This article has been accepted for publication in IEEE Transactions on Emerging Topics in Computing. This is the author's version which has not been fully edited and content may change prior to final publication. Citation information: DOI 10.1109/TETC.2023.3296772

Designing mobile technologies to encourage civic engagement: the role of situated motivational affordances

Mónica Sánchez de Francisco, Paloma Díaz, Teresa Onorati, Álvaro Montero and Ignacio Aedo

Computer Science and Engineering Department

Universidad Carlos III de Madrid

Abstract— **Social and ubiquitous computing opens up many opportunities to engage citizens in activities that benefit their communities. Technology is ready and available, but there are still open issues concerning how to engage people in activities that are not extrinsically rewarding or whose impact is not immediately perceived. In this paper, we explore the role that situated motivational affordances can play in encouraging citizens in one of such activities, early warning. With this purpose, we designed and implemented a gamified app, IWarn that was iteratively designed following an action-research process to align the needs and capabilities of two types of stakeholders: emergency managers and citizens. The situated motivational affordances framework was used to lead the evaluation considering the motivational affordances enabled by the app and the situation in which it was used. The IWarn app was evaluated in an in-the-wild deployment where 4 emergency workers and 17 citizens took part in a real exercise for one week. Our results suggest that the gamified elements helped to improve intrinsic and extrinsic motivation and user engagement. This work contributes to the social computing domain by illustrating a use case where carefully designed gamification can help in engaging citizens in participatory processes**

Keywords—civic engagement, social computing, civic tech, coproduction, gamification.

I. INTRODUCTION

Civic engagement entails citizens acting in a community to improve the living conditions or to shape its future [1]. In most urban areas new technology practices are emerging, including the pervasive use of smartphones, access to open information, and the use of urban apps and cloud computing [2]. In this technological context, the combination of social and ubiquitous computing has raised many expectations to enable civic engagement by offering almost endless opportunities to open the community challenges to the citizens' participation. Civic technologies, also referred to as civic tech [3], are those technologies that empower citizens to contribute to their communities. To this end, coproduction of service can be used. Coproduction consists of producing a good or service using inputs contributed by individuals who are not in the same organization [4]. Docial and ubiquitous computing can be exploited to design efficient coproduction services that benefit from and strengthen citizens' abilities by implementing participatory processes in which citizens collaborate, among them and with the authorities, to address real issues in real environments [5]. We will use term *civic participatory tech* to refer to this kind of emerging software applications aimed at turning civic engagement into a participatory process.

Designing *civic participatory techs* implies balancing the needs and expectations of all stakeholders: the organizations that will rely upon participation to produce the service or good as well as those of citizens who will be engaged in coproduction. The challenges for authorities include lack of control, information overload, and trust, as thoroughly discussed in [5]. Concerning citizens, who are the focus of the work reported in this paper, there are two key challenges to face: participatory techs have to motivate participation even when the benefits are not obvious or extrinsic [6]; and they have to be enjoyable and fun to encourage its usage [7]. An example of participation that is not extrinsically motivating is early warning, a phase in the emergency management cycle that starts when nothing has happened yet, but authorities are checking an area to evaluate potential risks. Since citizens do not perceive any risk yet, nor their contribution has an immediate impact on the environment, they can feel their participation is useless. In this case, the design of the civic participatory technology has to be rooted in motivating users. In this paper, we propose to combine the situated motivational affordances model [8] with gamification to design and, especially, to evaluate *civic participatory techs* that are not extrinsically motivating, that is, those whose impact is not immediately perceived or whose participants do not receive any explicit reward.

On the one hand, the situated motivational affordances model [8] offers a high-level conceptual scaffold that identifies relevant aspects concerning a situation (in our case, the participation in a specific coproduction service) and the artifact used (in our case the civic participatory tech). The model proposes to focus on the situation and the artifact affordances to enact useful interactions that are eventually connected to human motivational needs [6]. Nurturing such motivational needs can lead to improve intrinsic motivation as far as they connect with human needs and preferences. However, this model does not provide any criteria, methods or cues on how to proceed to design and evaluate motivating artifacts; it is just a conceptual scheme of aspects to consider to increase users' motivations.

XXX-X-XXXX-XXXX-X/XX/$XX.00 ©20XX IEEE

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 License. For more information, see https://creativecommons.org/licenses/by-nc-nd/4.0/

This article has been accepted for publication in IEEE Transactions on Emerging Topics in Computing. This is the author's version which has not been fully edited and content may change prior to final publication. Citation information: DOI 10.1109/TETC.2023.3296772

On the other hand, the term gamification refers to the use of game elements in non-game contexts [9] to promote the use of a system by motivating users with the intrinsically rewarding features of games [10], [11]. Hence its use can help to increase motivation though there is no solid evidence about how gamification elements can be applied in different contexts to increase motivation [21] and, therefore, more studies are required in this field.

In this work, we go a step further by instantiating the situated motivational affordances model [8] to provide cues and recommendations on how to integrate gamification elements by focusing on their relation with specific motivational needs, as well as to propose criteria and methods that can be applied to evaluate how the resulting technology can support civic engagement. The use case presented is an early warning participatory and gamified app, IWarn, whose development is already reported in [12]. The situated motivational affordances model [8] was used to lead an exploratory evaluation taking into account the motivational affordances enabled by the IWarn app and the situation in which it was used (i.e. early warning missions). The summative evaluation was carried out as an in-the-wild deployment where 4 emergency workers and 17 citizens took part in a real early warning mission for one week. Our results suggest that the gamified elements helped to improve intrinsic and extrinsic motivation and user engagement.

This work contributes to the social computing domain by illustrating a use case where carefully designed gamification can help in engaging citizens in participatory processes to coproduce service and, hence, to contribute to their community. Moreover, we apply and extend an existing framework, the situated motivational affordances model, to focus the design and the evaluation of civic participatory techs considering two complementary perspectives: the interaction affordances enabled by the technological artifact (namely artifactual motivational affordances) and the affordances enabled by the situation in which the artifact is used (namely situational motivational affordances). This double perspective enlarged the view of the app not only as a gamified civic app but as an artifact that can be used to connect participants with their environment and become aware of the problems or risks it could be affected by.

II. Related Works

To increase civic engagement and reach their societal goals, civic techs need first to motivate citizens to use them since this will eventually result in a higher commitment to the community [13], [14]. However, many activities supported by civic techs are not extrinsically motivating since they do not have an immediate impact on the community or the environment. Hence, citizens can be frustrated or disengaged from using a technology whose utility is not obvious, that is, they are not extrinsically motivating. This section reviews works related to designing technologies that need to be intrinsically motivating.

The situated motivational affordances model provides a conceptual scaffold to focus technology development on the satisfaction of human motivational needs [8] model, shown in Figure 1, identifies two main actors to consider: the *Artifact* that is developed and the *Situation* in which it is used, and both have to be considered and integrated during the design process. The *Artifact* supports a number of activities performed in a specific *Situation* (arrow from *Artifact* to the *Situation* in Figure 1). Both of them have motivational features that are called *Situational* and *Artifactual motivational affordances,* respectively. A *Situational Motivational Affordance* links a characteristic of the context of use with a user's motivation. For instance, when using an app for walking, moving around can improve users' knowledge on the area and satisfy their desire for learning. An *Artifactual Motivational Affordance* relates a function in the technological artifact with a user's motivational need. For instance, using badges in a gamified app can feed the desire for competence, if they are private, or leadership, if they are public. The situation of use affects both the types of affordances since the use of the artifact is shaped by the situation. Both affordances are materialized in the interaction process, and if it is successful will satisfy some users' motivational needs. In this way, the model provides a conceptual basis to understand the different aspects that should be taken into account, but it does not specify each of the components or the mechanisms and heuristics that can be used to design, improve, or evaluate them.

