult to ensure, while the HMDs usually also provide 3D sound and voice commands.
Exploring the Urban Context		
Participation	STR	The user could get location-based rewards to accomplish some objectives, like doing physical exercise or visiting restaurants or bars.
Contextual Information	STR	It would be helpful to know how many people are playing around to interact with them and additional information about the building
		It would be interesting to show the information more interactively, focus on the most curious facts, orientate the map depending on the player's point of view, and have a wider variety of objects and characters.
Connecting with the Urban Context		
Context of use	STR	The app could be employed in other situations, like guided tours in cities, monuments or museums,

		emergency training, hospital stays, health, physical activity, knowing new places, learning about all kinds of fields, marketing campaigns, group coordination activities, group therapy for disabled people, and environmental awareness.
Gaining Knowledge about the Urban Context		
Context of use	STR	The app could be helpful in gaining knowledge about other domains, like culture, sustainability, recycling, art, architecture, technology, or cooking.

Concerning the Pervasive Technology criteria, participants discuss using a smartphone and its advantages. Smartphones are used daily by everybody, anywhere, and at any time. If a person wants to know more about a building, a monument, or any hot spot in the city, she doesn't need additional devices, just the one in her pocket (Participation). Moreover, the mobile phone is less expensive, more portable, comfortable, and intuitive (Affordable Technology) than a more complex device such as AR glasses. In contrast, the HMDs provide a more natural interaction based on gestures with both hands (Context of Use).

For Exploring and Connecting with the Urban Context, the participants suggested some helpful improvements, such as people playing simultaneously to cooperate. Another one is additional details about the building, like the maintenance cost, the ecological footprint, the number of visitors per year, the architectonic elements, or the hot spots, which suggests that the interaction generated further interest. They also suggested finding a more interactive way to show the historical facts and offering more objects and characters (Contextual Information).

The participants have also indicated other contexts where the proposed application could be helpful. In general, they have pointed out two types of situations. The first one is where location-based rewards could encourage the users to accomplish some objectives (Participation), like physical exercises or marketing campaigns. The second one refers to experiences that require learning or adaptation (Context of Use), like emergency training, hospitals, group coordination activities, or group activities for disabled people. In the same direction of these results, in the Gaining Knowledge about the Urban Context criteria, the participants have listed other topics that could be interesting to explore with a pervasive AR game: culture, recycling, art, sustainability, architecture, technology, or cooking.

C. (Successful) Interaction (UE)

The (successful) interaction dimension corresponds to the User Engagement that the whole experience generates. For its evaluation, we have incorporated the UES-SF questionnaire [14] with 11 items distributed into four main factors (see Table 6): Perceived Usability, Reward, Focused Attention, and Aesthetic Appeal. For this dimension, Cronbach's Alpha estimates an acceptable internal consistency for the 11 items of the UES-SF questionnaire corresponding to α = 0.763 [38].

Table 6. Mean scores and standard deviation for the criteria in the (successful) interaction dimension.

(Successful) Interaction *(User Engagement)*	**Mean**	**Std Dev.**
Perceived Usability	4.68	0.65
Reward	4.48	0.68
Focused Attention	4.15	0.82
Aesthetic Appeal	3.70	0.97

Perceived Usability gets a score of 4.68 out of 5 (SD = 0.65). This result reflects a usability test that we have run in a previous study [36], where we fixed several usability flaws and limitations. The Reward criterion, scored with 4.48 out of 5 (SD = 0.68), denotes the willingness to recommend the game to others, use it in the future, be interested and immersed in the experience, and have fun. For Focused Attention, the value of 4.15 out of 5 (SD = 0.82) suggests that the participants reached a high level of concentration during the game, and at some point, they also lost track of time.

The Aesthetic Appeal criterion has generated controversy with a mean of 3.7 out of 5 and a standard deviation of 0.97. In particular, most of the participants (70%) scored the application design with a value higher than 4 out of 5. At the same time, the remaining chose a value of around 3 out of 5, indicating a more neutral opinion. This result can be explained by considering the users' previous experience with AR applications in relation to how the game has been designed. We wanted to propose an interactive experience that the players could easily recognize and get familiar with it. For this reason, we reused and adapted several elements already included in the successful application of Pokémon Go, like the map and the controllers, which was valued by most of the participants.

