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Towards a Blockchain Hybrid Platform for Gamification of Healthy Habits: Implementation and Usability Validation

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Abstract: (1) Background: In developed countries, public health faces a number of problems, including sedentary lifestyles and poor diets, which collectively contribute to the occurrence of preventable diseases. Noncommunicable diseases represent the leading cause of global mortality. Despite the promotion of healthy living, compliance remains a significant challenge. The integration of gamification into health apps has been demonstrated to facilitate behavioral change. Blockchain technology enhances the effectiveness of gamification by providing data trustability and support for auditable incentives. This feature is possible and easy due to the inherent characteristics of blockchain automating processes through Smart Contracts, rewarding participants and creating leaderboards in a transparent and reliable manner. The use of smart contracts and events enhances the traceability and reliability of decentralized applications, including healthcare. Interoperability in blockchain tools facilitates the deployment of complex environments. The aim of this research is the deployment of a tool for the implementation and testing of a gamification platform based on blockchain technology. (2) Methods: Pre-experimental research was carried out to assess the usability of the decentralized application developed. (3) Results: A decentralized application was developed with the objective of gamifying healthy habits. The application was evaluated using the System Usability Scale, obtaining a score of 80.49, and the Cronbach's Alpha score, which was found to be 0.75. (4) Conclusions: A prototype of a decentralized application connected with a blockchain network to reward challenge fulfilment was deployed. Despite being in early development, it demonstrated high usability. Employing blockchain technology guarantees transparency and traceability while remaining in compliance with legal requirements like the General Data Protection Regulation.

Keywords: blockchain; healthy habits; gamification; smart contract; challenge; public health; usability

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1. Introduction

Currently, some of the most significant issues related to public health in the so-called developed world are the sedentary lifestyle, the inadequate diets, and the existence of improper behavioral habits [1,2]. Many diseases and fatalities could be averted through maintaining a healthy lifestyle [2–5]. Poor dietary habits and insufficient exercise greatly increase the likelihood of acquiring chronic diseases [6,7]. Out of the top ten global causes of death, seven are attributable to noncommunicable diseases, accounting for 74% of annual deaths worldwide [8]. This issue is now considered the major public health crisis of the 21st century and is associated with substantial costs [9]. Therefore, it is within the general interest among developed countries to promote healthy lifestyles, from nutritional, physical, psychological, and behavioral points of view. The obstacle to remove in this line of actuation is the low adherence to recommended good practices in this frame [10]. These healthy habits should be taught and disseminated throughout our entire lifespan. They are essential for fostering healthy behaviors and should be ingrained in the individual [11].

The adoption of these healthy habits can be achieved using gamification strategies, defined as the use of game-like components to motivate and encourage individuals in non-game contexts [12]. This approach has gained popularity in health and fitness applications in recent years [13]. Gamification elements may include badges, leaderboards, points, and challenges [14]. There is increasing evidence of the use of gamified applications in the health sector; the use of health and fitness apps has been on the rise to monitor personal fitness and health parameters [15–17]. The scientific literature reveals the increasing use of applications oriented to nutrition and physical activities that take advantage of gamification [16]. Several studies have highlighted the need to continue researching the potential of gamified health applications to achieve behavioral changes [15,16,18]. Also, these challenges must be correct and suitable for the particular conditions and needs of each individual under consideration [19].

In the field of gamification, an emerging technology known as Blockchain (BC) is gaining momentum. Due to its specific features, it allows for the creation of environments that support the integration of rewards and tracking of activities in the frame of gamification for the adoption of, in this case, healthy lifestyle habits. By nature, BC technology is characterized by decentralization, traceability, reliability, transparency, open-source, autonomy, immutability, anonymity [20], and interoperability [21]. These characteristics favor the provision of strategies that enhance gamification models by automating processes through Smart Contracts (SC), rewarding participants, and creating leaderboards in a transparent and reliable manner through the security, transparency, and reliability that BC provides.

Blockchain operates on a peer-to-peer (P2P) network where nodes work together to maintain the integrity and high availability of data, eliminating the risk of failure or attack on a central server [20]. This decentralized approach, free from dependence on any specific server and thus not controlled by a third party, ensures that the service can validate data without needing a trusted intermediary. This makes it possible for users to verify the information in the system with the guarantee that it cannot be filtered, hidden, or manipulated by any agent on the network.

Apart from facilitating information archiving through this decentralized model, BC networks provide various specialized capabilities that can enable enhanced features. Notably, one such feature is the use of SC. These are programmed functions stored on the network itself. Their invocation, once deployed on the network, cannot be blocked even by any agent in the system. This provides a reliability impossible in other environments [22].

Another key feature of this model is the use of events, which are crucial for service traceability. These artefacts, so-called events, serve as information dissemination mechanisms. From a functional point of view, they are entries in the blocks of data, like any other transaction. In addition to regular entries, events include topics to facilitate their discovery and support for data logging. It has the additional advantage of not having an associated expenditure of network resources for its generation, unlike what happens with transactions in general. Therefore, the issuance of these events on the network constitutes a simple and efficient mechanism for notifying circumstances that take place on the network itself. In this way, it is possible to inform all users of internal events on the network in a simple way. Services intended to take advantage of gamification strategies can use this feature, as they offer a simple and cost-effective, in terms of resources, way to track achievements within the platform. This new paradigm of decentralized data is also quite suitable for the delivery of solutions using new approaches. To maximize the potential of this model, it is typical to utilize decentralized applications (dApps) for both mobile and traditional platforms. These applications are often hosted in a P2P setting, utilizing BC or other P2P networks to manage data and logic. The functional guidelines for these dApps are typically implemented as SC [23,24]. This technology has evolved to be used in environments very different from cryptocurrencies, such as Business Process Management [25], anti-counterfeiting [26], supply chains [27], or healthcare [28]. This kind of platform largely benefits from the interoperability between different BC networks to perform cross-blockchain token transfers and cross-blockchain SC invocation and interaction [21]. Achieving this milestone allows different entities or companies to cooperate more efficiently in complex environments.