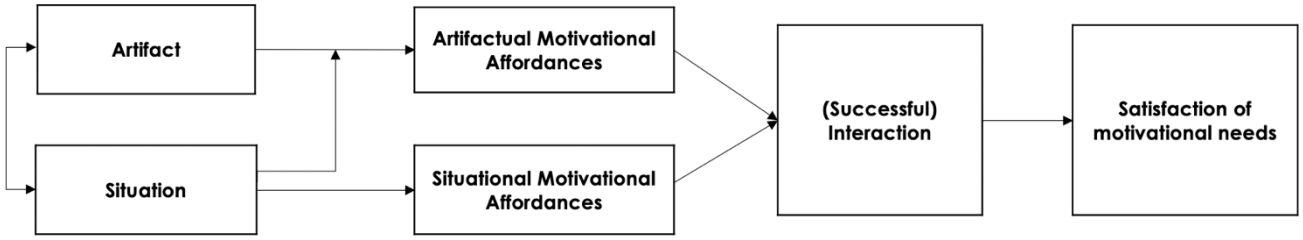


Fig. 1. Situated motivational affordances model [8].

Motivational affordances can be implemented using gamification since it has been claimed that it supports user engagement and motivation [10], [11], [15]. Indeed gamification elements are used to improve civic engagement in platforms like Community PlanIt [16], Love Your City! [17] and Geo-Zombie [18]. There are two types of motives regarding user interaction in gamification: intrinsic and extrinsic motivations. Intrinsic motivation is achieved when people do something because they find it enjoyable and genuinely believe there is an underlying value [19]. Extrinsic motivation happens when people do something because they are either trying to avoid something or get something in return [20]. Based on Thiel and Fröhlich [21], each intrinsic and extrinsic motivation can be divided into the three categories summarised in Table I that can be used to design and evaluate gamified applications. However, according to the authors, more studies are required to understand how gamification elements impact the users' intrinsic and extrinsic motivation.

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 License. For more information, see https://creativecommons.org/licenses/by-nc-nd/4.0/

This article has been accepted for publication in IEEE Transactions on Emerging Topics in Computing. This is the author's version which has not been fully edited and content may change prior to final publication. Citation information: DOI 10.1109/TETC.2023.3296772

TABLE I.
MOTIVATION TYPES [21])

Intrinsic motivations	Extrinsic motivations
Pleasure: People do things for fun	Reputation: People aim to fulfill some internalized values or moral goals
Social: People enjoy having the opportunity to interact with other people	Institutional: People wish to fulfill expectations or comply with external requirements.
Learning: People like learning new things and solving challenges	Personal: People like to satisfy self-concepts such as interpersonal relations, relatedness, and other social satisfiers.

A step further to design for supporting motivation is described in [6], where a number of specific motivational affordances for gamified technologies are proposed. Such affordances are connected to people's motivational needs that can be psychological and social, as summarised in Table II. Psychological needs include the desire for autonomy (choice), competence (skills), and relatedness (relationships) [6], [22]. Social needs are acquired through learning processes and encompass the longing for achievement (do well), affiliation (approve and get approved), intimacy (secure relationships), and leadership and followership. The authors propose using gamification elements such as assignments and goals, badges and credits, leaderboards, and groups to enable motivational needs.

This work builds on these frameworks and uses a specific case study, participatory early warning, to go a step further in the literature on gamification to support intrinsic motivation in *civic participatory techs*.

TABLE II.
MOTIVATIONAL NEEDS [6], [22]

Psychological needs	Social needs
Autonomy: it is the psychological desire to make self-determined decisions.	Achievement: human beings need to do something well to show their skills to the rest.
Competence: human beings tend to have the desire to improve at something, that is, to acquire the necessary skills to perform a task efficiently (Reeve, 2018).	Affiliation and intimacy: Affiliation is the need for human beings to be approved by others and make others happy and satisfied.
Relatedness (Relationship): people tend to have the need to establish relationships with others.	Leadership and Followership: It refers to the desire to impact and influence others.

III. CASE STUDY: IWARN, A TOOL TO SUPPORT PARTICIPATORY EARLY WARNING

Early warning is part of the emergency management cycle. It starts before nothing has happened when communities need to identify the potential risks and hazards they could be exposed to and get ready to react as efficiently as possible. Early warning is initiated when precursors of potential risks or hazards are detected (such as expected high temperatures for wildfires). It consists of monitoring the evolution of such precursors and the potentially affected area to decide whether the situation is evolving into a real risk and which could be its effect. Participatory early warning engages citizens in collecting data in situ that decision-makers can later analyze to decide when and how to act [23]. Social and ubiquitous computing offers the possibility to integrate citizens in this monitoring process, since most of them are equipped with smartphones and are knowledgeable about the potentially affected area. However, this is an example of participation that is not extrinsically motivating since citizens do not perceive any risk yet, nor their contribution has an immediate impact on the environment. In this context, it is crucial to propose technologies that can help keep citizens motivated and willing to participate.

IWarn is an Early Warning System (EWS) that enables citizen participation. It was iteratively designed following an action-research process in which emergency managers and citizens were involved to align the needs and capabilities of both kinds of stakeholders. The system is composed of a desktop interface for emergency operators who manage early warning alerts and involve citizens in monitoring missions. Missions are performed using a gamified mobile app. The system and the design process are thoroughly described in [24]. A comparative study of a gamified vs. a non-gamified previous version of the app demonstrated that gamification "(a) *the gamification makes users feel more curious and involved in the social objectives of the application*, (b) *it improves the joy of using the app* (c) *it significantly enhances the attention and commitment while users act in a mission*" [Marco]. However, professional emergency managers were worried about using pure and non-controlled gamification that could promote over-engagement in citizens who could be obsessed with earning badges instead of making useful contributions [12, 24]. Hence, in the final version of the app we had to balance the user motivations with the situation of use, that also involves professional workers trying to make sense of the information provided by citizens. In this paper, we will focus on how we used gamification and the situated motivational affordances model to improve motivation and engagement when using the final version of IWarn. The following sections describe the tool and its gamification elements.

A. IWarn description

IWarn is a gamified mobile application to participate in early warning missions. EWS operators create missions defined for a geographical area that last a specific time slot. Each mission has a leader, who is a volunteer or a person known and trusted by the organization. The leader must motivate participation, coordinate participants, and filter out useful information for the operator. The leader was a role that emerged during the iterative design to deal with information overload and trust on the EWS operators side by curating the data sent to the desktop system and to control the actions of over motivated citizens [24]. During previous evaluations, this role also was useful to encourage participants with messages to guide their actitivity [12]. Citizens can be invited by the operator, the leader, or by other participants. Participation is not anonymous to avoid a lack of trust in the EWS [24].

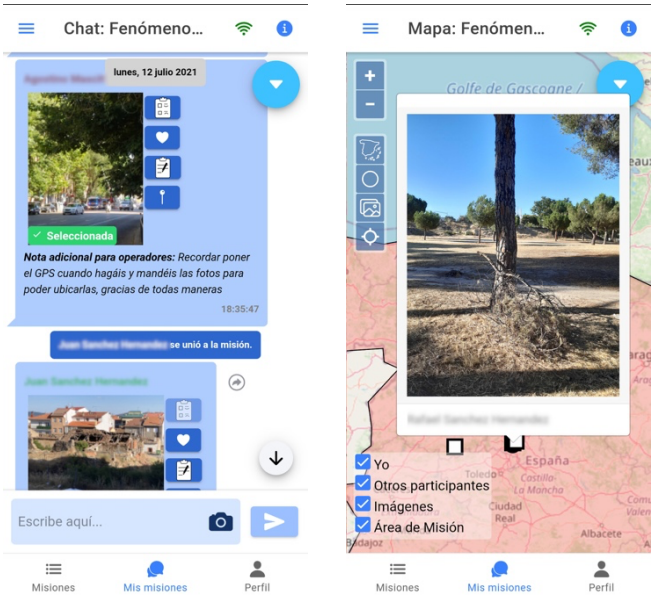
Similarly, the use of a dedicated app was chosen to be able to control participation, so it could be really useful for coproducing an efficient service: checking areas before crises or hazards happen to be ready to react. Using social networks wouldn't make sense since nothing is happening yet, so citizens are not sharing information spontaneously. Moreover, early warning is previous to issuing any alert, so sharing information on social networks could derive on a fake perception of danger by the population.

