Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.
Unlock Me: A Real-World Driven Smartphone Game to Stimulate COVID-19 Awareness

Nishtha Phutela a, Atluri Nikiitha Chowdary a, c, Shreyansh Anchlia a, Dheryta Jaisinghani b, Goldie Gabrani a

a Computer Science and Engineering Department, School of Engineering and Technology, BML Munjal University, Gurugram, India
b Department of Computer Science, University of Northern Iowa, Cedar Falls, Iowa US
c Computer Science Department, University of Colorado Boulder

ARTICLE INFO

Keywords:
Serious Games
COVID-19 Awareness
Human-Computer Interaction
User Research
Game Design
Game Evaluation
In-game Analysis
MSC:
00-01
99-00

ABSTRACT

Despite having numerous platforms to promote coronavirus awareness, a part of the population is not well informed about the basic knowledge related to the pandemic. This inspired us to design and implement a free-to-play game, Unlock Me, to help people learn about coronavirus easily yet effectively. A user-centric approach to designing the game has helped us understand the challenges people face and eventually to deliver an interactive game. We conducted an evaluation study across multiple age groups to understand the impact of Unlock Me to enhance COVID-19 learning of the player and to evaluate the quality of the game. The results are obtained by studying the player behavior and performing comparative analysis with Model for the Evaluation of Educational Games (MEEGA+), a standard game evaluation model. Our evaluation shows that there has been an increase in the awareness of players by 53% compared to pre-game awareness. 52.40% of the players found the game to be usable with a good player experience and learning.

1. Introduction

Ever since the COVID-19 outbreak, more than 284 million people have been infected with the virus worldwide causing about 5.5 million casualties (Erin Cunningham, 2021). New types of variants are emerging every few weeks with the recent one being the Omicron variant which is reported to have a high mutation rate (Umair Irfan, 2021). According to experts, the lack of caution and precautionary measures are fueling the spread of COVID-19 (Sourik Biswas, 2021). With the widespread COVID-19 cases, it becomes essential for people to follow basic precautionary measures to avoid the proliferation of this virus. One of the main reasons for the increase in the number of COVID-19 cases are the negligence of people towards following basic preventive measures against COVID-19. The World Health Organization (WHO) has asked people to follow some precautionary measures like social distancing, wearing a mask, using a sanitizer and washing hands regularly (World Health Organization, 2020a). Following such practices could help the people from getting infected with COVID-19 but people are not used to implementing such practices in their daily lifestyles. Ignorance of these precautionary measures could be unintentional, but it results in multiplication of the virus (Harvard Medical School, 2021).

For increasing COVID-19 awareness among the population, various countries have launched different types of smartphone applications. For example, the COVID-19 Smart Management System (SMS) app in South Korea aims at showing the locations visited by corona infected people, and the COVIDSafe app of Australia traces the number of people a COVID-19 infected person has come in contact with Chabba (2020). Also, the Arogya Setu App in India is for self-assessment of COVID-19, contact tracing, nearby diagnostic and vaccination centers in the neighbourhood (Chabba, 2020). According to a recent survey conducted on a small group in India, only 21.7% of the people checked the Arogya Setu app daily and 11% of them did not even use the application (D. and V., 2020). These apps cite information from the WHO in the form of videos and FAQs but do not provide an interactive way to spread awareness about COVID-19. Most countries have launched awareness campaigns to help people learn about COVID-19 treatment and vaccination. For instance, the Indian government launched a COVID-19 awareness campaign to curb the spread of COVID-19 cases, especially in Maharashtra. The campaign consisted of 16 vans traveling across states with precautionary measures displayed on the LED screens.
attached to them (ANI, 2021). Similar campaigns have been implemented in the United States, Europe, and Australia. Despite the campaigns implemented, the number of COVID-19 cases has increased predominantly worldwide. According to a study by RTI International, among 1000 Americans, 36% of the people had a great deal of knowledge related to COVID-19 (RTI International, 2020). Although public campaigns provide information to a vast audience, they would not engage the audience. People would eventually forget the information shared with them over time. Hence, it is necessary to inculcate the precautionary measures and COVID-19 information in their daily lifestyle through interactive and engaging means.

Although Social media platforms act as a great source of spreading awareness related to COVID-19, they can also spread misinformation. According to the WHO, there has been an infodemic on all social media platforms about COVID-19 thus making it difficult for the people to differentiate between trustworthy and fake news (World Health Organization, 2020b). There has been much news related to the kind of misinformation being published on social media platforms like Facebook, Twitter, and Instagram (Apke and Omar, 2021). The WHO technical communication and social media teams have tried to clarify most of the misinformation. However, it is not possible to track each misinformation and provide the correct information (World Health Organization, 2020b). Hence, it becomes crucial to create a platform that has relevant and regulated information.

The education and health sector has been using game-based learning since the early 2000s. Using games in learning has also proven to be engaging and enable intrinsic motivation among users to learn effectively (Boyle et al., 2011). Games have elements like fun, goals, rewards, and problem solving that aid learning. Serious games have played a significant role in learning, lifestyle management, and disease awareness. A meta-analysis of the use of serious games for lifestyle management has indicated that serious games positively impact the users (DeSmet et al., 2014). The study also states that the users could obtain long-lasting knowledge about healthy lifestyle management. According to a literature review of 512 games, 83% of the 47 knowledge acquisition games were found to be impactful and provided the desired learning outcomes among the users (Boyle et al., 2016). A comparative study between game-based and non-game-based learners showed that the ones who played competition-driven circuit games performed better than the ones playing the non-competitive circuit game (DeLeeuw and Mayer, 2011). Competitive features like scoreboard, bonus and incentives have proven to motivate and foster deep learning. Learning by doing methodology in educational games helps develop knowledge and positive behaviour in users (Dewey, 1986). This importance of game-based learning is, in general true. For this study, we have considered COVID-19 as a use case. The methodology used and the lessons learned do not just apply to COVID-19 games but to any game which seeks to impart learning and change human behaviour. For instance, spreading awareness about a disease is one such application area.