The suggestions for employing blockchain technology in the domains of physical activity, exercise, sports, and active aging are still undeveloped, as many of the distinctive attributes of blockchain, like smart contracts, are not fully utilized yet.

Currently, as indicated in Lopez-Barreiro et al. [29], the proposals for the use of BC in the domain of healthy practices are in an immature state, as many of the distinctive attributes of BC, like SC, dApps, events, and others, are not fully exploited. However, it is worth mentioning some proposals in which, to a certain extent, some of these characteristics are applied to improve habits or quality of life in their users. For example, Alsalamah et al. [30] suggested a platform designed to encourage exercising and support wellness-oriented living by incentivizing participants with his/her own cryptocurrency for reaching their goals on a BC platform. In Jamil, Kahng, et al. [31] and Jamil, Qayyum, et al. [32], they provided users with customized workout and feeding plans based on their measurements and body composition details; the use of BC was merely for safety. In Mulyati et al. [33], a data storage system was created for tracking belt promotions in Taekwondo, ensuring that scores were recorded with transparency and immutability. In all these proposals, BC technology is used in one way or another, but without full utilization as indicated in Lopez-Barreiro et al. [29]. Nevertheless, the practical implementation of those proposals, according to the authors, is quite limited. Also, it is worth mentioning that there are other applications in which gamification has been implemented, but in a traditional way, i.e., without the use of this technology. That would be the case for Hoevenaars et al. [34], in which an application to promote healthy habits in people in wheelchairs was developed. In Cameron et al. [35], authors checked the usability of a chatbot called iHelpr to improve the mental health of participants.

Therefore, this work aims to deploy a tool for the implementation and testing of a gamification model based on BC technology. The goal of this model is to explore the functionality and viability of this approach to install healthy habits in the population.

2. Materials and Methods

The cornerstone of this work lies in the use of the so-called “challenge” artefact as the key element for the gamification strategy. These challenges precisely define and encompass quantifiable tasks related to physical, mental, nutritional, or sleep activities, all aimed at enhancing the user’s health and intended to evolve into healthy habits. They are defined in terms of periodization with the objective of fostering holistic enhancements in individuals’ health according to their needs and characteristics [19].

In order to meet these requirements, a prototype of a dApp was developed to present the gamification model mentioned above using a concrete challenge called “Planking”. This challenge is designed to inspire participants to perform a plank exercise daily for a span of 15 consecutive days. To ensure its effectiveness and convenience, a pre-experimental study was carried out to evaluate the usability of the system. This research was approved by the Research Ethics Committee of the University of Vigo (code: 09-181223) and was carried out in accordance with the Helsinki Declaration (2013 version).

2.1. System Architecture

For the provision of the user interface, a system architecture was proposed in which the user interacts through a dApp to access the described functionalities (see Figure 1).

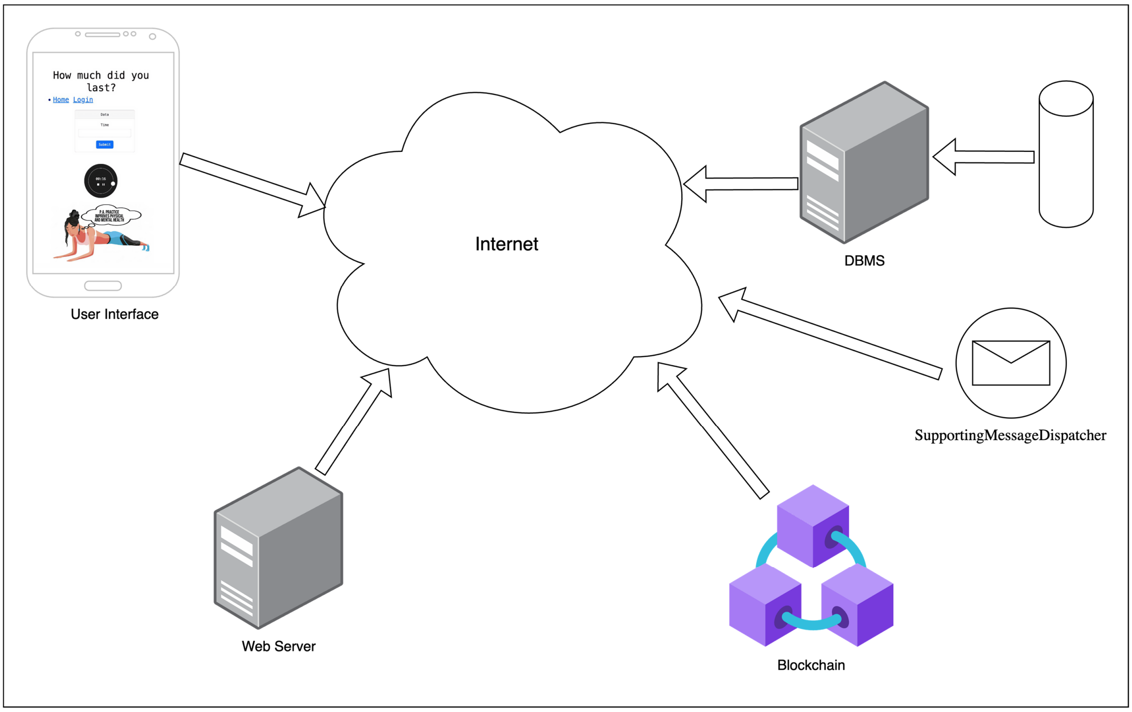

Figure 1. Representation of the system architecture.