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 License. For more information, see https://creativecommons.org/licenses/by-nc-nd/4.0/

This article has been accepted for publication in IEEE Transactions on Emerging Topics in Computing. This is the author's version which has not been fully edited and content may change prior to final publication. Citation information: DOI 10.1109/TETC.2023.3296772

During the mission, leaders and participants collect pictures of the potentially affected area, looking for issues that should be taken into account or any other information required by the EWS operator. The main interactive interface is the chat, where participants share information and get feedback (see the left screen in Figure 2). There are two other areas where they can check the missions they participate in and their profile. Finally, there is a map to visualize the images already taken and the current location of the active participants (see the right screen in Figure 2). The leader also has a gallery to select the most valuable pictures, a participant list to invite more volunteers and to give them a personal thank you message, and a report section to close the mission and notify the EWS operators.

Fig. 2. Two screens of the IWarn app: the chat (left) and the map (right).



B. *Implementing Gamification Elements on IWarn*

The IWarn app includes several elements (see Table III) to encourage citizen participation in early warning activities. For each feature, we include a description and the type of gamified element according to the taxonomy proposed in [6] that identifies the following kinds of gamified elements: (1) assignments, quests, and goals; (2) points, credits and levels; (3) achievements and badges; (4) virtual goods; (5) leaderboards and collections; (6) friends, teams, and groups; and, (7) reminders.

To understand how these elements influence civic engagement, we link them to the motivational affordances [20] and the motivational needs [6] they aim to support. For example, through the *Push Notification* feature, participants receive a notification each time a member of the same team participates in the mission as a *reminder* of the need to participate in the common goal (see Description in Table III). This mechanism implements the need to look for the approval of other users and contributes to establishing a relationship among them. Moreover, the *Push Notification* helps to improve the need for affiliation as you are part of a team that is pursuing a common goal and, at the same time, intimacy. On the one hand, all members are notified when someone is active, creating a shared sense of belonging to a well-defined collaborative team worried about its environment. On the other hand, there are private feedbacks that the leader can send to recognize your participation (e.g., "*Thanks for covering that area!*") or ask for additional information (e.g., "*I cannot see the problem, can you take a more detailed picture or describe it?*"), establishing a one-to-one communication channel.

TABLE III. GAMIFIED FEATURES IN IWARN.

Features	**Description**	**Gamified element [6]**	**Motivational Affordances** [20]	**Motivational Needs** [9]
Push Notification	Users receive a notification each time a team member participates in the mission.	- Reminders - Friends, teams, and groups	- Approval by other users. - Secure and rewarding relationships.	Social Needs: - Affiliation and Intimacy.
Reply Messages and Private Feedback.	Users receive private feedback from the leaders to guide their activity or to motivate them, as well as reply messages from other citizens.	- Assignments, quests, and goals	- Engaging in relationships with others. - Approval by other users - Secure and rewarding relationships.	Psychological Needs: - Relatedness Social Needs: - Affiliation and Intimacy.
Participatory Missions	Users take part in a mission collaborating with other citizens and a leader who is an expert.	- Assignments, quests, and goals - Friends, teams, and groups	- Engaging in relationships with others. - Self-determination choices. - Willing to do something well. - Influence on others and followership.	Psychological Needs: - Relatedness - Autonomy Social Needs: - Achievement. - Leadership and Followership.
Chat	Citizens chat freely about possible hazards in their environments and share pictures. Doubts and additional feedback are received from the leader.	- Assignments, quests, and goals - Friends, teams, and groups	- Engaging with others. - Acquire the needed skills to perform a task. - Self-determination choices. - Collaborate in the missions - Influence on others and followership	Psychological Needs: .- Relatedness - Competence - Autonomy Social Needs: - Affiliation and Intimacy. - Leadership and Followership.
Thanks	The leader, who is an expert, thanks citizens for their participation in the missions.	- Achievements and badges	- Willing to do something well. - Approval by other users. - Secure and rewarding relationships.	Social Needs: - Achievement. - Affiliation and Intimacy.

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 License. For more information, see https://creativecommons.org/licenses/by-nc-nd/4.0/

This article has been accepted for publication in IEEE Transactions on Emerging Topics in Computing. This is the author's version which has not been fully edited and content may change prior to final publication. Citation information: DOI 10.1109/TETC.2023.3296772

Top citizens ranking	Users' objective achievements are reflected in the Top Ranking.	- Leaderboards and collections	- Willing to do something well. - Approval by other users - Secure and rewarding relationships.	Social Needs: - Achievement. - Affiliation and Intimacy.
Badges	When the mission ends, the team members receive an award.	- Achievements and badges	- Willing to do something well.	Social Needs: - Achievement.
Anonymous geolocation and identity.	Citizens can anonymize their geolocation and identity.	- Friends, teams, and groups	- Self-determination choices. - Approval by other users - Secure and rewarding relationships.	Psychological Needs: - Autonomy Social Needs: - Affiliation and Intimacy
Upload profile photos	Citizens can personalize their profiles.	- Friends, teams, and groups	- Self-determination choices.	Psychological Needs: - Autonomy

In the first version of the app that was compared with a non-gamified version [37], there were elements that promoted the competition, like points and levels. When assessed with EM workers in a focus group they were worried about this kind of motivators that could end up in citizens sending all kinds of information or putting themselves in danger just to get points [24]. The app was completely redesigned, balancing motivators and looking for a collaborative and non-competitive approach based on teams and guided by an expert who will provide confidence both to the team and to the EM operators. The concept of "thanks" was introduced as a more meaningful recognition of the contribution provided by an expert and not directly by the system. Additionally, the role of this expert, the leader, was reinforced to boost participation and to guide participants during the mission, solving doubts and giving feedback about the participation. Thus, the changes affected both the Artifact implemented but also the Situation, that is the way the mission was executed.

IV. A Framework to evaluate IWarn

To evaluate how the IWarn app affects the users' intrinsic and extrinsic motivations, we have instantiated the different dimensions in the situated motivational affordances model [8]. Figure 3 shows the six dimensions (bold labels) identified in Deterding's model and how they are particularised for our case study (italic labels). In the outside, three elements need to be identified: the **Artifact**, the **Situation,** and the **Motivational Needs** that should be satisfied. The gamified IWarn app for smartphones represents the **Artifact**, and the participatory early warning mission is the **Situation**. The **Motivational Needs** we pursued to meet with the design include autonomy, competence, relatedness, achievement, affiliation and intimacy, and leadership and followership, as described in Table III. In the dotted area, the evaluation mechanisms for the three dimensions are defined. The **Artifact Motivational Affordances** will be evaluated, focusing on the intrinsic and extrinsic motivators they enable following [21]. The **Situational Motivational Affordances** refer to the connection enabled between the citizens and the context where the interaction occurs. To evaluate this dimension, we rely upon the concept of Personal Urban Awareness (PUA) introduced in a previous study where a game played in a former historical building was used to connect citizens and passersby with an urban area [25]. Both affordances are expected, according to the original model, to affect the **Interaction**, whose success will be measured using the well-known concept of User Engagement [29], as the goal of a civic participatory tech is to engage users in the participation process. In the remaining of this section, we describe how we evaluated the artifactual and situational affordances and the successful interaction.

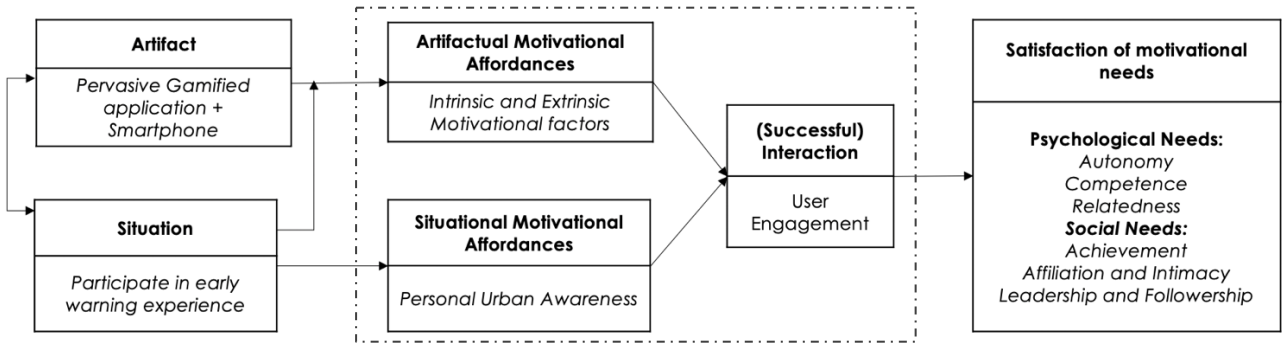


Fig. 3. The evaluation framework for the gamified IWarn app.