5.6 Results for User Interest & Awareness Dimensions

As shown in Figure 3, the proposed framework establishes a relation between its main three dimensions: the situational and artefactual motivational affordances and the (successful) interaction. To analyze how this relation works, we run a correlation analysis to look for any correspondence among the different criteria in the questionnaire. Considering the small number of participants in the study and the use of Likert scale data, we have decided to apply the Spearman's rank-order correlation [44]. This analysis aims at discovering the existence of monotonic relations between the scores obtained for the different dimensions and criteria in the questionnaire (see Table 3, Table 4, and Table 6). It is based on the Spearman's correlation coefficient r which can take values from 1 to -1: (i) 1 indicates that the variables increase in the same way; (ii) -1 represents a negative association where one of the variables increases while the other decreases; (iii) values towards 0 mean a weaker correlation between variables. The detailed results are in Table 7.

Firstly, we computed the correlation between the (successful) interaction and the situational motivational affordances, obtaining $r(18) = .69$, $p = .0006$. This result seems to suggest that entertainment, satisfaction, curiosity, and aesthetics are crucial to increasing users' informal learning and interest in the surroundings when playing a pervasive AR game to explore a historical urban context.

Secondly, we study the correlation between all the criteria of the two dimensions of situational motivational affordances and User Engagement. We found a positive correlation between the Interest in the surroundings and each UE factor, being the strongest one with the Reward, $r(18) = .61$, $p = .004$. Based on this correlation, we can conclude that the players that get a higher reward score from the game also have a higher interest in the surroundings. Another interesting positive correlation is with the Perceived Usability, $r(18) = .56$, $p = .009$, which describes the relationship between the user interest and the degree of control and effort spent during the game. Other positive correlations are with Focused Attention, $r(18) = .56$, $p = .010$, and Aesthetic Appealing, $r(18) = .52$, $p = .017$. These data point out other aspects that can influence the user interest, including the feeling of being absorbed in the experience and the game's appearance. Moreover, users who have a positive opinion about the Perceived Usability, Focused Attention, and Aesthetic Appealing of the game are also more interested in the surroundings.

Finally, there are some positive correlations between the criteria Usefulness for gaining knowledge and Reward, r (18) = .67, p = .001, Focused Attention, r (18) = .57, p = .008, and Aesthetic Appealing, r (18) = .56, p =.009. From these values, we could conclude that the users who more enjoyed the experience also consider that they learned about the historical context of the environment during the game. Also, they would recommend similar applications to discover other interesting facts about the urban surroundings to their friends.

All the positive correlations confirm some of the results that we have already discussed in the previous section and, especially, they suggest a strong relationship among two dimensions, namely situational motivational affordances and (successful) interaction, to evaluate user interest and awareness.

Table 7. The results from the correlation analysis by Spearman applied among the criteria from the Situational Motivational Affordances and the User Engagement dimensions.

	Focused Attention	***Perceived Usability***	***Aesthetic Appeal***	***Reward***	**(Successful) Interaction (UE)**
Situational motivational affordances (PUA)	-	-	-	-	.699***
Interest in the surroundings	.560*	.564**	.523*	.610**	
Usefulness for gaining knowledge	.574**	-.002	.562**	.677**	
Connect with some Context	.316	.194	.119	.327	
Artifact motivational affordances	-	-	-	-	.347

Legend: * = $p < .05$, ** = $p < .01$, *** = $p < .001$

6. Findings and Limitations

The experimental study presented in this work is an example of how the proposed framework can be applied to evaluate the effects of an AR pervasive game on the users' interest and awareness. The analysis of the answers of the participants shows both strengths and limitations of our contribution. Participants' opinions were highly positive, and, therefore, they enjoyed the game and the overall experience. Moreover, thanks to the Spearman´s correlation coefficients, we found out that playing pervasive AR urban games makes the users more interested in what is happening around them with a particular emphasis on challenging issues like sustainability. For example, during the experiment, while the players were focusing on building a cannon to rescue the citizens in the guardroom, they were also discovering interesting facts from the historical quiz. In this way, they became aware of the critical role of preserving an area's cultural legacy. These findings are aligned with similar contributions in the area of playable cities. In [45], the authors analyzed the AR game Pokémon Go finding AR technology the right solution for engaging players with their surroundings. Lehner et al. concluded that the citizens feel excited to have a city as a playground and discover or rediscover their neighborhood or city [17].