In the initial step, the user will utilize a browser to connect to the server that hosts the dApp. This connection provides a straightforward web interface, enabling interaction with both the system and the BC network. A database management system (DBMS) is included in the model to manage access to and modification of sensitive end-user data, such as personal data, that could uniquely identify the user. Additionally, the system includes support for the use of an open BC network. In particular, in this case, a pilot has been deployed using the Sepolia testnet [36]. This network, by its nature, is completely autonomous and is used for the anonymized recording of data related to user activities.

Figure 2 illustrates a typical interaction sequence within the system. As can be observed, the sequence begins with a user logging into the system via their dApp and interacting with the web server (checkpoint 1 in Figure 2). The users input their access credentials, and the server logs them into the system. Subsequently, in this prototype, the user must select the challenge to make use of the platform (see point 2 in Figure 2). In the following interaction, the user records the actions related to the Planking challenge on the BC network through the dApp (refer to point 3 in Figure 2). This action can be repeated multiple times. Each time, the smart contract responsible is invoked to perform a series of tasks, such as issuing the event on the network, recording the operation on the BC, and checking the status of the challenge. Point 4 illustrates the process carried out; if the conditions for the challenge's success are met, a reward is issued. Finally, as depicted in point 5, the agent called "SupportingMessageDispatcher" is responsible for sending messages to users in order to promote user engagement, as described in Williamson et al. [37].

Due to its technical nature, the data stored in BC networks is immutable, traceable, and transparent. In this way, all participants can check their own status without the possibility of fraud by potential malicious third parties. Through the application, SCs responsible for resource allocation are invoked once the challenge under consideration is completed.

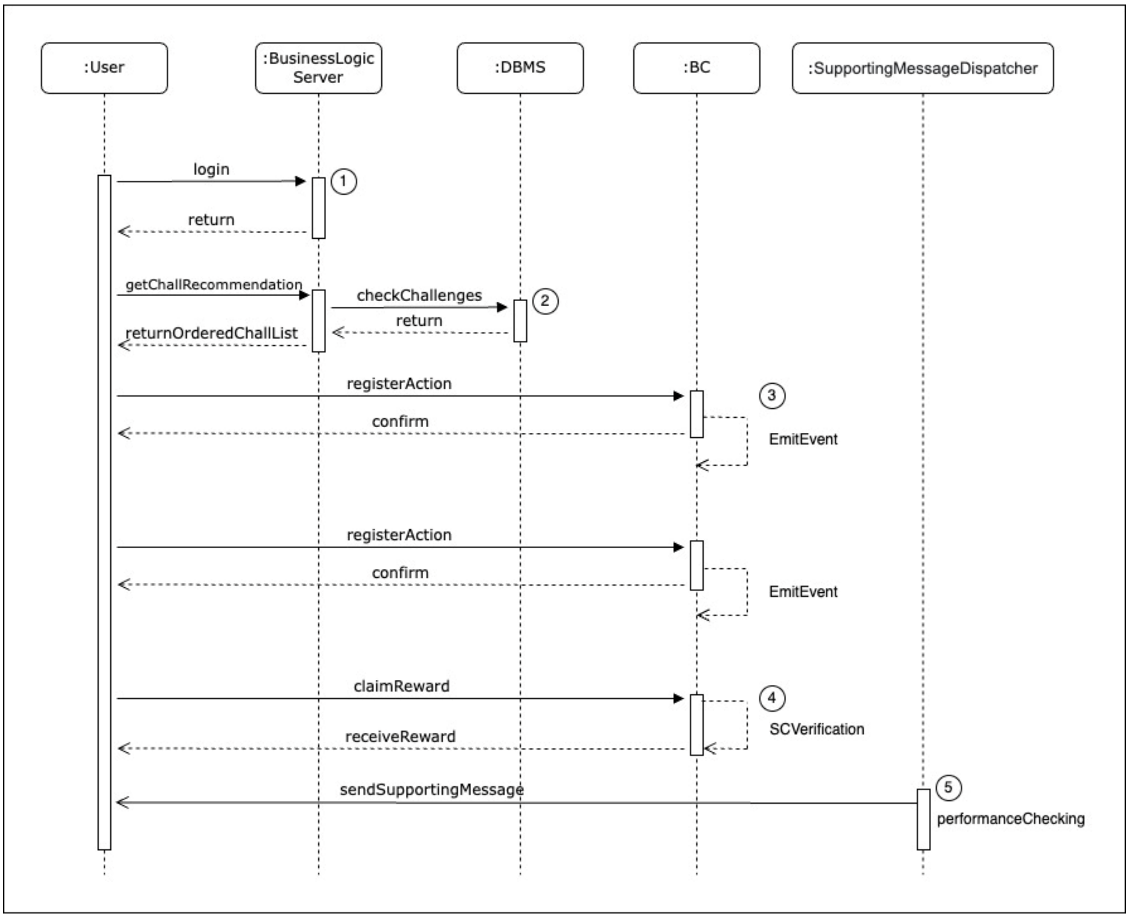

Figure 2. Representation of the system interactions.