To evaluate the **Artifactual Motivational Affordances** generated by the IWarn app, we have used the categorization proposed by Thiel and Fröhlich in [21] that was devised to engage citizens in participation processes (see Table I). In this way, the interaction with the app is assessed in the experiment in terms of *Pleasure*, *Social,* and *Learning* as intrinsic factors, and *Reputation*, *Institutional,* and *Personal* as extrinsic factors. Accordingly, we have designed a 5-point Likert scale questionnaire (ranging from 1 = "strongly disagree" to 5=" strongly agree.") with 12 items to assess them. The questionnaire is included in Table IV.

TABLE IV.
QUESTIONNAIRE ITEMS FOR THE ARTIFACTUAL MOTIVATIONAL AFFORDANCES, ORGANIZED BY INTRINSIC / EXTRINSIC MOTIVATION > MOTIVATION TYPE.

Q

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 License. For more information, see https://creativecommons.org/licenses/by-nc-nd/4.0/

This article has been accepted for publication in IEEE Transactions on Emerging Topics in Computing. This is the author's version which has not been fully edited and content may change prior to final publication. Citation information: DOI 10.1109/TETC.2023.3296772

No.	*Question*
Intrinsic Motivations > Pleasure	
Q01	It was fun to participate in the mission.
Q02	I enjoyed using the application while exploring the environment and participating in the mission.
Extrinsic Motivations > Personal	
Q03	The mission where I participated was of particular interest to me.
Q04	I felt useful in the mission.
Extrinsic Motivation > Institutional	
Q05	During the mission I felt that I was contributing to the safeguarding my environment.
Q06	I feel that my participation has had an impact on early warning management.
Intrinsic Motivation > Socialization	
Q07	I enjoyed collaborating with my mission team.
Q08	The chat has helped me feel part of the mission team.
Extrinsic Motivations > Reputation	
Q09	I felt that my contributions were valued
Q10	I felt valued by the mission team leader.
Intrinsic Motivations > Learning	
Q11	During the mission, I learned about possible risks in my environment.
Q12	Participating in this mission has allowed me to learn about the prevention of certain problems in my environment.

The **Situated Motivational Affordances** The PUA is defined as the connection between people and their urban environment, and it comes from the combination of two concepts: the first is the perception and feeling of the surroundings [26], and the second is an educational approach to motivate citizens to interact with their environment [27]. The PUA represents how an informal process like using the IWarn app can boost general interest in the place where the app is used. It is composed of the following three factors:

1. The *user interest in the environment*. IWarn encourages users to explore and observe the environment, take geolocated photos, and share them with the other participants in the mission. Moreover, the leaders can ask the participants to explore a specific area and take more photos. All these actions could provoke interest in other aspects of the area covered.

2. The *usefulness to gain knowledge*. During an IWarn mission, participants have the possibility to learn about the possible risks in their surroundings but also to observe other interesting elements. In this way, after using the app, participants can feel motivated to learn more about that area.

3. The *connection with the surroundings*. The missions could make the participants more aware and sensitive about aspects of the environment, like the existence of physical barriers for disabled people. Hence, we can assess whether using the app enables a higher connection with surroundings, which is especially weak in many urban areas where inhabitants are immersed in a hectic life style.

To assess these factors, we designed a 5-point Likert scale questionnaire (ranging from 1 = "strongly disagree" to 5=" strongly agree.") with 12 items (see Table V). Part of this questionnaire has already been used in a previous contribution for evaluating a pervasive game to learn about the historical facts of an urban area [28]. That use case was not gamified neither collaborative.

TABLE V.
QUESTIONNAIRE ITEMS FOR THE SITUATED MOTIVATIONAL AFFORDANCES, ORGANIZED BY EVALUATION CRITERIA.

No.	*Question*
Interest in the surroundings	
Q01	After using this app, would you like to know more about other problems that exist in the environment or the area where you have carried out the mission?
Q03	Would you like to use this app to participate in other missions in the same environment?
Q08	To what extent do you consider that your interest in the place where you have carried out the missions has increased, such as, for example, following the evolution of the problems that you have encountered or that other people in your group have encountered?
Q10	Did participating in this mission made you feel part of what is happening in your environment / city?
Usefulness for gaining knowledge about several aspects of the context (ecology, sustainability, ...)	
Q02	Do you think this app has helped to value and be more susceptible to the importance of some aspects of your environment related to the mission, such as the importance of (cornices in your neighborhood)?
Q04	Do you consider this type of app a useful tool to raise awareness and involve citizens in tasks of their local environment (e.g., the environment, public management, emergency management)?
Q05	Would you recommend using this app to your friends or family to get involved or collaborate on tasks in their local environment (e.g., the environment, public management, emergency management)?
Q06	While using the app, to what extent do you consider that you have acquired specific knowledge about the problem in which you participated?
Connect with some context	
Q07	To what extent do you consider that getting involved in this mission has made you more aware of the problems in your environment, such as being more aware of specific architectural barriers?
Q09	To what extent would you contact an institution or neighborhood association to improve your environment if you have been aware of other environmental problems?

The **Successful Interaction** dimension is related to the users' overall experience interacting with the artifact to satisfy their needs. In this case, we use the concept of user engagement as evaluation criterion since the main goal of the app is to engage users. To measure it, we rely upon the well-known User Engagement Scale Short Form (UES-SF)

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 License. For more information, see https://creativecommons.org/licenses/by-nc-nd/4.0/

This article has been accepted for publication in IEEE Transactions on Emerging Topics in Computing. This is the author's version which has not been fully edited and content may change prior to final publication. Citation information: DOI 10.1109/TETC.2023.3296772

questionnaire [29]. User Engagement is evaluated according to four factors: *Focused Attention*, defined as the act of being cognitively absorbed during interaction with the app, *Aesthetic Appeal* as the attractiveness of the application, *Perceived Usability* as the degree of control and effort required to use the app, and *Reward*, identified by the level of enjoyment of the user and the willingness to recommend or use it in the future. The result is a 5-point Likert scale questionnaire (ranging from 1 = "strongly disagree" to 5=" strongly agree.") with 12 items (see table VI).

TABLE VI.
QUESTIONNAIRE ITEMS FOR THE SUCCESSFUL INTERACTION DIMENSION, EXTRACTED FROM THE UES- SF QUESTIONNAIRE, ORGANIZED BY 4 FACTORS: FOCUSED ATTENTION (FA), AESTHETIC APPEAL (AE), PERCEIVED USABILITY (PU), AND REWARD (RW).

No.	*Question*
FA-S.1	I lost myself in this experience.
FA-S.2	The time I spent using IWarn just slipped away.
FA-S.3	I was absorbed in this experience.
PU-S.1	I felt frustrated while using this IWarn.
PU-S.2	I found IWarn confusing to use.
PU-S.3	Using IWarn was taxing.
AE-S.1	IWarn was attractive.
AE-S.2	IWarn was aesthetically appealing.
AE-S.3	IWarn appealed to my senses.
RW-S.1	Using IWarn was worthwhile.
RW-S.2	My experience was rewarding.
RW-S.3	I felt interested in this experience

When using the UES- SF for an evaluation, all the items should be randomized, and dimensions should not be visible to participants [29]. The items associated with the Perceived Usability (PU) criterion are in negative form. When calculating the mean value for each criterion and the overall UE score, it is crucial to pay attention to negative elements.

In conclusion, the situated motivational affordances model for evaluating the IWarn app includes three questionnaires. Each has specific items for one of the three central dimensions of Deterding's model (see the dotted area in Figure 3): the Artifactual Motivational Affordances, the Situational Motivational Affordances, and the Successful Interaction.

V. EXPLORATORY STUDY

To evaluate the impact of the gamified app on civic engagement, we carried out an experimental and exploratory study based on the framework defined in the previous section. The purpose is to investigate the possible factors that increase engagement in activities that are not extrinsically rewarding, such as early warning monitoring. Additionally, we aim to understand whether engaging with the app would impact the participants' relation with or interest in their surroundings. To implement a meaningful mission that could connect with a real case in a real environment, we involved EM practitioners in designing a mission that monitored potential precursors of floodings due to heavy rain. The mission was carried out during the month of July when the weather in the area is dry and very hot, so there is no sign of risk and, hence, there is not a clear motivation to go out and help to prevent a potential risk that doesn't seem real or urgent. These experts also contacted real emergency volunteers to play the leader's role.