For spreading awareness about different situations or diseases, many game-based awareness applications have been developed (Luz et al., 2016; Cook and Twidle, 2016; B. et al., 2013). But to spread COVID-19 awareness, very few games have been developed. To educate users about the precautionary measures related to COVID-19, a mobile game SurviveCovid-19, has been developed (Venigalla et al., 2022).

To find a game’s impact on users, it is essential to thoroughly evaluate the game using the existing game evaluation models. Although the game SurviveCovid-19 was developed to inform people about COVID-19 norms, it is also expected to test the user’s knowledge throughout the game. The game also does not adapt user-centric methodologies in the designing process and does not use a standard evaluation model or in-game analysis to give a behavioral analysis of the player and evaluate game performance.

The inception of developing Unlock Me (Shreyansh Anchlia, 2021), came when the first wave of COVID-19 hit India. People’s stress levels increased as they were confined to their homes during the lockdown. People broke the government’s lockdown rules, not understanding the sensitivity of the situation. When the government made strict rules, people felt locked and wanted to move out of their homes. Hence the name Unlock Me. So our objective was to develop a game that would entertain the people while they were inside their homes. Unlock Me simulates real-life situations and experiences to help players understand and feel for discriminating between correct and wrong practices, thereby reducing their risk of contracting the virus.

Within Unlock Me, we have introduced certain features to help people get accustomed to the game and ease their learning process. A product is effective if it positively influences the user’s actions regarding productivity, learning outcomes, or decision-making. To know the level to which the game, Unlock Me was influential in creating awareness about COVID-19, we performed extensive game evaluation (B. et al., 2016). There have been various methods to measure the effectiveness of user interface over time, some of which are the input-output model (Garris et al., 2002), the game-based evaluation model (GEM) (Oprins et al., 2015) and the MEEGA+ evaluation model (Giani et al., 2016). These models are replicable. We have considered the parameters and factors used in the MEEGA+ model to provide a comprehensive design and evaluation of our game. It is the latest game evaluation model available to date (Giani et al., 2016). The players were presented with multiple challenges throughout the game, and how they respond to these challenges has been recorded to understand the game’s effectiveness. We have tried to empirically deduce the factors used in the MEEGA+ model using in-game analysis of the player’s progression during gameplay.

This method of in-game analysis can prove helpful in data-driven validation of the player experience. It does not require direct interaction with the players (Drachen et al., 2013). For instance, authors in Johnson et al. (2018) discuss the importance of validation using factor analysis of the two standard game experience scales - PENS and GEQ. Our approach of validation using in-game analysis can aid in the validation of many game scales, provided the mapping of game experience to in-game events is correct.

Our significant contributions, in this paper:

1. We adopted a user-centric methodology where we conducted iterative design activities to conceptualize Unlock Me based on insights from the real world. We have also explained the inclusion of these activities into the game development process. We describe in detail the involvement of the users in the game development and the type of usability issues that got uncovered because of involving users and using in-game analysis. [Section 3]

2. We designed and developed Unlock Me to have deeper knowledge penetration and easier understanding for users from diverse age groups. We have overcome the pitfalls of the existing game interfaces using real-world driven game features. We have bench-marked these features by associating them with the design principles used in Human-Computer Interaction (HCI). In addition to this, we also present the significance of utilizing each game feature in instilling awareness about various COVID-19 norms among the players. Unlock Me is freely available on the Google Play Store and runs on all devices with Android version 4.4 and above. The game will be made open source upon acceptance of the paper. [Section 4]

3. We used a novel procedure to evaluate the game as a learning tool and as a user-centered game across age groups by combining the standard MEEGA+ game evaluation model and the in-game analysis. Analysis using the in-game analysis helps us understand about the procedure and metrics used for evaluation as a learning tool and as a user-centered game. We see an improvement from a minimum of 22% to a maximum of 90% in the lessons learned by users in the age group 17-21 years; this shows that our game effectively delivered the desired COVID-19 learning. We also present our findings from other age groups and inferred that even though people from these groups could learn and operate the game, the elderly faced the maximum challenge in completing it. Evaluation of Unlock Me as a user-centered game has been done using the
MEEGA+ model. The validation of this model has also been done by devising metrics from in-game analytics. To the best of our knowledge, we are the first to validate the MEEGA+ model by studying real-time playing behavior. 52.40% of the players in the age group 17-21 years found the game to be usable with a good player experience and learning by the end of the game. School children in the age group 10-16 years also found the game learnable. [Section 5]

We discuss the related work in Section 2, limitations and future work in Section 6. We conclude the work in Section 7.

2. Related Work

Following the widespread use of serious games in learning, many serious games have been developed. Authors in Gang et al. (2011) developed a modified version of the Mario brothers’ game to help children learn about type-1 diabetes and control their blood sugar levels. Another game has been proposed in Bingham et al. (2012) to help children with cystic fibrosis to learn self-management therapies. The game is controlled by a spirometer that measures the breath flow. The intensity of the challenges allows players to use the device and hold their breath efficiently. For helping autistic patients, a game called KickAss was developed (Dörner et al., 2016). The game mainly aims at helping autistic adolescents in improving their social interaction by confronting them with different social situations and helping them learn from the choices they select for those situations. Besides the games mentioned above, many other serious games have been developed for diseases like cancer, diabetes, Alzheimer’s, cognitive impairment, autism, and obesity (Dörner et al., 2016).

There are very few games designed to spread awareness among the public. Bruno Santos developed the eVision game to educate people around the world about environmental threats (Cook and Twiddle, 2016). The game uses augmented reality to capture the surroundings and helps users analyze the ecological threats in that area. The use of augmented reality and a constant interactive assistant called snowkin have proved to increase the persuasive ability of the game. Another game was developed to create hurricane safety awareness among the public of Malaysia (Rosli et al., 2017). The game provides a hurricane safety checklist to the users and asks them to perform the tasks in the game. Confronting the users with real-life situations and tasks keeps them connected, and as a result, they can apply the tasks in their real-life. The game uses a Game Development Life Cycle, which helps in the design and development of the game in an organized manner. But, with just three levels to progress, the game does not provide a sense of challenge and stimuli to the user. When it comes to promoting awareness for a community disease, a game called Dr. Ludens’ LSG was developed to educate local populations about two tropical diseases, Visceral Leishmaniasis (VL) and American Cutaneous Leishmaniasis (ACL) (Luz et al., 2016). The game uses a rural farm set up to help users relate to their present environment. The players had to perform specific in-game actions like remove infected dogs, clean leaves, and dry water puddles based on instructions. A quiz was also added to gain extra points along with the points collected from the in-game actions. An in-game quiz encourages deeper learning into the disease and improves the player’s retain ability over a more extended period. Although a few experts from the domain evaluate the game, a fixed set of parameters and factors is not considered for measuring the game’s impact.