2.2. Data Model

2.2.1. User Characterization

One of the basic needs of the system is the appropriate characterization of the participant through a detailed user profile. This way, it is possible to determine whether the challenge is suitable for them or not. To do this, a set of standardized questionnaires will be conducted to capture the necessary information. On the one hand, we seek to know the sociodemographic characteristics of the subjects and their physical particularities, as well as their availability in terms of time, material, and installation. Using this data, a complete characterization of the areas related to physical and mental quality of life, quality of diet, and sleep quality is assessed (Figure 3). This characterization model has been validated by Lopez-Barreiro et al. [19].

It is worth noting that this sensitive information obtained from the user will be stored just in a conventional database. This approach ensures that if a user requests to delete their data, it is feasible. The BC, where information cannot be removed or updated, only contains information about challenges and an anonymized identifier.

This way, it is possible to comply with the Spanish legal framework, the General Data Protection Regulation (GDPR). This law responds to a European directive on the matter and is analogous to the ones existing in other European countries and their surroundings. In Figure 1, the hybrid structure of the system is shown, which includes both an updatable information system (the DBMS) and an immutable one (the Ethereum BC network).

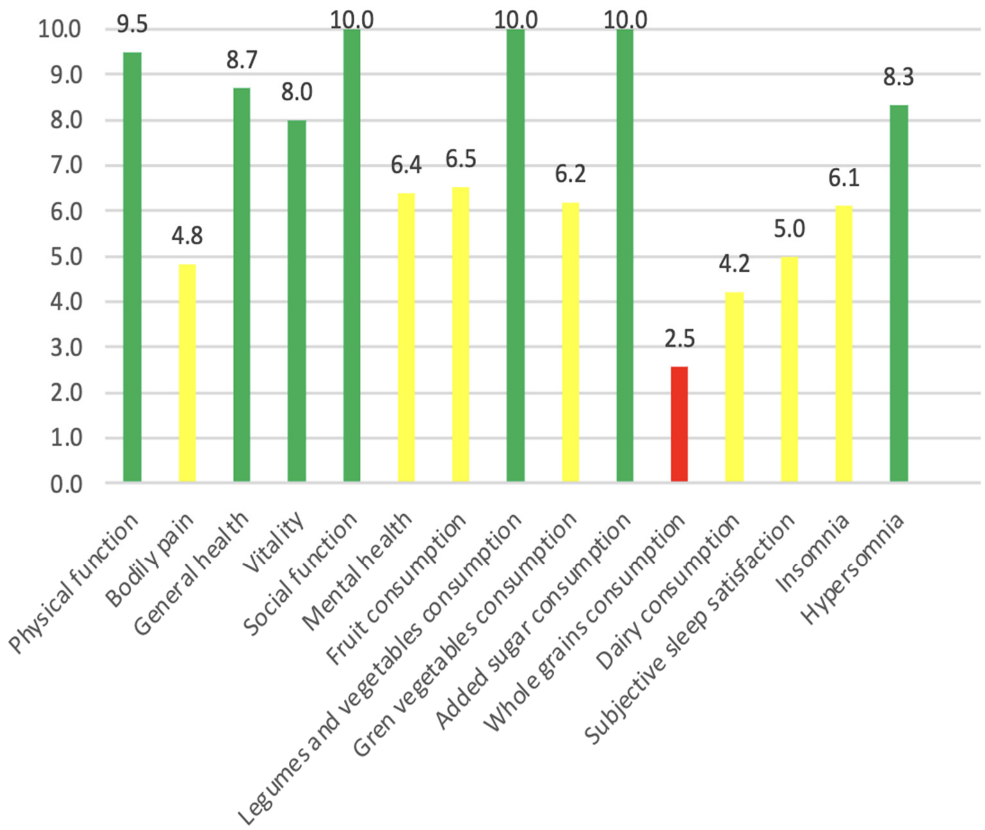

Figure 3. Example of a user profile. The dimension scores are differentiated by colors: scores in the first third in vermillion, the middle third in golden, and the larger third in olive.

2.2.2. Challenges Characterization

A detailed description of the challenges is fundamental. In order to meet this requirement, a model is proposed with a similar orientation to the model applied to characterize the user profiles. The complete and formal characterization of the challenges allows third parties to create challenges that can be introduced into the system, subject to evaluation and approval of the activities and benefits they may generate. For the definition of these challenges, agents must use controlled fields and vocabularies, as exposed in Lopez-Barreiro, Garcia-Soidan, et al. [19].

Two major blocks of information can be established in the characterization of the challenges. On the one hand, descriptive information about the challenge, such as name, description of the activities that compose it, the sociodemographic characterization of the intended subject, their physical particularities, and their requirements in terms of time, material, and installation. On the other hand, it is necessary to provide a characterization of those dimensions that will generate a positive impact and to what degree it will do so. Finally, each challenge will have an assigned Effort Required that indicates an estimation of the required effort needed to perform the challenge. This information is stored in a conventional database for its simplicity of access and updating.