A. Methodology

As a first step, we contacted the fireman head of Fuenlabrada, a city near Madrid with more than 190.000 inhabitants, to organize a meeting to explore their participation. In a second phase, we decided and designed together the mission that would be related to one of their main concerns: climate change and citizens' security. They proposed the mission "Adverse weather events" and put us in contact with the Civil Protection manager in Fuenlabrada to recruit volunteers who could act as leaders in the mission. Four of the civil protection volunteers showed interest in it. To recruit citizens, we contacted people through Whatsapp and Telegram groups used by the civil protection volunteers. The people who showed interest in participating in the evaluation received a digital consent form with information about the study's goals and gave us their consent to collect their data. Participation in this study was completely voluntary, and there was no explicit reward since we were evaluating an activity that was not extrinsically rewarding. Once the participants signed the consent form to participate in the mission and filled out a survey with their emails and usernames, we registered them into our database. We gave them a username and password to log in to the application and start using it by participating in one of the available missions.

The first time leaders logged in to IWarn, they found an invitation to the mission "Adverse weather events". They had to follow a tutorial to get familiar with the app functionalities and interfaces. Once they accepted, they could invite registered citizens to participate in the mission and become part of her team. The mission was described as follows: "Collaborate with the emergency services to prevent possible dangerous situations by reporting risks such as blocked scuppers, trees, branches, cornices or facades at risk of falling". Once a citizen accepted, the participation duration was set to 1 week. After users participated in the mission, we closed the missions. Then we sent the three questionnaires to the participants to collect data about their experiences.

During the study, we did not collect any sensitive or personal information. It is important to mention that in this evaluation, we only consider the answers collected from the citizens since they are the target profile to evaluate the gamification elements and the effects of using this pervasive application to encourage their involvement in public service coproduction. All the data were collected, stored, and processed anonymously, and the ethics committee of our institution approved the process.

B. Participants

We recruited 21 volunteers to participate in the experiment, but only 17 actively participated in the missions. The ages ranged between 25 and more than 54 years old (18% from 25 to 34, 41% from 35 to 44, 18% from 25 to 54, and 23% from more than 54). Considering that participants' gender may be fluid and impermanent at the time of the experiment, we collected half the responses of the participants who defined themselves as male, 40% as female, and 10% who preferred not to state a gender.

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 License. For more information, see https://creativecommons.org/licenses/by-nc-nd/4.0/

This article has been accepted for publication in IEEE Transactions on Emerging Topics in Computing. This is the author's version which has not been fully edited and content may change prior to final publication. Citation information: DOI 10.1109/TETC.2023.3296772

C. Apparatus

The app was developed using Ionic Framework 5 and Angular and compiled for Android and iOS. The app was also published in both platforms' official stores to facilitate the participants' installation. The Capacitator library is used to access native mobile capacities such as the camera or GPS, and the OpenStreetMaps library helps to provide maps. Users' media contents are collected and provided by an API Rest server developed in Node.js[1] and Express[2]. The server stores the information in a SQL database (MariaDB[3]) and has access to the Firebase service to send Push Notifications to the users or groups of users.

D. Material

The questionnaire included an initial demographics section to gather data about users and the three different parts already described in the previous section. Participants had to evaluate a total of 36 items with a 5-point Likert scale (ranging from 1=" strongly disagree" to 5=" strongly agree."). The questionnaires are included in the Appendix.

E. Results

1) Artifactual Motivational Affordances (Intrinsic and extrinsic motivations)

The artifactual motivational affordances assessment included 12 items scored on a 5-point Likert scale, and the Cronbach's Alpha for the questionnaire was α = .85 [30], [31]. As shown in Table IV, each item is associated with an intrinsic (int) or extrinsic (ext) motivation: pleasure (int), personal (ext), institutional (int), socialization (ext), reputation (ext), and learning (int) [21].

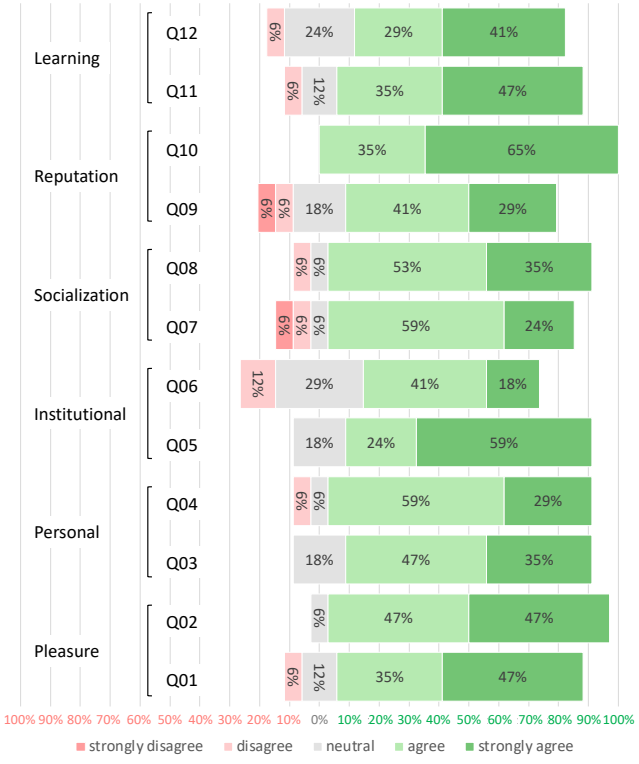


Fig. 4. Likert Scale Chart for the intrinsic (Learning, Socialization, and Pleasure) and extrinsic (Personal Institutional and Reputation) motivations.

Analyzing the collected answers, we can observe that the participants agreed and strongly agreed on both motivations (see the distribution of the responses in Figure 4). In particular, looking at pleasure and learning, participants highly enjoyed the experience and appreciated it as a possibility to learn more about the environment. The artifactual motivational affordances assessment included 12 items scored on a 5-point Likert scale, and the Cronbach's Alpha for the questionnaire was α = 0.85 [30], [31]. As shown in Table IV, each item is associated with an intrinsic (int) or extrinsic (ext) motivation, choosing between pleasure (int), personal (ext), institutional (int), socialization (ext), reputation (ext), and learning (int) [21]. Analyzing the collected answers, we can observe that the participants agreed and strongly agreed on both motivations (see the distribution of the responses in Figure 4). In particular, looking at the pleasure and the learning motivations, they highly enjoyed the experience and appreciated the underlying value of the application as the possibility to learn more about the environment, the risks, and the problems around them.

2) Situated Motivational Affordances (PUA)

The Situated Motivational Affordances dimension included 10 items scored on a 5-point Likert scale, and the Cronbach's Alpha for the questionnaire was α = .84 [30], [31]. The questions are organized into the three PUA criteria (see Table V): (i) user interest in the environment, (ii) usefulness to gain knowledge, and (iii) connection with the surroundings. The participants' responses showed that they mainly agreed and strongly agreed with all the questionnaire items (see the distribution of the responses in Figure 5). We can observe, in particular, that they felt they gained knowledge about their surroundings' sustainability and ecological well-being after using the application. They have also indicated they were interested in more active roles to help solve certain risky situations, like cleaning sewers or streets.

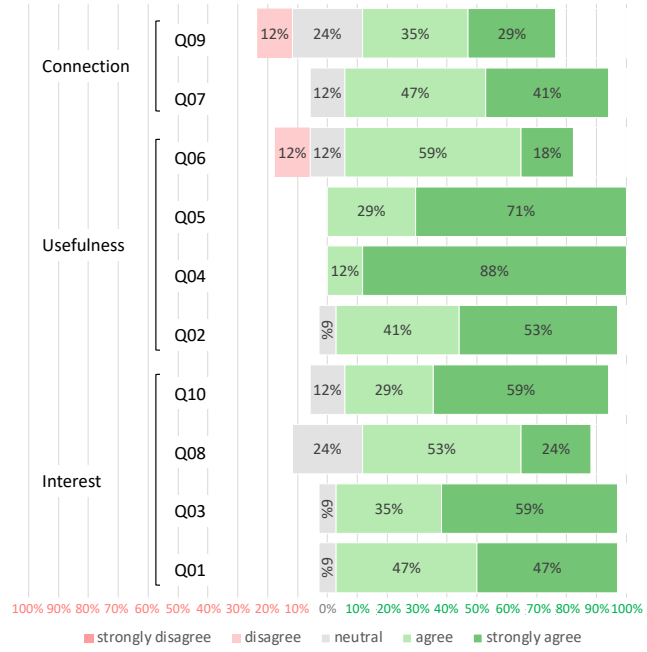


Fig. 5. Likert Scale Chart for the Situated Motivational Affordances.