In all the games mentioned above, a proper evaluation model has not been used to evaluate the game. Garris presented an input-process-output model of instructional or learning game (Garris et al., 2002). A game cycle that included the input/ game characteristics and rules, user judgments, behavior, and learning outcomes was followed. Garris considered different dimensions like fantasy, challenge, mystery, rules and goals, and sensory stimuli to describe the game characteristics. User judgments include the level of immersion, interactivity, interest, and confidence, while user behavior has concentration and sustained involvement in the game. User feedback was also collected in the process to support performance. The learning outcomes of the cycle mentioned above could be skill-based, procedural, declarative, or affective, depending on the game’s goal. Later, a few other frameworks have also come into existence. Authors in de Freitas (2006) developed a four-dimensional framework to help design an efficient game so that the players could learn without any hindrances. This four-dimensional framework consists of context, representation, learner specification, and pedagogy used. Context mainly consists of place, availability, and tech access to the users and considers the game environment collectively. Learner Specification focuses on the user: their age, demographic, technical expertise, skills, and preferences. Representation includes fidelity, level of immersion, interactivity, user profile, and learning outcome. Pedagogy represents the teaching approach used, be it situative, associative, or cognitive. Although this framework was developed to help design a serious game, it can evaluate a game with the same parameters. Another Game-based learning evaluation model was created in 2015 (Oprins et al., 2015), which is a modified form of input-process-output model by Garris et al. (2002). The input consists of the personal attributes of the player like age, personality, experience, cognitive abilities, and demographic. The process consists of design indicators, learning indicators, and environmental influences. The design indicators further consist of usability, challenge, control, and story of the game. Learning indicators include self-efficacy, motivation, engagement, self-directedness, learning activity, and mental effort. The output phase consists of the learning outcomes of the user in terms of knowledge gained, scores obtained, performance, and behavioral changes.

The latest model, called the MEEGA+ evaluation model, aims at finding the quality of educational games (Giani et al., 2016). It consists of a questionnaire to evaluate factors like usability, player experience, and learning outcomes. These factors further had different dimensions and questions related to them. For example, the usability factor has dimensions like aesthetics, learnability, operability, accessibility, and user error protection. We have used the MEEGA+ model for our base evaluation since it is the latest and reliable.

3. Conceptualizing Unlock Me with Real-world Driven Building Blocks

The development of an awareness-based educational game requires a deep analysis of the problem area and requirements of the users to create good user experiences and engage the users in playing the game. Hence, it is essential to put users at the center of game design and development. This user-centered approach consists of early focus on end-users, tasks and measuring user reactions at every stage (Rogers et al., 2002).

We have incorporated this approach by doing multiple iterations and frequent user feedback. Our users comprise people from three different age groups: The first group contains university students aged 17-21 years. The second group contains school children aged 10-16 years. The third age group is 30-50 years, It comprises few working professionals and few elderly.

The development of Unlock Me happened through four phases, namely: discover, define, develop and deliver (Fig. 1).

These four phases have been explained below.

3.1. Discover

The first phase is the discover phase, where user requirements are collected. An initial study was conducted among 20 people of varying age groups. This step was done to understand the problems faced from the user’s perspective. The better we understand our user needs and requirements, the better would be our solutions.

The study comprised face-to-face interviews and group discussions for seven days.

The main objective during the investigation was to know:

1. People’s knowledge about the virus.
2. People’s opinion about the existing coronavirus based apps.
3. People’s expectations from our awareness game.

We asked a set of 9 questions related to people’s current awareness about COVID-19 and their opinions about the existing awareness platforms. An overview of responses from the people are given in Fig. 2.

It is evident from Fig. 2 that most people did not follow the basic precautions like washing their hands after removing masks and using a sanitized mask every day. When detailed questions like “How long does the virus stay on plastic surfaces?” were asked about coronavirus, most people were unable to answer. When enquired about the reasons behind the lack of coronavirus awareness, people shared the following opinions:

1. Websites like the Centre for Disease Control (CDC) and WHO contained information about the virus and the safety measures, but many people found them monotonous. They said it was difficult for them to visit each site and read information related to the virus. Instead, they preferred a platform that could combine entertainment with the necessary information from trusted sites like CDC and WHO.
2. Many people said they did not follow the precautionary measures properly because they kept forgetting about them over time. They felt that the current apps only focused on diagnosing the virus.

3. Additionally, when asked about their preferred method to learn this information, most of them suggested activities that were fun and engaging.

3.2. Define

In the discover phase, we collected some opinions of the people related to the existing COVID-19 awareness platforms along with their needs and requirements. After the users shared their opinions about the existing platforms, we asked them about their opinions on a game-based learning platform. This idea was proposed by us to the users after they suggested the need for a fun-based learning platform, to know how they feel about the idea. Almost everybody in the study felt that it was a great idea as it would be interactive and the incentives in the game would motivate them to play. In the Define phase, we identified the main problems of the people from the responses collected. Another iterative feedback session was done with a different set of participants to confirm the problems faced by the first set of users. The main problems were identified after the feedback session. From their responses and from brainstorming among the research team, the following problems were identified related to the existing COVID-19 platforms:

1. They lack the fun and engagement factors while providing COVID-19 awareness.
2. They do not provide a mechanism to increase the memorability of the user
3. The existing platforms do not test the user knowledge over time.

Unlock Me game is designed to address these problems.