The pool of proposed challenges will be composed of a series of actions. These actions will be subject to monitoring and auditing to determine whether the challenge has been completed or to what extent it has been complied with. In this way, it is possible to establish the rewards linked to the challenges and, therefore, generate the sought-after healthy habits. For example, a simple challenge related to healthy eating, such as "Eat at least three pieces of fruit daily", consists of three actions of eating a piece of fruit. To succeed in this challenge and obtain the rewards, a user will have to record this action three times in the same day for a determined number of days. This information is stored on the BC to ensure the above-mentioned features related to traceability and immutability.

2.3. Action Registration in the System

The developed prototype makes use of the inherent resources of the BC network for the most secure possible recording of the actions specific to each challenge. In this sense, when a certain action related to a challenge occurs in the real world, the pre-established function in the associated SC is invoked on the Ethereum network.

2.3.1. Data Storage on the BC Network

To carry out the actual storage of data on the decentralized data network that constitutes BC, it was necessary to define a unique structure (see Figure 4). This structure hosts information about the challenge itself, the action related to the former fulfilled, the user invoking the SC, and whether the action has already been rewarded or not.

```
struct ExerciseData {
    uint256 challengeId;
    uint256 action;
    uint256 value;
    bool evaluated;
  }
mapping(address => mapping(uint256 => ExerciseData)) private exercises;
```

Figure 4. Structure for the action registry.

The invocation of the SC triggers several consequences. The first one is that an "event" is emitted on the network itself. This "event" (defined as shown in Figure 5) notifies all participants on the network that a certain user has performed a particular action within the framework of the challenge.

```
event Register(address payable indexed _from, uint indexed challengeId,
string _value);
```

Figure 5. Code for the message sending.

Within the framework of this platform, when it is appropriate to register the action associated with the challenge, the code shown in the following image (Figure 6) will be executed. This code stores in a secure manner the data with a proper timestamp and emits the event to let other participants know about this new piece of information.

```
// add a record regarding an action in the frame of a challenge
function setExercises(uint256 _challenge, uint256 _action, uint256 _value)
public {
   exercises[msg.sender][block.timestamp/ 1 days] = ExerciseData(_challenge,
_action, _value, false);
}
// send notification of an action
   function notifyEvent( string memory _value) public {
     emit Register(payable(msg.sender), challengeId, _value);
}
```

Figure 6. Event registry code.

The sending of Ether will be carried out within the SC itself once its availability has been validated and the fulfilment of its conditions has been verified (Figure 7).

The reader can verify how the functions in Figure 7 check the completion of a plank in each of the last 15 days, as required for the Planking challenge. Additionally, the SC takes care of marking those actions that have already been awarded to avoid duplicate payments for a single action.

```
 function getExerciseData(uint256 _date) public view returns (uint256,
uint256, uint256, bool) {
        return (exercises[msg.sender][_date].challengeId,
exercises[msg.sender][_date].action, exercises[msg.sender][_date].value,
exercises[msg.sender][_date].evaluated );
    }
    function didChallenge15Days() public returns (bool) {
      for (uint256 i = 0; i < 15; i++) {
            uint256 day = (block.timestamp / 1 days) - i;
            if (exercises[msg.sender][day].action == 0 ||
exercises[msg.sender][day].evaluated) {
                return false;
            }
        }
        For (uint256 i = 0; i < 15; i++) {
            uint256 day = (block.timestamp / 1 days) - i;
            exercises[msg.sender][day].evaluated = true;
        }
        return true;
    }
     function rewardEther(address payable _recipient) public payable {
        require(didChallenge15Days(), "Condition not met");
        _recipient.transfer(msg.value);
    }
```

Figure 7. Smart contract verification code of compliance with the challenge requirements.

2.3.2. Sending Messages to the User

Also, to keep the user engaged in the process, in the Planking challenge, the following messages were identified as pertinent based on the model described in Lopez-Barreiro, Alvarez-Sabucedo, et al. [10] to be sent to the user:

- If no training has occurred within the first day of the challenge, the user will receive a generic message emphasizing the benefits of physical practice: "Engaging in physical activity improves both your physical and mental health";
- If three days have passed since the start of the challenge without any training, the user will receive a specific message highlighting the consequences of neglecting core strength training: "Failing to complete your core-strength training sessions can adversely affect your health";
- Upon registering the completion of a plank on the first day, users will receive a personalized message focused on the benefit: "Well done! You've completed your daily training. Keep it up to enhance your quality of life";
- Upon completing a full week of performing the abdominal plank, users will receive a personalized message emphasizing the benefits of physical activity: "Great job, [user's login]! You've completed half of this challenge. Keep it up to further enhance your balance";
- Finally, when the users reach their goal of 15 consecutive days of completing the challenge, upon completing the challenge of performing the abdominal plank consistently, users will receive a personalized message highlighting the benefits of physical activity: "Congratulations, [user's login]! You've completed this challenge. Keep it up! You are reducing the likelihood of experiencing lower back pain".