[1] https://nodejs.org/en
[2] https://www.npmjs.com/package/express
[3] https://www.npmjs.com/package/mariadb

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 License. For more information, see https://creativecommons.org/licenses/by-nc-nd/4.0/

This article has been accepted for publication in IEEE Transactions on Emerging Topics in Computing. This is the author's version which has not been fully edited and content may change prior to final publication. Citation information: DOI 10.1109/TETC.2023.3296772

3) Successful Interaction (UE)

To measure the Successful Interaction dimension, we used the UES-SF questionnaire [29] that measures four factors (see Table VI): *Aesthetic Appeal* (AA), *Focused Attention* (FA), *Perceived Usability* (PU), and *Reward* (RW). The Cronbach's Alpha for the questionnaire was α = .71 [30], [31]. As shown in Figure 6, the results indicated that all the factors scored around a value of 4.

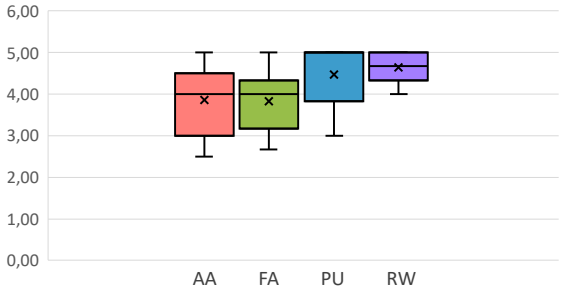


Fig. 6. Likert Scale Chart for the Situated Motivational Affordances.

Notably, most users scored the four factors with similar values with very few outliers. For example, the median for the Perceived Usability is a value of 5 with 4 out of 17 outliers (see Figure 6). This suggests that participants felt in control while interacting with the application and considered adequate the required effort to use it. Another interesting result can be observed for the Aesthetic Appeal factor, where there seems to be a wider distribution of the participants' scores from a minimum value of 2,5 to a maximum of 5, reflecting different opinions about the appearance of the app. The high values obtained for Reward indicate that participants enjoyed the experience and would recommend the application in the future (measured through Reward [29]). Finally, *Focused Attention* values show that they participants were somewhat absorbed during the experience. However, a higher value could be negative since participants should not pay too much attention to the app whilst walking on the streets.

4) Correlation study

We analyzed the relationship between the dimensions in the questionnaires to determine whether they are somehow related. Considering that the responses are scored using an ordinal scale (i.e., Likert scale), we have opted for Spearman's rank-order correlation [32]. The variables are the dimensions of the three questionnaires: the six intrinsic and extrinsic motivations (i.e., Pleasure, Personal, Institutional, Socialization, Reputation, and Learning), the three situated motivational affordances (i.e., Interest, Usefulness, and Connection), and the four factors of the user engagement (i.e., Aesthetic Appeal, Focused Attention, Perceived Usability, and Reward). We have focused on discovering the existence of monotonic relations between user engagement and each motivation and affordance.

We have found a positive and very strong correlation between Pleasure and Focused Attention, $r(15) = .800$, $p < .001$. The Pleasure dimension also positively and strongly correlates with Aesthetic Appeal, $r(15) = .608$, $p = 0.01$, and Reward, $r(15) = .594$, $p = 0.01$. It also exists a positive and strong correlation between the Aesthetic Appeal factor and the Learning motivation, $r(15) = .610$, $p < .01$, and the Connection affordance, $r(15) = .650$, $p < 0.01$. Finally, The Reward factor has a positive and strong correlation with the Learning motivation, $r(15) = .739$, $p = 0.001$, and the affordances Interest, $r(15) = .765$, $p < .001$, and Usefulness, $r(15) = .642$, $p < 0{,}01$. These correlation suggest a potential influence between the motivations and the affordances and, hence, in experiencing a successful interaction with the artifact. Though these correlations do not imply a cause-effect relation, they suggest that paying attention to the user motivations that could be enabled by the use of a technological artifact and the possibilities opened up by its use in a specific situation, are two factors that might help designers device more useful and successful interactive experiences.

VI. Lessons Learnt

The development and design of IWarn had two clear goals: to engage citizens in early warning monitoring activities as a support for coproduction of this service and to increase their interest in their environment as a side effect of their involvement in the activities. In the experimental study, we found that the Reward and Perceived Usability factors of user engagement got higher scores, meaning that the gamified elements used in the app successfully engaged participants who were willing to recommend it and use it again in the future. Moreover, the app successfully drew the curiosity and interest of the users.

Apart from the specific findings about the IWarn app reported in this paper, we have derived some lessons from using the proposed conceptual framework and following an action research cycle with real stakeholders involved in the design and evaluation [12]. The following paragraphs summarize these lessons that can help in the design and evaluation of engaging civic techs.

Lesson 1 – Engaging in gamified missions can positively impact citizens' interest in their surrounding environment. Immersed in a hectic life style, urban dwellers are not always aware of the spaces they live in, the opportunities they offer, the community activities that could be organized to make spaces more livable or sustainable, or even the problems that could be solved to make others' lives better. Gamified apps like IWarn have a clear goal: in our case, monitoring a specific space and looking for problems. However, they also have a hidden goal that involves pushing citizens to move around the environment and focus their attention on it to be more aware of all these issues, as suggested in [33]. Indeed, our study results about the Situated Motivational Affordances using the three PUA dimensions (interest, usefulness and connection) suggest that using the gamified IWarn application might increase the users' relation with their surrounding environment. Participants were forced to explore and observe the area they were monitoring, and not only did participants become interested in it (Q08 in Figure 5), but most of them considered that participating in the mission had made them feel part of what was happening in their environment (Q10 in Figure 5). Our participants also stated that they would use the app to improve their environment if they were informed about other environmental problems (Q03 in Figure 5). All these initial findings can indicate that to build a stronger relationship between participants and their environment, designers of *participatory civic techs* should pay attention to the motivational affordances of the situation in which the app will be used, and not only on the technological artifact features and functionalities.

Lesson 2 – Intrinsic and extrinsic motivators must be balanced to design pleasurable and fun experiences. Usability and utility are not enough to engage in *civic participatory*

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 License. For more information, see https://creativecommons.org/licenses/by-nc-nd/4.0/

This article has been accepted for publication in IEEE Transactions on Emerging Topics in Computing. This is the author's version which has not been fully edited and content may change prior to final publication. Citation information: DOI 10.1109/TETC.2023.3296772

techs, particularly when the utility is not immediately perceived. A careful design focusing on how to connect with motivational needs is required to create stronger connections with users. Gamification can be a valuable tool in this context, but it is not the goal: it might not be enough to motivate useful and meaningful participation. Indeed during the iterative design of IWarn, we conducted several focus groups with EM experts who were quite reluctant to include gamification as they thought that overstimulated citizens are usually more dangerous than passive citizens [24]. The framework by Thiel and Fröhlich [21] offers a good starting point to anchor gamification elements to specific motivational affordances. In our case, we reflected on the elements to include, as shown in Table III, and then we tested their real impact when evaluating the artifactual motivational affordances (see figure 4). Reputation was the extrinsic motivation better perceived by participants. In this case, the participation of a real expert as leader of the group who was constantly interacting and evaluating contributions was fundamental. This role was detected during the focus groups with experts who clearly stated that civic participation needs to be monitored or led by professional workers to filter out useless information, to avoid putting citizens into dangerous situations, and to sustain participation through meaningful feedback [12]. As an extrinsic motivator, most participants liked the socialization feature of the app and the opportunity to collaborate with other people, especially the use of the chat, which made them feel part of a team. They also gained knowledge about possible risks in their area and prevention measures.