The proposed questionnaire includes three different parts corresponding to the three dimensions of the framework. To estimate its reliability, it is crucial to focus on the internal consistency of each dimension. For this reason, we analyze the Cronbach Alpha as well as the distribution of the collected answers. The Situated motivational affordances dimension has the highest α indicating that the items included in the questionnaire can be considered an acceptable and consistent measure, as proposed in [38, 42]. The (successful) interaction is evaluated using the well-known and established UES-SF [14] that does not need any further reliability test. About the Artefactual motivational affordances questionnaire, we get the lowest α that mainly depends on the small number of items [42]. To estimate its consistency we also analyze the scores and standard deviations obtained for the 2 items in this dimension observing a similarity in both the scores and the standard deviations (see Table 4). This similarity can be considered an alternative way to measure the correlation among the items as the Cronbach alpha is based on the variance and both the variance and the standard deviation measure the dispersion of the dataset [46]. For this reason, we can estimate that there is a consistency between the items used to evaluate the artifactual dimension.

In the light of these results, the framework could be used to evaluate how different playful experiences affect citizens' perception of other aspects of the urban context, like socioeconomic impacts or risk detection for early warning. To this scope, it is crucial to cope with the limitations identified in the current experimental study. First of all, we have involved a limited number of users as part of a preliminary study to understand the potential of the proposed framework. In the future, we are planning to involve a higher number of participants with a more diverse profile in terms of age, abilities, and competencies to confirm the findings pointed out here.

Another aspect that needs to be taken into account is the adaptation of the questionnaire to consider other interaction modes and technologies. One of them is the social interaction among players which could represent an additional incentive to make the playable cities more engaging, as already mentioned in [2]. The other refers to how interaction with technology can evolve [26]. A user can improve her skills with the AR game whereas playing or the used artifact could be implemented using a different technological platform depending on the context. These changes can affect several aspects of the questionnaire, like user engagement and urban awareness.

7. Conclusions and Future Works

This paper proposes an evaluation framework to explore how playable cities can make people aware of a specific urban area. Whereas it is possible to find several methods to evaluate user engagement in literature, there are very few contributions dealing with the capability of technology to raise user interest and awareness in their surroundings. The proposed framework extends an existing conceptual model, the situated motivational affordances by Deterding, with a set of criteria for the specific artifact and situation to evaluate.

The framework has been used with a historical AR game to explore a university campus, collecting qualitative and quantitative data. The results confirm our initial hypothesis that engaging users in a playful experience like the AR urban game improves their interest in what happens around them. In particular, they become aware of all the issues affecting the area's cultural legacy, like sustainability, socio-environmental, and socioeconomic development.

Another interesting finding from the evaluation is that these results are independent of the specific AR game and environment. We could draw similar conclusions by changing the application and the context. Among the incentives to make the playable cities more engaging, Innocent pays special attention to the social interactions among players [2]. Consequently, including this aspect in our framework would be an interesting approach to deal with other motivational issues such as socialization, collaboration, and competition. In future works, we are planning to review the framework considering the results obtained from this experimental research and apply it to other case studies. One of them could be the usage of an early warning application that allows citizens to identify and notify risky situations in their surroundings.

Acknowledgments. This work is supported by the project sense2MakeSense grant funded by the Spanish State Agency of Research (PID2019-109388GB-I00).

D. Compliance with Ethical Standards

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

E. References

1. Leorke D (2020) Reappropriating, Reconfiguring and Augmenting the Smart City Through Play. pp 51–70
2. Innocent T (2018) Play about Place. In: Proceedings of the 4th Media Architecture Biennale Conference. ACM, New York, NY, USA, pp 137–143
3. Calafiore A, Rapp A (2016) Gamifying the city: Pervasive game elements in the urban environment. In: In Workshop on Fictional Game Elements 2016 co-located with The ACM SIGCHI Annual Symposium on Computer-Human Interaction in Play (CHI PLAY 2016). pp 1–6
4. Ferreira V, Anacleto J, Bueno A (2017) Designing ICT for thirdplaceness. In: Playable Cities. Springer, Singapore, pp 211–233
5. Fischer PT, Hornecker E (2017) Playable Cities. 163–185. https://doi.org/10.1007/978-981-10-1962-3
6. Laato S, Pietarinen T, Rauti S, et al (2019) A review of location-based games: Do they all support exercise, social interaction and cartographical training? CSEDU 2019 - Proceedings of the 11th International Conference on Computer Supported Education 1:616–627. https://doi.org/10.5220/0007801206160627