3.3. Develop

The third phase focuses on prototyping and developing possible solutions to the problem statement. Specific parameters like fantasy, challenge, goals, sensory stimuli, mystery, and control were considered to create an interactive human-centric game and address the lack of fun and engagement factors. These parameters have been considered taking into account the input-process-output model of game design and development (Garris et al., 2002). Fantasy involves using an imaginary environment to evoke mental images of situations that do not exist in the real world. Games with fantasy context have proven to show greater interest while learning. Challenge involves the use of progressive levels of difficulty. Goals refer to defining a clear set of instructions before and during the gameplay for the players. Sensory Stimuli consists of the use of attractive graphics and sound effects. Mystery refers to the use of surprises and information that cause curiosity among the players. Control refers to providing the authority to regulate an action in the game to the players. An overview of these parameters have been mentioned in Table 2. A detailed explanation of the game ideation, design, and development process has been discussed in Section 4.

Throughout the game development process, users were involved to provide their opinions on different features developed in every version of the game. We took user inputs through questionnaires and video interviews. These consolidated inputs were used to choose and build upon the game features. Each time some features were added to the game, the update was shared with users to get their feedback. We used a technique similar to Microsoft’s “activity-based planning”. This technique involves studying what users do to perform certain activities like reading a newspaper, reading the information displayed on LED billboards, distributing information through LED billboards, etc. We have used the study results to choose and build upon the game features. We used various methods, from asking users to using an instrumented version of the software to observe user interactions with the game. This instrumented version of the software records user actions through event-based logging (game analytics). We used game analytics to validate the users’ feedback and balance the game so that the next set of users do not face similar difficulties. Each time the developer completed a feature, the users tested it. We then analyzed the data and fed the findings back into development. Through this iterative process the usability of our game improved significantly. It also helped to enhance the user experience. Table 1 shows the details of each iteration of game development. In this table, Iteration is the iteration number, Duration is the number of days over which the iteration was complete, Number of Participants is the number of participants of varying age groups who participated in the study, Method of Feedback is the method used by researchers to elicit user feedback. Some of the useful feedback that we received were as follows:

1. Users reported difficulty crossing a particular level in one of the iterations
2. Users felt that the initial instructions given to them in the game tutorial were not informative and didn’t explain the rules clearly
3. Users felt a lag in the game character movement in the first version of the game.

### Table 1
User involvement in various iterations in game development. These iterations helped us to uncover major usability issues.

| Iteration | Duration (days) | Number of Participants | Type of Participants | Method of Feedback |
|-----------|-----------------|------------------------|----------------------|--------------------|
| 1         | 3               | 5                      | Researchers          | Think-Aloud and Online Interview |
| 2         | 10              | 7                      | Researchers and Junior Professors | Video Interview and Game analytics |
| 3         | 4               | 5                      | Researchers          | Video Interviews and Observation |
| 4         | 4               | 5                      | Researchers and Senior Professors from civil engineering | Think-Aloud, Video Interviews and Focus Group |
| 5         | 10              | 30                     | Users from diverse backgrounds | Play Store Release and Game Analytics |
| 6         | 3               | 5                      | Researchers          | Internal testing |
| 7         | 2               | 20                     | Researchers and University Students | Video Interviews, Moderated Online Sessions and Game Analytics |
| 8         | 3               | 100                    | University Students | Moderated Online Sessions, Group Discussion, Google Forms, Online Interview, Online Moderated Sessions, Play Store Release, Game Analytics |
| 9         | 14              | 30                     | Research Groups, School Students and Elderly | Play Store Release, Game Analytics |

### Table 2
Game Parameters used to develop a game.

| S. No | Parameter | Description |
|-------|-----------|-------------|
| 1     | Fantasy   | Involves usage of imaginary game setup and animated characters |
| 2     | Mystery   | Optimal level of informational complexity |
| 3     | Goals     | Aims at providing clear instructions and set of goals to be achieved in each level |
| 4     | Stimuli   | Involves usage of dynamic graphics, sound effects to grab attention |
| 5     | Challenge | Aims at creating and maintaining an optimal level of difficulty throughout the game |
| 6     | Control   | Aims at providing a sense of control in the hands of users to choose the challenge |
Each iterative development session included gameplay preceded by instructions and rules, user observations, and detailed feedback. These sessions were conducted online on Google Meet with a moderator to help the users in case they get stuck somewhere. The researchers and participants were involved, any inconsistencies with the testing procedure or task flow were corrected and implemented before the next round of data collection.

3.4. Deliver

For the product to have a significant impact on the users, it is essential to evaluate it. We used a mix of the traditional evaluation model that is MEEGA+$, and in-game analysis to evaluate the game efficiently. The MEEGA+$ model was used for data collection in the form of a post-game questionnaire (Giani et al., 2016). Even though most of the games use a questionnaire-based evaluation model, it could be possible that the users might not give honest feedback. Eventually, the findings may be faulty. To efficiently evaluate the learning outcomes and the quality of the game, we have used a method that will make this process more reliable. This method of indirectly inferring user’s feedback on the game has been done using in-game analytics. This method captures users playing behavior (or the way the user perceives the game) through specific events. These events have been carefully designed and raised when the player accomplishes something or interacts with various elements in the game. The game servers receive the curated analytics and provide an interface to view and download them through a dashboard for further processing.

The observations from the iterations in develop phase were also validated using the method of in-game analytics (Table 1).

4. Design and Development of Unlock Me

It becomes crucial for the player to enjoy and learn by performing simple actions through the interface in an educational game. Thus having an effective interface is of utmost importance. Figure 3 highlights the game flow and game play. The game Unlock Me has been designed considering the input-process-output model parameters of game design. These parameters, when implemented, result in an effective instructional game (Garris et al., 2002). Table 3 describes the way these parameters have been incorporated in the game. For each parameter, a feature was added that could potentially solve the problems associated with the usability of the existing COVID-19 interfaces. These features have been described in Table 4. Each feature has been added in compliance with the standard Human-Computer Interaction (HCI) principles of designing an interactive interface (Rogers et al., 2002).

In this section, the terminologies used in the game, game plot, user scenario, and implementation of the game have been explained.