An independent agent in the system is used, which is responsible for these messages and carries out the dispatch of messages to the users automatically. To do this, it combines the information extracted from the events in the BC with existing information in DBMS of the system. Figure 8 shows an excerpt of the code that searches the BC records for relevant events and, after a superficial analysis, sends the data to the function that will carry out the final sending of emails to registered users using the information stored in the DBMS. Those users who do not have records on the network will also receive the corresponding email. This feature is external to the BC itself. Messages within the platform are sent to the user via channels external to BC, in particular, via email. This is a strategy to improve user engagement with the proposed solution using the gamification principles on several channels.

```
 async () => {
const logs = await provider.getLogs(paramSearch);

logs.forEach(obj => {
       let UserId = obj.data.getUserId();
       let data = obj.data.getValue();
       sendMessage(UserId, hex_to_ascii(data));
       console.log("- UserId: " + UserId );
       });
};
```

Figure 8. Excerpt of the code responsible for verifying the execution of actions and facilitating the dispatch of pertinent messages.

2.3.3. User Interface

As previously indicated, users have access to a web interface through which they can interact with the system. Specifically, Figure 9 displays its login page and confirmation page, which includes an encouraging message to stimulate users' participation. Upon logging in, the user can access the functionalities described in previous sections. In this way, access is universal, as any device provided with a browser can use the system.

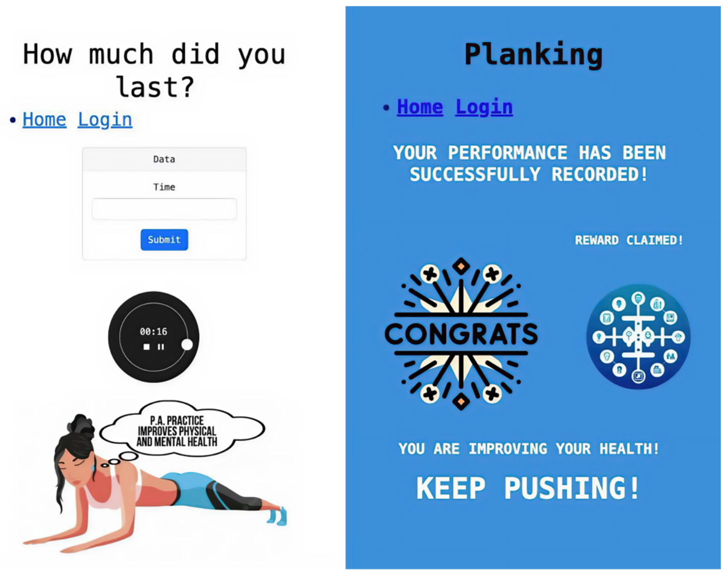

Figure 9. User interface for the event registry for the plank challenge and reward assignation.

The Planking challenge used to verify the effectiveness of this prototype requires maintaining a proper abdominal plank position for a certain duration, replicating the posture of the "prone plank test". This involves supporting the body's weight on the toes and forearms while lying face down with a neutral pelvis position [38,39]. Users log into the proposed dApp, get into the described position, and, using the stopwatch provided in the interface, they control the duration of the exercise. The moment they lose this correct position, they stop the stopwatch, record the duration of the activity, and receive a confirmation message and motivation to continue taking part in the challenge. Rewards are presented to the user on two distinct occasions during the challenge: first, when they correctly perform an abdominal plank, and second, when they achieve the overall challenge, which requires performing the actions for 15 consecutive days. These rewards are distributed in the form of the platform's tokens, which are backed by the BC. Figure 10 shows a user testing the application with the provided interface for this purpose with a stopwatch to control the duration of the exercise and the final motivation panel to continue with the practice of physical activity.

Figure 10. User testing the dApp correctly performing the abdominal plank.

The actions that users must record in this challenge are, therefore, the duration of each abdominal plank each time they perform it by means of the dApp provided to implement this healthy habit. In the pilot deployed for testing purposes, a healthy population group was chosen, consisting of 71 users (44 men and 27 women) with an age of 18.5 ± 3.2 years (mean ± SD). According to the gamification model, rewards should be given in an automatic and transparent way to reinforce the habit. For this, the developed dApp verifies the fulfilment conditions and assigns rewards when appropriate, as previously discussed.

In the scenario of the developed prototype, there is a SC in place. Its role is to validate the fulfilment of the challenge requirements and allocate the suitable reward. This reward is given in the token of the testnet utilized for deploying the prototype, namely Sepolia, in this instance. In addition to the reward received by the users to incentivize their participation, they receive emails following the model described in previous sections. Furthermore, to cultivate the desired gamification atmosphere, users have the ability to monitor their own progress as well as that of others, thereby promoting a sense of healthy competition among them.

2.4. System Usability Assessment

To assess the system's usability, the prototype was presented to 71 users (44 men and 27 women) with an age of 18.5 ± 3.2 years (mean ± SD). All these users participated in the evaluation of the model using the System Usability Scale (SUS). This is a 10-item questionnaire, developed by Brooke [40], intended to evaluate the usability of devices and systems, including health applications on smartphones [41].

This scale evaluates aspects such as ease of use, complexity, and necessary learning. The questionnaire items are evaluated on a Likert-type scale ranging from zero to five. The SUS score is calculated by adding the scores of the odd items, subtracting five from the scores of the even items, and multiplying the result by 2.5. This results in a score ranging from 0 to 100. A score above 68 is considered above average, and furthermore, Bangor et al. [42] indicate that a score above 70 points is considered acceptable for an application. The analyses were performed with the STATA 15.0 program for MacOS® (STATA Corporation, College Station, TX, USA, EE.UU.).