7. de Lange M (2015) The Playful City: Using Play and Games to Foster Citizen Participation
8. Nijholt A (2017) Towards playful and playable cities. Springer, In Playable Cities (pp. 1-20). Springer, Singapore.
9. Santos V, Burguès RP (2018) Authoring a serious pervasive game for reflecting upon urban spaces. In: Lecture Notes of the Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering, LNICST. pp 74–84
10. Koivisto J, Hamari J (2019) The rise of motivational information systems: A review of gamification research. International Journal of Information Management 45:191–210. https://doi.org/10.1016/j.ijinfomgt.2018.10.013
11. Florian J. Zach and Iis P. Tussyadiah (2017) To Catch Them All—The (Un)intended Consequences of Pokémon GO on Mobility, Consumption, and Wellbeing. Information and communication technologies in tourism 217–227
12. Liao T, Humphreys L (2015) Layar-ed places: Using mobile augmented reality to tactically reengage, reproduce, and reappropriate public space. New Media and Society 17:1418–1435. https://doi.org/10.1177/1461444814527734
13. Deterding S (2011) Situated motivational affordances of game elements : A conceptual model. CHI 2011 Workshop Gamification Using Game Design Elements in NonGame Contexts 2011 3–6. https://doi.org/ACM 978-1-4503-0268-5/11/05
14. O’Brien HL, Cairns P, Hall M (2018) A practical approach to measuring user engagement with the refined user engagement scale (UES) and new UES short form. International Journal of Human Computer Studies 112:28–39. https://doi.org/10.1016/j.ijhcs.2018.01.004
15. Sánchez-Francisco M, Díaz P, Aedo I (2018) Improving urban environment awareness through pervasive AR games. Proceedings of the Workshop on Advanced Visual Interfaces AVI 82:1--82:3. https://doi.org/10.1145/3206505.3206586
16. Kasapakis V, Gavalas D, Bubaris N (2013) Pervasive games research: a design aspects-based state of the art report. Proceedings of the 17th

panhellenic conference on informatics 152. https://doi.org/10.1145/2491845.2491874
17. Lehner U, Reitberger W, Baldauf M, et al (2014) Civic engagement meets pervasive gaming: Towards long-term mobile participation. Conference on Human Factors in Computing Systems - Proceedings 1483–1488. https://doi.org/10.1145/2559206.2581270
18. Chang M, Jungnickel K, Orloff C, Shklovski I (2005) Engaging the city: Public interfaces as civic intermediary. Conference on Human Factors in Computing Systems - Proceedings 2109–2110. https://doi.org/10.1145/1056808.1057110
19. Razafimahazo M, Laya N, Genev P, et al (2014) Mobile augmented reality applications for smart cities. ERCIM News 98:45–46
20. Xu Y, Barba E, Radu I, et al (2011) Pre-patterns for designing embodied interactions in handheld augmented reality games. 2011 IEEE International Symposium on Mixed and Augmented Reality - Arts, Media, and Humanities, ISMAR-AMH 2011 19–28. https://doi.org/10.1109/ISMAR-AMH.2011.6093652
21. Prandi C, Roccetti M, Salomoni P, et al (2017) Fighting exclusion: a multimedia mobile app with zombies and maps as a medium for civic engagement and design. Multimedia Tools and Applications 76:4951–4979. https://doi.org/10.1007/s11042-016-3780-9
22. Hamari J, Malik A, Koski J, Johri A (2019) Uses and Gratifications of Pokémon Go: Why do People Play Mobile Location-Based Augmented Reality Games? International Journal of Human-Computer Interaction 35:804–819. https://doi.org/10.1080/10447318.2018.1497115
23. Deterding S, Innocent T, Hassan L (2021) Fighting Post-Truth with Storification. https://youtu.be/5RNgSCFXjNg. Accessed 15 Oct 2021
24. Bærentsen KB, Trettvik J (2002) An activity theory approach to affordance. In: Proceedings of the second Nordic conference on Human-computer interaction. pp 51–60
25. Weiser P, Bucher D, Cellina F, de Luca V (2015) A Taxonomy of Motivational Affordances for Meaningful Gamified and Persuasive Technologies. Proceedings of EnviroInfo and ICT for Sustainability 2015 22:. https://doi.org/10.2991/ict4s-env-15.2015.31