4.1. Game Terminology

1. Game map: The navigable game area that is available during each level.
2. Characters: The game has one player and multiple non-player characters. The player is police personnel whose job is to patrol the game map searching for people who are violating COVID-19 lockdown guidelines (Fig. 4 [A], [B]). Violators are the non-player characters, and it is vital to catch these violators to stop the spread of COVID-19 (Fig. 4 [B]).
3. Timer: This is a countdown, which indicates the time remaining until the level ends. The duration of this timer depends on the difficulty of the level and size of the game map (Fig. 4 [J]).
4. Check points: These are barriers for the violators placed by the player during the game. Checkpoints are used to catch the violators to avoid direct contact of the player with violators (Fig. 4 [C]).
Table 4: Overview of the features in the game and the challenges they are solving.

| Challenge                        | Feature                  | HCI Design Principle | Significance                                                                 |
|----------------------------------|--------------------------|----------------------|------------------------------------------------------------------------------|
| Lack of fun and engaging factors | HP bar                   | Visibility           | Simulates health for a virtual player character teaching the players about the spreading of COVID-19. This bar can be easily viewed and read by the user while being concentrated on the game. |
| Tactile feedback                 | Feedback                 |                      | Involves the player deep into the game by simulating sensations of touch using vibrations. This is calibrated in the game to know something big has happened like explosions. |
| Leader-boards                    | Feedback                 |                      | Users can view where they stand in comparison to other players thereby increasing competitiveness among players. |
| Achievements                     | Feedback                 |                      | Increases player retention, engages the user to reach a target and provides a feeling of satisfaction to the user. |
| Customize                        | Visibility               |                      | Enhances player engagement as the user can change skins and beautify the game as per their liking. |
| Statistics                       | Feedback                 |                      | Provide detailed analysis of user’s performance. Visually represent the data with graphs and diagrams that can be easily understood by the user. |
| Lack of testing user knowledge   | Sanitizer                | Affordance           | Sanitizer affords the player the opportunity to protect their health by equipping themselves with sanitizers. |
| Quiz                             | Feedback                 |                      | Would increase the memorability and the learning outcome of the users eventually. |
| Lack of providing memorable      | Mythbusters              | Visibility           | Provides facts related to COVID-19 awareness in detail. Unlocks after completing half of the questions in question bank. |
| information                       | Info Block               | Affordance           | Shows COVID-19 norms during the game, that must be followed by the people. |

5. COVID-19 bombs: These are game obstacles created by violators and infect the player if they contact them. These bombs are represented by COVID-19 symbols (Fig. 4 [D]) and express that coronavirus can stay on surfaces or could be airborne. Even when the COVID-19 infected violator has left the area, the virus can persist and infect the player if the player comes in contact with the COVID-19 bomb.

6. Levels and Survival mode: There are 11 stages in the game of Unlock Me, the first being level 0, a guided tutorial. In levels 1 to 9, the violators are to be caught by the player using checkpoints. Level 10 is the survival mode where the player aims to evade the violators without using checkpoints.

7. Experience points (XP): This is a measurement to quantify a player’s experience in the game (Fig. 6c). XP is calculated based on the performance of the player using this formula:

\[
XP = (n^m*b) + \sum(t) + e
\]

where,
\( n = \) number of violators caught
\( m = \) A multiplier that increases if you catch more violator’s in shorter time frame
\( b = \) Base score for catching the violator’s
\( t = \) The time remaining after each violator is caught
\( e = \) A bonus that is awarded for level 10 - survival mode.

After gaining enough XP, the player level increases, which unlocks a question from the question bank. The amount of XP required to make the player level up is calculated using this formula:

\[
XP\text{ required to level up} = (100*\text{current XP level}) + 1000
\]

8. Health Points (HP): This is a value representing the player’s health at a game level. Players lose the level if no HP remains. The fear of losing HP can make the user learn about physical distancing and the value of using preventive measures (Fig. 4 [I]).

9. Question Bank: This part of the game contains a set of COVID-19 related questions of different difficulty levels. This feature encourages deeper learning of the COVID-19 precautions (Mehdi Khosrow-Pour, 2015). Inside the question bank, players can answer a question related to COVID-19 as soon as they reach a new level (Fig. 6d). These questions are repeated like flashcards to help users remember the information easily.

10. Info blocks: These are cubes present in the game level’s background that show COVID-19 norms. Some basic prevention measures are displayed during the game, analogous to billboards, to make the player aware of COVID-19 norms known as an info block. (Fig. 4 [E])

11. Myth-busters: This section of the game contains clarifications and facts from WHO about some common misconceptions related to COVID-19. (Fig. 5a [D])

4.2. Game Plot

The player’s main aim is to catch the violators within the given time frame by creating checkpoints in the game map (Fig. 6a). While patrolling, the player might encounter COVID-19 bombs.

The repercussions of encountering the violators will make the players realize the importance of social distancing. The COVID-19 bombs will educate the users about the infection left over the surfaces by covid infected people and make the users understand the significance of disinfection of surfaces.

The game has a feature of collecting sanitizers that players can use to regain HP and receive a temporary shield that protects the player from violators and COVID-19 bombs. Throughout the game, COVID-19 precautionary measures are displayed in the info blocks to help increase the memorability of these measures.