These findings suggest that the gamified IWarn application could have increased users' intrinsic motivation. Additionally, our participants felt helpful during the mission, since they thought that they contributed to safeguarding their environment, and valued that fact of their contributions being valued thanks to the recognition of the leader. These results illustrate that participants' extrinsic motivations in IWarn were high, which aligns with Thiel and Fröhlich's study [21], suggesting that reputation and motivation are essential factors in gamified applications. Based on Thiel and Fröhlich's, there is no significant difference between extrinsic and intrinsic motivation. Nevertheless, the intrinsic results are a little higher in our exploratory study, pointing out that the application value can go beyond the explicit rewards they can obtain with the application.

Lesson 3 - Situated motivational affordances impact in a successful interaction. Enjoyment and perceived utility during the app experience are linked with promoting user interest in the surroundings and context. IWarn encourages taking geolocated photos and sharing any potentially dangerous circumstance found in the environment to help EM, while the sharing also happens with other participants in the mission. The app provides a map to check the user's participation in real-time, making them aware of the early warning situation in which they collaborate. Using the map during the mission increases users' interest and knowledge about the environment, as suggested in [7], which states that the longer users use digital map applications, the more they become aware of the surroundings. The implementation of the map and the use of geolocated photos made users perceive the app's utility while enjoying it and leading them to use it in the future to help in other missions.

VII. Conclusions and Future Works

In this paper, we have described how the situated motivational affordances model can help in devising *civic participatory techs* through a specific use case that was not extrinsically rewarding. In this way, we aim at contributing to the design and evaluation of engaging *civic participatory techs*. To this scope, we have shown the importance of the app context and domain of interest to make the participants' real intrinsic motivations salient, as already proposed in [20]. The intrinsic motivations are important to increase user engagement in the long term, as pinpointed in [35]. The correlation analysis shows that the evaluation of the situated and artifactual motivational affordances might be related to the users' motivational needs. This result points to a possible satisfaction of the users' motivational needs during the design of the app as a key factor in designing useful interactions.

Our study results suggest that gamification might be beneficial for engaging citizens in early warning monitoring applications and can increase urban awareness. IWarn helped participants in the exploratory study to create emotional links with the problems that the environment around them can suffer and the willingness to contact institutions to help solve them. In this way, they built a positive image of themselves as they were contributing to improve their city. For example, sharing the location of each team member enhances peripheral awareness, fosters a sense of connection, and builds trust within shared social groups, as shown in [36]. Another interesting fact is enhancing the collaboration between citizens and authorities, in our case, emergency workers, to support a service coproduction. In this case, we observed that the role of the leaders was crucial to sustaining participation, as they use the chat to give volunteers more details about the mission, talk personally with them about their contributions and thank them. This interaction can contribute to a better understanding of the citizens about the missions and an increasing collaboration and commitment.

Social computing offers many possibilities to engage citizens in their communities, but apart from deployments, what is still needed is a strong conceptual framework that could help in the design of efficient and motivating applications. In this work, we presented a specific case study and the design and evaluation mechanisms we used to focus the development on motivations. The use of the motivational affordances model forced us to devise the technological development from two complementary perspectives: the interaction affordances enabled by the technological artifact (namely artifactual motivational affordances) and the affordances enabled by the use of the artifact in a specific situation (namely situational motivational affordances). In this way, we had a broader view of the possibilities of interaction that could be offered taking into account the specific context of use, collaborative early warning. Our case was not explicitly rewarding since there was no sign of risk to participate in the mission neither any kind of reward was offered. Hence the focus on intrinsic motivators was fundamental.

Though our results were encouraging, the work here reported is an example on how to instantiate an existing conceptual model to evaluate and design civic participatory tech applications. From the point of view of the evaluation, further work and experiments are required to test and adapt the proposed questionnaires to different situations and goals in order to be able to come up with a generalizable framework.

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 License. For more information, see https://creativecommons.org/licenses/by-nc-nd/4.0/

This article has been accepted for publication in IEEE Transactions on Emerging Topics in Computing. This is the author's version which has not been fully edited and content may change prior to final publication. Citation information: DOI 10.1109/TETC.2023.3296772

From the point of view of the design, we presented how to use gamification elements from [6] to satisfy motivational affordances [20] and needs [9]. In this case, what is needed is to formalize all the knowledge on artifactual affordances using mechanisms such as heuristics and design patterns that could guide designers in applying the right solution for a given recurrent problem. Moreover, design frameworks to help developers focus on the situation and not only on the artifact are also needed. With the advent of technologies like mixed and augmented reality, whose use is tied to specific locations, understanding the potential of the situation of use and exploiting all its capability to create emotional links with users becomes more and more relevant to create useful and successful experiences that connect us with our context and communities.

ACKNOWLEDGMENT

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

REFERENCES

[1] R. P. Adler and J. Goggin, "What Do We Mean By 'Civic Engagement'?," *Journal of Transformative Education*, vol. Vol. 3, no. No. 3, pp. 236–253, 2005, doi: 10.1177/1541344605276792.

[2] M. Hank, M. Foth, M. Tomitsch, C. Satchell, and M. Hank Haeusler, "From Users to Citizens: Some Thoughts on Designing for Polity and Civics," pp. 623–633, 2015, doi: 10.1145/2838739.2838769.

[3] J. Saldivar, C. Parra, M. Alcaraz, and R. Arteta, "Civic technology for social innovation A systematic literature review".

[4] E. Ostrom, "Crossing the great divide: coproduction, synergy, and development.," *World Dev*, vol. 24, pp. 1073–1087, 1996.

[5] P. Díaz, J. M. Carroll, and I. Aedo, "Coproduction as an approach to technology-mediated citizen participation in emergency management," *Future Internet*, vol. 8, no. 3, 2016, doi: 10.3390/fi8030041.

[6] P. Weiser, D. Bucher, F. Cellina, and V. De Luca, "A Taxonomy of Motivational Affordances for Meaningful Gamified and Persuasive Technologies," in *Proceedings of EnviroInfo and ICT for Sustainability 2015*, 2015, vol. 22. doi: 10.2991/ict4s-env-15.2015.31.

[7] C. Prandi, M. Roccetti, P. Salomoni, V. Nisi, and N. J. Nunes, "Fighting exclusion: a multimedia mobile app with zombies and maps as a medium for civic engagement and design," *Multimedia Tools and Applications*, vol. 76, no. 4, pp. 4951–4979, 2017, doi: 10.1007/s11042-016-3780-9.

[8] S. Deterding, "Situated motivational affordances of game elements : A conceptual model," *CHI 2011 Workshop Gamification Using Game Design Elements in NonGame Contexts 2011*, no. July, pp. 3–6, 2011, doi: ACM 978-1-4503-0268-5/11/05.

[9] S. Deterding, D. Dixon, R. Khaled, and L. Nacke, "From game design elements to gamefulness: Defining 'gamification,'" *Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments, MindTrek 2011*, no. September, pp. 9–15, 2011, doi: 10.1145/2181037.2181040.

[10] *Pelling, N. "The (short) prehistory of gamification". Funding Startups (& other impossibilities), 2011, vol. 9*

[11] J. Hamari, J. Koivisto, and H. Sarsa, "Does gamification work?–a literature review of empirical studies on gamification," in System Sciences (HICSS), 2014 47th Hawaii International Conference on. IEEE, 2014, pp. 3025–3034.

[12] P. Diaz, M. Sanchez-Francisco, T. Onorati, A. Montero, and I. Aedo, "IWARN: A people-centered approach for early warning," in *Proceedings of the 55th Hawaii International Conference on System Sciences*, 2022, vol. 7, pp. 2451–2460. doi: 10.24251/HICSS.2022.306.

[13] L. Hassan, "Governments Should Play Games: Towards a Framework for the Gamification of Civic Engagement Platforms," *Simulation and Gaming*, vol. 48, no. 2, pp. 249–267, 2017, doi: 10.1177/1046878116683581.

[14] M. Neuenhaus and M. Aly, "A Key HCI based - concept for Creating Empathy for Refugees Extended Abstract," *Workshop in Refugees & HCI Workshop: The Role of HCI in Responding to the Refugee Crisis. In 2017 CHI Conference*, 2017.