26. Attfield S, Kazai G, Lalmas M (2011) Towards a science of user engagement (Position Paper). WSDM Workshop on User Modelling for Web Applications
27. Sutcliffe A (2009) Designing for User Engagement: Aesthetic and Attractive User Interfaces. Synthesis Lectures on Human-Centered Informatics 2:1–55. https://doi.org/10.2200/S00210ED1V01Y200910HCI005
28. O'Brien, H. L., & Toms EG (2008) What is User Engagement? A Conceptual Framework for Defining User Engagement with Technology. J Assoc Inf Sci Technol 59:938–955. https://doi.org/10.1002/asi
29. Miyahara S, Sadakata T, Okuda H, Oku M (2007) Discovery search system that supports the user's interest using the referrals of other users. International Journal of Human-Computer Interaction 23:131–142. https://doi.org/10.1080/10447310701363072
30. White RW, Bailey P, Chen L (2009) Predicting user interests from contextual information. Proceedings - 32nd Annual International ACM SIGIR Conference on Research and Development in Information Retrieval, SIGIR 2009 363–370. https://doi.org/10.1145/1571941.1572005
31. Qiu F, Cho J (2006) Automatic identification of user interest for personalized search. Proceedings of the 15th International Conference on World Wide Web 727–736. https://doi.org/10.1145/1135777.1135883
32. Claypool M, Brown D, Le P, Waseda M (2001) Inferring user interest. IEEE Internet Computing 5:32–39. https://doi.org/10.1109/4236.968829
33. Schmidt K (2004) The Problem with "Awareness": Introductory Remarks on 'Awareness in CSCW.' Computer Supported Cooperative Work 11: 285–298. https://doi.org/10.1023/A:1021272909573
34. Stapp WB (1969) The Concept of Environmental Education. Environmental Education. https://doi.org/10.1080/00139254.1969.10801479
35. Sun S, Yu Y (2021) Dimension and formation of placeness of commercial public space in city center: A case study of Deji Plaza in Nanjing. Frontiers of Architectural Research 10:229–239. https://doi.org/10.1016/j.foar.2020.08.001

36. Fabiano F, Sánchez-Francisco M, Diaz P, Aedo I (2018) Evaluating a pervasive game for urban awareness. Proceedings of the 20th International Conference on Human-Computer Interaction with Mobile Devices and Services Adjunct, MobileHCI 2018, Barcelona, Spain, September 03-06, 2018 197–204. https://doi.org/10.1145/3236112.3236140
37. Hutchinson H, Hansen H, Roussel N, et al (2003) Technology probes. In: Proceedings of the conference on Human factors in computing systems - CHI '03. ACM Press, New York, New York, USA, p 17
38. Schrepp M (2020) On the Usage of Cronbach's Alpha to Measure Reliability of UX Scales. J Usability Stud 15:247–258
39. Ursachi G, Horodnic IA, Zait A (2015) How Reliable are Measurement Scales? External Factors with Indirect Influence on Reliability Estimators. Procedia Econ Finance 20:679–686. https://doi.org/10.1016/s2212-5671(15)00123-9
40. Hair JF, Black WC, Black B, et al (2010) Multivariate data analysis., 7th ed. Pearson College Division
41. Nunnally JC, Bernstein IH (1994) Psychometric Theory. McGraw-Hill, New York
42. Taber KS (2018) The Use of Cronbach's Alpha When Developing and Reporting Research Instruments in Science Education. Research in Science Education 48:1273–1296. https://doi.org/10.1007/s11165-016-9602-2
43. Corbin J, Strauss A (2008) Basics of Qualitative Research (3rd ed.): Techniques and Procedures for Developing Grounded Theory. SAGE Publications, Inc., 2455 Teller Road, Thousand Oaks California 91320 United States
44. Spearman's Rank-Order Correlation. In: Leard Statistics. https://statistics.laerd.com/statistical-guides/spearmans-rank-order-correlation-statistical-guide.php. Accessed 4 Nov 2021
45. Rauschnabel PA, Rossmann A, tom Dieck MC (2017) An adoption framework for mobile augmented reality games: The case of Pokémon Go. Computers in Human Behavior 76:276–286. https://doi.org/10.1016/j.chb.2017.07.030
46. Dodge Y (2003) The Oxford dictionary of statistical terms. Oxford University