The game starts with level 0 (tutorial), which gives guided gameplay.
Fig. 4. Game plot containing game elements - [A] Player [B] Violator [C] Inserted Checkpoint [D] COVID-19 bomb [E] Info Block [F] Sanitizer [G] Number of checkpoints available [H] Score Multiplier [I] Health bar [J] Timer [K] Number of violators left to be caught

Fig. 5. Screenshots of Gameplay

(a) Main Menu of Unlock Me showing the navigation options - [A] Tutorial [B] Level based game [C] Question bank [D] Myth-busters [E] Customization [F] User Statistics [G] Leader-boards and Achievements

(b) Level menu

(c) Start screen of level-1
After completing the tutorial, the player can begin playing from level 1, and once the player completes the level, some XP is generated, and the next level is unlocked. An example of the scorecard with XP generated after playing level 1 is given in Fig 6 c, where the player gains 765 XP out of 1000 XP. With the XP gained, if the user levels up, a question is unlocked from the question bank, which the player can solve. A screenshot of the questions in the question bank is given in Fig 6 d. Solving these questions helps the players gain coins that, combined with the coins earned during gameplay, can allow the players to customize the appearance of the police car (depicted in Fig. 7b). The question bank has been added to encourage in-depth learning and to test the player’s knowledge about COVID-19. After half of the questions have been solved, the Mythbusters section is unlocked (Fig. 7a). This section helps the players to clear some misconceptions related to the vaccination against COVID-19, treatment, and diagnosis of COVID-19. This section is beneficial in removing the fears of the players to follow specific precautionary measures. Some of the common misconceptions are wearing a mask causes CO2 intoxication, vitamin C supplements can help prevent COVID-19, and COVID-19 vaccines change a person’s DNA and cause infertility. The Myth-Busters contained in this section have been cited from the WHO website (WHO, 2020). During the gameplay, the players can access the statistics section, placed on the left side of the main menu.
To enhance the feel of the environment from a player's perspective (Section 5.1.1) and metrics (Section 5.1.2), used for evaluation of each of these goals are discussed in the following sections.

5.1. Evaluation as a COVID-19 Learning Tool

Our main motive to design the Unlock Me game was to help the players learn about COVID-19 and implement the knowledge gained in their daily lifestyle. To realize this objective, we have conducted a pre-game COVID-19 assessment and compared those scores with the scores of the questions during the gameplay. In this section, we present the procedure (Section 5.1.1) and metrics (Section 5.1.2), used for evaluation of Unlock Me as a learning tool.

5.1.1. Procedure

To evaluate the amount of COVID-19 knowledge gained by the participants through the game, we conducted two types of assessments:

We used a perspective camera with a heads-up overlay display (HUD) canvas displaying the various stats and information. This camera is placed at an angle of 15 degrees tilted along the x-axis. This implementation gives depth to the 3D visuals and enhances the game's visuals, making the interface attractive and fun for the players. One of the main problems identified during the user survey was that most people didn't find the existing platforms fun and interactive. Hence, improving the graphics and flow of the game helps address that problem. We used 2D and 3D lights along with particle effects to lighten the scene. After putting additional post-processing, global and local volumes enhanced the colors and made the scene more vibrant. The effects used were bloom, depth of field, color adjustments, vignette, white balance, shadows, mid-tones, and highlights. The camera transitions from perspective to an orthographic camera with a 0-degree tilt and larger Field of View (FOV) while placing checkpoints in the game to avoid missclicks and maximize the area visible. This camera transition is done using a combination of "Cinemachine," a tool for handling cameras, and by a C# script. C# scripts have been used throughout the development of the game. We used Unity analytics to track the actions performed by each user while playing the game. The in-game analysis is obtained from the Unity server on which the game data is sent for storage by the player’s devices. Each event action that the user performs during the game is sent to the server as custom events.

5. Unlock Me Evaluation: As a game and As a COVID-19 learning tool

We adopt a two-fold evaluation process for Unlock Me, where the former considers the efficacy of it as a learning tool and the latter as a game. We describe each of these below:

1. COVID-19 Learning Tool: To evaluate the impact of the game in enhancing COVID-19 learning among the players.
2. User-centered Game: To evaluate the quality of the game.

Since we have used COVID-19 as a use case so we are evaluating the efficacy of our tool with this use case. We conducted evaluation in two phases. In the first phase, we performed a large scale evaluation of the initial prototype of Unlock Me with 141 university students having average age of 21 years. In the second phase, we wanted to check the robustness of this approach so we extended evaluation study for different age groups. The details for these diverse age groups is given in Section 3. But due to COVID-19 restrictions and miscellaneous challenges like unable to provide remuneration, we publicized game in research groups. Even though we tried but given the time duration that we had and the lack of resources, there were few downloads. Hence the dataset for second evaluation study is limited.

All participants were required to download and install Unlock Me from the Google play store. These participants were also briefed about the evaluation process, as shown in Fig. 6.

The procedure and metrics for the evaluation of each of these goals are discussed in the following sections.

### Table 5

| No | COVID-19 norm | Game Feature | Description |
|----|---------------|--------------|-------------|
| 1  | Social Distancing | Violators & info blocks | Encountering with the violators will reduce the health points of the player, thus making the players realize the importance of social distancing. The info blocks remind the users to maintain social distancing in public places. |
| 2  | Use of sanitizers | Sanitizer power up & info blocks | By using sanitizers, the players can protect themselves from losing health points after encountering a COVID-19 Bomb or a violator. The info blocks keep reminding the players to use sanitizer after coming back home from outside. |
| 3  | Wearing Masks | Question Bank, info blocks & Myth-Busters | Question bank contains few questions related to the correct usage of masks. Info blocks remind the players to use masks when in public places. Myth-Busters clear some pre-conceived notions about usage of masks like usage of masks could lead to CO2 intoxication. |
| 4  | Vaccination | Question Bank & Myth-Busters | Questions related to the importance, effectiveness and duration of the vaccines have been asked in the question bank section. Myth-Busters contain clarifications to the common misconceptions related to the vaccines like COVID-19 Vaccines affect ones DNA. |
| 5  | Cleaning and disinfection | COVID-19 Bombs & Question Bank | Since COVID-19 Bombs are present on the ground or any surface, it warns the players to not touch any surface outside and if they do, they will have to use a sanitizer to regain their HP. Questions related to the use of recommended disinfectants are given in the question bank section. |

(Fig. 5a [F]). Statistics contain the player’s progress, the number of levels cleared, the number of questions answered, and the overall score (Fig. 7c).

The players have been educated about the various COVID-19 norms, precautionary measures, and information throughout the game. These features and the COVID-19 norms that the players are getting educated about are mentioned in Table 5. Also, a list of the game’s main features and their significance in addressing the player problems have been given in Table 4.