[15] B. Morschheuser, L. Hassan, K. Werder, and J. Hamari, "How to design gamification? A method for engineering gamified software," *Information and Software Technology*, vol. 95, no. October 2017, pp. 219–237, 2018, doi: 10.1016/j.infsof.2017.10.015.

[16] E. Gordon and J. Baldwin-Philippi, "Playful civic learning: Enabling reflection and lateral trust in game-based public participation," *International Journal of Communication*, vol. 8, no. 1, pp. 759–786, 2014, doi: 1932–8036/20140005.

[17] Stembert, N. and Mulder, I. (2013) Love your city! An interactive platform empowering citizens to turn the public domain into a participatory domain. International conference Using ICT, Social Media and Mobile Technologies to Foster Self-Organisation in Urban and Neighbourhood Governance. May 16-17, TU Delft.

[18] C. Prandi, P. Salomoni, M. Roccetti, V. Nisi, and N. J. Nunes, "Walking with Geo-Zombie: A pervasive game to engage people in urban crowdsourcing," *2016 International Conference on Computing, Networking and Communications, ICNC 2016*, pp. 0–4, 2016, doi: 10.1109/ICCNC.2016.7440545.

[19] H. Alamri, V. Lowell, W. Watson, and S. L. Watson, "Using personalized learning as an instructional approach to motivate learners in online higher education: Learner self-determination and intrinsic motivation," *Journal of Research on Technology in Education*, vol. 52, no. 3, pp. 322–352, Jul. 2020, doi: 10.1080/15391523.2020.1728449.

[20] A. Bowser *et al.*, "Using gamification to inspire new citizen science volunteers," *ACM International Conference Proceeding Series*, pp. 18–25, 2013, doi: 10.1145/2583008.2583011.

[21] S. Thiel and P. Fröhlich, "Gamification as motivation to engage in location-based public participation?," no. Progress in location-based services 2016, G. Gartner and H. Huang, Eds. Cham: Springer International Publishing, 2017, pp. 399–421. doi: 0.1007/978-3-319-47289-8_20.

[22] J. Reeve, *Understanding motivation and emotion*. John Wiley & Sons, 2018.

[23] de León, J. C. V., J. Bogardi, S. Dannenmann, and R. Basher, "Early warning systems in the context of disaster risk management.," *Entwicklung and Ländlicher Raum*, pp. 23–25, 2006.

[24] P. Diaz, T. Onorati, M. Romano, and I. Aedo, "Designing affordable technologies to integrate citizens in early warning activities," Proceedings of 12th International Conference on Ubiquitous Computing and Ambient Intelligence, vol. 2, no. 19, 2018, Art. no. 1253, doi: 10.3390/proceedings2191253.

[25] M. Sánchez-Francisco, P. Díaz, F. Fabiano, and I. Aedo, "Engaging Users with an AR Pervasive Game for Personal Urban Awareness," in *Proceedings of XX International Conference on Human Computer Interaction*, 2019, pp. 1–7. doi: 10.1145/3335595.3335630.

[26] K. Schmidt, "The Problem with 'Awareness': Introductory Remarks on 'Awareness in CSCW,'" *Computer Supported Cooperative Work 11:*, no. December, pp. 285–298, 2004, doi: 10.1023/A:1021272909573.

[27] W. B. Stapp, "The Concept of Environmental Education," *Environmental Education*, 1969, doi: 10.1080/00139254.1969.10801479.

[28] M. Sánchez-Francisco, P. Diaz, T. Onorati, and I. Aedo, "Connecting citizens with urban environments through an Augmented Reality Pervasive Game," *Under Review on Multimedia Tools and Applications*, 2022.

[29] H. L. O'Brien, P. Cairns, and M. Hall, "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*, vol. 112, no. July 2017, pp. 28–39, 2018, doi: 10.1016/j.ijhcs.2018.01.004.

[30] Paul. Kline, *An Easy Guide to Factor Analysis*. London: Routledge, 2014. doi: 10.4324/9781315788135.

[31] U. Sekaran and Bougie Roger, *Research methods for business: A skill building approach.* John Wiley & Sons, 2013.

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 License. For more information, see https://creativecommons.org/licenses/by-nc-nd/4.0/

This article has been accepted for publication in IEEE Transactions on Emerging Topics in Computing. This is the author's version which has not been fully edited and content may change prior to final publication. Citation information: DOI 10.1109/TETC.2023.3296772

[32] "Spearman's Rank-Order Correlation," *Leard Statistics*. https://statistics.laerd.com/statistical-guides/spearmans-rank-order-correlation-statistical-guide.php (accessed Nov. 04, 2021).

[33] R. Westerholt, H. Lorei, and B. Höfle, "Behavioural effects of spatially structured scoring systems in location-based serious games-A case study in the context of OpenStreetMap," *ISPRS International Journal of Geo-Information*, vol. 9, no. 2, p. 129, 2020, doi: 10.3390/ijgi9020129.

[34] H. L. O'Brien and E. G. Toms, "What is user engagement? A conceptual framework for defining user engagement with technology," *Journal of the American Society for Information Science and Technology*, vol. 59, no. 6, pp. 938–955, Apr. 2008, doi: 10.1002/asi.20801.

[35] M. Hajarian, A. Bastanfard, J. Mohammadzadeh, and M. Khalilian, "A personalized gamification method for increasing user engagement in social networks," *Social Network Analysis and Mining*, vol. 9, no. 1, pp. 1–14, 2019, doi: 10.1007/s13278-019-0589-3.

[36] C. Pang, R. Pan, C. Neustaedter, and K. Hennessy, "City Explorer: The design and evaluation of a location-based community information system," *Conference on Human Factors in Computing Systems - Proceedings*, pp. 1–15, 2019, doi: 10.1145/3290605.3300571.

[37] Romano, M., Díaz, P., & Aedo, I. (2022). Gamification-less: may gamification really foster civic participation? A controlled field experiment. Journal of Ambient Intelligence and Humanized Computing, 13(9), 4451-4465.

Monica Sanchez-Francisco is a phD student in Computer Science and Technology and a collaborator of the DEI - Interactive System group Lab at Universidad Carlos III de Madrid. She holds a Master of Sciences in Cognitive Science and Interactive Media at Universitat Pompeu Fabra. Her current thesis is framed in HCI discipline. She has been working in projects and participating in the development of applications related to her research in the field of pervasive technology and civic engagement.

Paloma Díaz is Full Professor at the Computer Science and Engineering Department of Universidad Carlos III de Madrid where she is the head of the Interactive Systems research group. Her main research interests include interactive systems engineering, collaborative systems, visualization and ubiquitous computing applied to domains such as education, cultural heritage, crisis informatics, health and industry. She has led international and national projects and published more than 200 papers. She is senior member of ACM and IEEE.

Teresa Onorati is associate professor at the Computer Science Department of Universidad Carlos III de Madrid, where in 2013 she received her PhD in Computer Science. She also holds a B. Sc. and a M. Sc. in Computer Science from La Sapienza Università di Roma. Her research interests focus on semantic modelling, visual and immersive analytics, and information visualization for supporting a better understanding of how information and people sentiments propagate within a complex data ecosystem

Álvaro Montero Montes holds a Ph.D. in Computer Science and Technology at Universidad Carlos III de Madrid, and he is also a member of Interactive System Group. His main research areas are augmented reality, virtual reality, and end-user development. During his training as a doctoral student, he got a competitive PhD student grant of Spanish Education and Science Minister, he carried out a 3-month research stay at HIT Lab NZ (Human Interface Technology Lab New Zealand), and he published in several high-impact international journal and conferences. Also, he has been participating and collaborating in other DEI group's research lines providing his knowledges and experience.

Ignacio Aedo holds a degree and a PhD in Computer Science from the Universidad Politécnica de Madrid and he is Professor in the Department of Computer Science and Engineering at Universidad Carlos III de Madrid. He has coordinated several national and international projects in the field of emergency management, learning technology and interactive systems, collaborating with companies and public institutions. He is co-author of five books and more than two hundred publications in journals and conferences about his areas of work, trying to propose new ideas that help people to improve their quality of life through technology.

.

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 License. For more information, see https://creativecommons.org/licenses/by-nc-nd/4.0/