3. Results

As previously mentioned, the deployment of this tool was carried out on the Sepolia testnet. This network provides support for the necessary tests with nearly no cost and provides an appropriate environment to check if the performance achieved ensures its correct operation and meets the established goals.

The proposed model is tested on a certain challenge that was declared suitable for all the participants in the test. This decision was taken after the characterization of all participants using the model presented in this paper and the evaluation of the features and requirements of the selected challenge. Once the challenge is set, the Planking challenge in this testing environment, the progress of the participants in the challenge can be recorded and processed. This progress is automatically verified by the SC designed for this purpose, granting the corresponding reward to the user when appropriate. In this case, the user receives a corresponding amount of Sepolia ETH in their account. This information can be consulted on the platform and with external tools, such as Metamask (Figures 11 and 12), and it is available for everybody on the Sepolia net.

As previously stated, the test group consisted of 71 end users. This tool was introduced to them for validation by means of the SUS. The aggregated scores obtained from this survey are shown in Table 1.

Table 1. Final scores obtained on the SUS as aggregated values.

Adjective	Count	Mean SUS Score	Standard Deviation
"Worst imaginable"	0	-	-
"Poor"	2	47.50	0.00
"Ok"	8	64.38	5.13
"Good"	27	76.57	2.51
"Excellent"	6	82.50	0.00
"Best imaginable"	28	90.80	5.00

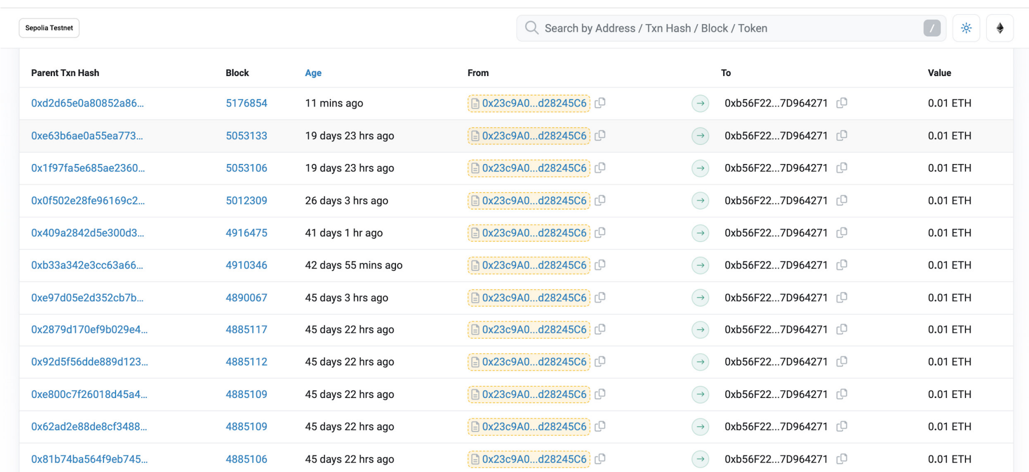

Figure 11. Transaction rewards received by one user after completing the challenge.

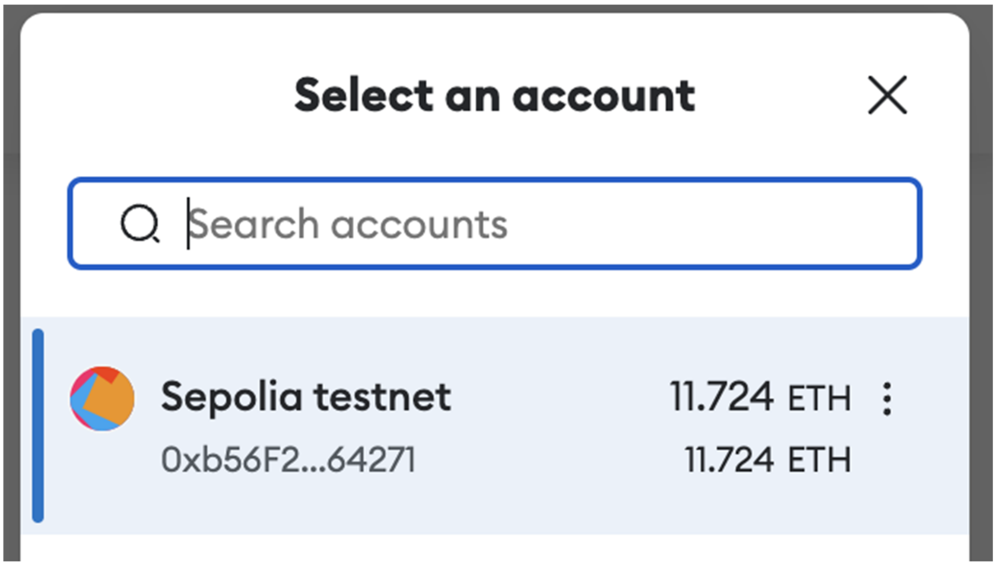

Figure 12. Metamask interface showing the Sepolia testnet.

Once the results from each individual user were calculated as the sum of each answer using the criteria mentioned in previous sections, the total ratings were grouped following the adjective categories [42]. As shown in Table 1, two users rated it as "Poor", which represents 2.8% of the ratings; eight users rated it with a score corresponding to "Ok", which represents 11.3% of the responses; 27 users gave it a "Good" rating, which represents 38%; six users considered it "Excellent", which represents 8.5% of the responses; and 28 of the 71 users rated it as "Best imaginable", which represents 39.4% of the scores. In none of the cases did the users rate the presented tool as "Worst imaginable".