4.3. Game Mechanics

To develop the game prototype, we used the Unity3D game engine. To simulate the objects in the scene and to ensure that they respond to collisions and forces, Unity provides a physics engine. 2D physics to make the mechanics of the games. Initially, the levels were made using 2D graphics called sprites created in GIMP (GNU Image Manipulation Program), a freely distributed program used for image retouching and composition. To enhance the feel of the environment from a player’s perspective, we placed 3D objects and used a perspective camera. In terms of game development, a camera is a system that shows the player’s action from different angles. There are two types of cameras called orthographic and perspective camera. A perspective camera is used with 3D objects capturing how we see the real world. In the real world, if we look at a long road (from our perspective), it appears to be tapering at the end. A similar view is represented in the game using the perspective camera. On the other hand, an orthographic camera is commonly used with 2D objects, and it has no perspective.
1. Pre-game Questionnaire: In the pre-game assessment, participants were given an online questionnaire consisting Multiple Choice Questions (MCQs), where they were assessed on their existing awareness about COVID-19.

2. In-game Questions: In the in-game assessment, participants answered COVID-19 related questions (MCQs) from the question bank while playing the game.

The questions that we selected for both these modes of assessment were divided into three categories: easy, medium, and hard. We made these categories as per the difficulty level of the questions. The easy questions were presented to the users first to establish familiarity with the experimental procedure. Presenting easy questions first is following the law of initial values (Stern et al., 2001). Medium and hard questions followed this. Easy questions were assigned 4 points, medium 5 points, and hard 6 points in both the modes of assessment.

5.1.2. Metrics

For both the evaluation modes, the Average Score per Difficulty level (ASD) has been calculated. However, the ASD differs for pre-game and in-game assessment. The number of attempts allowed during the pre-game assessment is only one, while the player can take multiple attempts to answer the questions correctly during the in-game assessment. In the second evaluation phase, we allowed user to take multiple attempts for pre-game assessment as well so the same formula for calculating ASD was used for pre-game and in-game assessment.

1. The pre-game COVID-19 assessment ASD score was calculated using this formula:

\[
ASD_{(pre – game)} = \frac{\sum_{i=1}^{Q} \left( \frac{\sum_{j=1}^{N} S_{j}}{N} \right)}{Q}
\]  

\( Q \) = Number of questions per difficulty level  
\( S \) = Score obtained for each player per question  
\( N \) = Number of players

2. In-game Questions: The average scores of the questions for each difficulty level are calculated by taking the cumulative average scores of all the questions that belong to that particular difficulty level. The formula for calculating the ASD during the gameplay is given below:

\[
ASD_{(in – game)} = \frac{\sum_{i=1}^{Q} \left( \frac{\sum_{j=1}^{N} S_{j}}{T} \right)}{Q}
\]  

\( Q \) = Number of questions per difficulty level  
\( N \) = Number of players  
\( S \) = Maximum score per question according to its difficulty level  
\( T \) = Total number of tries taken to solve the question correctly

5.2. Evaluation as a User-centered Game

To efficiently evaluate the quality of the game, we have drawn an indirect inference from our in-game analysis and made a comparison with a traditional game evaluation model called MEEGA+. This section presents the procedure (Section 5.2.1), and metrics (Section 5.2.2) used to evaluate Unlock Me as a User-centered game. This comparison has been made based on three main factors: usability, player experience, and learning outcomes. These factors have been described below:

1. Usability: Usability refers to “ensuring that interactive products are easy to learn, effective to use, and enjoyable from the user’s perspective” (Rogers et al., 2002). Hence, to measure usability, the MEEGA+ model provides us with sub-dimensions: Aesthetics, Learnability, Operability, Accessibility, and User Error Protection. Aesthetics measures the game’s overall visual appearance comprising color, movement, fonts, and layout. Learnability is the measure of how easily players can learn the game. Operability refers to the ease with which players play the game, and accessibility refers to the game’s availability to different kinds of people irrespective of age, game experience, region, etc. User error protection is the ability of the game to help players rectify their errors during gameplay.

2. Player Experience: Player Experience refers to the desirable and the undesirable aspects of an interface from the user’s perspective. The sub-dimensions of player experience are confidence, challenge, satisfaction, fun, focused attention, and relevance. Confidence refers to the feelings of mastery or self-efficacy achieved by playing the game. Challenge refers to the progressive difficulty levels used in the game. Operability refers to the ease with which players play the game, and accessibility refers to the game’s availability to different kinds of people irrespective of age, game experience, region, etc. User error protection is the ability of the game to help players rectify their errors during gameplay.
3. Learning Outcomes: Learning Outcomes refers to the ability of the interface to induce some skills or knowledge about a specific topic. The sub-dimensions of learning outcomes are short-term learning and learning goals. Short-term learning focuses on the direct knowledge gained after playing the game. Evaluation of learning goals involves addressing the problems related to learning. It mainly consists of the assessment of levels of awareness, remembering, understanding and application.

5.2.1. Procedure
We collected game-related data to evaluate the quality of the game through the following techniques:

1. After downloading the game, we asked the participants to play the game and complete all the levels. The participants had to play the game and answer the COVID-19 questions associated with each level in the game. In-game analysis used the anonymous data collected through this gameplay.

2. MEEGA+ Model: The MEEGA+ model uses a post-game questionnaire to assess the game’s impact on the players (Giani et al., 2016). We provided the participants with the MEEGA+ questionnaire (in the form of a feedback form). The form had questions in a 5-point rating scale format (1-strongly disagree, 2-disagree, 3-neutral, 4-agree, 5-strongly agree).