In aggregate terms, the presented tool obtained an average rating of 80.49 ± 11.15 points (mean ± SD) on the SUS, with a maximum of 100 points and a minimum of 47.5 points. This rating situates it within the 'Good' category, according to the adopted criterion. It is just an average of 0.31 points away from achieving the 'Excellent' score. In addition to these descriptive data, Cronbach's Alpha test was performed to check the internal consistency of the responses, obtaining a value of 0.75, which indicates good internal consistency. Good internal consistency is considered with values between 0.7 and 0.9. Values above 0.95 indicate redundancy in the test [43].

4. Discussion

In terms of gamification, the aim is to create a comprehensive gamification environment. In this regard, BC networks, with their characteristic features, are very convenient for carrying out these initiatives. Leaderboards and the allocation of rewards and prizes contribute to motivating the completion of these challenges. Through the verification process conducted by the SCs, the users' progress in the respective challenges is automatically assessed. This allows for the assignment of their scores, their classification, and the distribution of their rewards.

In addition to these elements properly described as gamification elements by Zichermann et al. [14], this platform applies the model presented in Lopez-Barreiro, Alvarez-Sabucedo, et al. [10]. In this model, the delivery of a series of messages of different types (general, directed, and personalized, focused both on the benefit and the detriment) is organized to maintain direct contact with the user and encourage participation in the challenges.

In light of the presented results, compared to similar proposals found, it is worth noting some similar examples, such as Alsalamah et al. [30], where healthy habits are encouraged by rewarding with system-specific cryptocurrencies, but with a very low level of development, Technology Readiness Level-3 (proof of concept in the laboratory).

Conversely, in our proposal, the adherence to healthy challenges is supported by means of an interface that, according to the SUS results, seems friendly and simple, rewards users with cryptocurrencies, and encourages them to perform physical activity with motivating messages. In addition to this, it also complies with data protection laws by implementing the hybrid system represented in Figure 2.

The proposals presented in Jamil, Kahng, et al. [31] and Jamil, Qayyum, et al. [32] provided users with customized workout and feeding plans based on their anthropometric and body composition data using BC only to ensure data security and integrity and, again, with a low level of development. This proposal lacks a gamification environment and motivating messages. In Mulyati et al. [33], a data storage system was created for tracking belt promotions in Taekwondo, ensuring that scores are recorded with transparency and immutability. The use of BC was not clear as it is simply used for its transparency and immutability features but without implementing any BC-specific service.

Other existing solutions implement gamification environments, but in a traditional way without the benefits derived from this technology. This would be the case for Hoevenaars et al. [34], in which they develop an application to promote healthy habits for people in wheelchairs, also checking the usability perceived by the system users. In Cameron et al. [35], they checked the usability of a chatbot called iHelpr to improve the mental health of the participants. In both solutions, the usability of the system presented to the users was checked, obtaining, in the first case, 58.6 points in the SUS, which indicates an average score in adjective ratings of "Ok", determined only by 14 users, compared to the average rating of our proposal of 80.49 points, rated as "Good", coming from the ratings of 71 users. Regarding the latter proposal, the iHelpr chatbot obtained an average score of 88.2, placing itself with a score of "Excellent" with the rating of only seven subjects, compared to our results, slightly lower at 80.49, obtained from 71 participants.

5. Conclusions

Modern societies are grappling with health disorders, broadly defined, in part due to a deficiency of healthy habits. This is the motivation behind the development of the proposed platform. Its objective is to provide tools that foster the establishment of healthy habits among the general population by leveraging gamification strategies.

In this line, regarding gamification, new technologies such as BC can play a very prominent role due to, fundamentally, their ability to externalize the need for a reliable third party in record keeping. With this technology, we enable the capability to track and record user activities through third-party applications. These applications engage users with automatic rewards and provide assured tracking.

A prototype application has been created that communicates with the BC network to assign rewards for registering the actions corresponding to challenges. Even in its early stage of development, this prototype has exhibited a high degree of usability.

We have leveraged the benefits of BC technology without infringing upon current legal regulations, such as the GDPR. This approach facilitates capabilities that are not achievable in alternative environments, such as transparency and traceability of information, thereby eliminating the reliance on external entities.

6. Limitations and Future Work

This work only considered healthy individuals who are keen to improve their health habits as its target audience. Future work could focus on audiences with specific needs or limitations whose challenges and conditions may require greater supervision or additional care, as well as athletes with some experience and training.

The testing and validation of the prototype were carried out under very localized conditions and environments. Work is underway on a more extensive deployment closer to the general population.

It would be interesting to include the use of oracles that externally record the events of the challenges in a fully automatic manner, as this type of tool should be as non-invasive as possible. On the other hand, these types of solutions should also be as holistic as possible in order to be fully integrated into everyday life and become an important part of it to improve adherence as much as possible.

It is essential to note that BC technology is still in an immature phase of development. It has some specificities in its internal operating logic that vary from models based on the client-server paradigm. Therefore, the design of the SCs must be carried out considering these issues derived from its distributed nature and potential vulnerabilities due to its early stage of maturity.

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Data Availability Statement: The original data presented in the study are openly available at https://github.com/juan-lopez-barreiro/Data/blob/main/Data%20SUS%20asi-3038109.xlsx, accessed on 10 July 2024.

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