5.2.2. Metrics
An overview of the factors used in the MEEGA+ and the in-game analysis has been given in Table 6. We were able to evaluate the following:

1. Metrics from the in-game analysis: The MEEGA+ factors that have been measured using in-game analysis are stated below:
   (a) Learnability: Since learnability is how easy the game is for the players to learn, we calculated the percentage of players who cleared the initial level in the first attempt itself. The initial levels considered were levels 0 and 1. Since level 0 is a guided gameplay level, the players would learn about the rules and controls of the game in this level, and level 1 is the basic level to help players adapt to the environment. If a player clears both level 0 and level 1 in the first attempt, it indicated that the player has not only followed the instructions given in level 0 but has also implemented them in level 1 correctly. The formula that we used to calculate the percentage of players who cleared levels 0 and 1 in the first attempt is given below:

$$\text{% of players who cleared levels 0 & 1 in the first attempt} = \left( \frac{\sum W}{\sum F} \right) \times 100 \quad (5)$$

   \(W = \text{Total wins for levels 0 & 1}\)
   \(F = \text{Number of players that attempted the level}\)

(b) Operability: Operability is the measure of how easy it is for the players to operate and play Unlock Me. To know the ease of gameplay, we measured the percentage of players who cleared the initial easy levels of the game in the first attempt. Levels 1, 2, and 3 were taken because they belong to the easy category, and from level 4, the difficulty increases and the success rates drop. If a player clears levels 1, 2, and 3 continuously in the first attempt, it indicates that the player can use the controls and play the game with ease. The formula used to calculate the percentage of players who cleared levels 1, 2, and 3 in the first attempt is given below:

$$\text{% of players who cleared levels 1, 2, 3 in the first attempt} = \left( \frac{\sum W}{\sum T} \right) \times 100 \quad (6)$$

   \(W = \text{Total wins for levels 1,2,3}\)
   \(T = \text{Number of players at the attempted level}\)

(c) User Error Protection: The game can provide a mechanism to rectify the error made by the player during gameplay. In Unlock Me, after making an error of either coming in contact with the violators or the COVID-Bombs, players can use a sanitizer to regain HP. Here, we calculate the percentage of players who have used sanitizers greater than the average usage at all levels.

Suppose a player uses all the sanitizers provided to them at each level to rectify their errors. In that case, it indicates that the game is helping them revive their error through a particular mechanism. The formulas used to calculate the percentage of players using sanitizers are given below:

### Table 6

| MEEGA+ factors used for evaluation of the quality of game | Validating factors |
|----------------------------------------------------------|--------------------|
| **Factor** | **Sub-factors that can be validated** | **MEEGA+ Question asked** | **Validating factors** |
| Usability | Aesthetics | The game design is attractive (interface, graphics, text, font) | - |
| | Learnability | I needed to learn a few things before I could play the game | Percentage of players who cleared levels 0 & 1 in the first attempt |
| | Operability | The game is easy to play | Percentage of players who cleared levels 1, 2 & 3 in the first attempt |
| | Accessibility | The game allows customizing the appearance (font & colour) according to my preferences | - |
| | User error protection | When I make a mistake, it is easy to recover from it quickly | Percentage of users whose average sanitizer usage was greater than the average usage |
| Player Experience | Confidence | The contents and structure helped me to become confident that I would learn with this game | - |
| | Challenge | This game is appropriately challenging for me and provides challenges at an appropriate pace | Increase in anxiety level and completion level |
| | Satisfaction | Completing the game tasks gave me a satisfying feeling of accomplishment | - |
| | Fun | I had Fun playing the game | - |
| | Focused Attention | I was so involved in the gaming task that I lost track of time | - |
| | Relevance | I prefer learning with this game to learning through other ways (e.g., other teaching methods like COVID-19 Awareness platforms and campaigns) | - |
| Learning Outcome | Perceived Learning | The game contributed to my learning about COVID-19 and I feel satisfied with it | Score comparison from pre-game assessment and questions answered during gameplay |
| | | I was able to remember information related to COVID-19 through this game | - |
5.3. Results

In this section, we present the results for both phases of evaluation across all three age groups. First, the evaluation of the COVID-19 learning among players is presented, followed by the results of the evaluation of the quality of the game.

5.3.1. Evaluation as a learning tool

University students (17-21 years): The comparison between ASD for pre-game questionnaire and in-game questions is represented in Fig. 9.

1. Pre-Game Questionnaire: The average scores that we calculated were 2.18 out of a maximum score of 4 per question in the easy difficulty level. Medium difficulty level had an average score of 1.87 out of a maximum score of 5 per question. The hard difficulty level had an average score of 1.42 per question out of a maximum score of 6.

2. In-Game Questions: The average score during gameplay for easy difficulty level was found to be 3.44 per question out of a maximum score of 4. The medium level of difficulty had an average score of 3.20 per question out of a maximum score of 5 and the hard level of difficulty had an average score of 2.70 per question out of a maximum score of 6 points.

It can be observed that the average score per difficulty level keeps increasing. There has been an increase in the average score by 22% in the in-game questions compared to the pre-game questionnaire for the easy questions. For the medium questions, there has been an increase in average score by 71%, an increase of 90% for the hard questions, and an overall increase of 53%. The gap between the average scores of the pre-game assessment and the in-game assessment widens with the increase in difficulty level. The increase in gap shows that after attempting the questions multiple times and reading about the information related to those questions, the player learned about the information and eventually was able to answer the question. Combining all the difficulty levels, we can say that there has been an increase of player knowledge related to COVID-19 by 53%.

School children (10-16 years): The participants were 25 school students having majorly moderate game playing experience (Low = 5, Moderate = 18, High = 7). This school was within the campus of our university. Around the time of data collection, these participants were having their sessional exams so could spare only 30-40 minutes of time. They were willing to play the game but did not want to fill the pre-game questionnaire as they thought this questionnaire would add to their exam anxiety. We also did take notes for few of them based on their experiences after playing the game. This group of participants obtained an ASD of 3.27 in the easy difficulty level, 3.07 in the moderate difficulty level and 2.23 in the hard difficulty level of the game. This metric was learning among players is presented, followed by the results of the evaluation of the quality of the game.
calculated from in-game analysis.

**Working Professionals** (30-40 years) and **Elderly** (41-50 years): Our third group for evaluation study comprised of 10 working professionals (downloads received from play store upon posting in research groups) in the age group of 30-40 years and 10 senior people in the age group of 41-50 years. As mentioned in the primer of Section 5, we got limited participants in this category. The elderly people refused to fill the MEEGA+ form and pre-game assessment form but were ready to tell us their experiences. They were less digitally skilled. They liked our idea of game. They could play the game up to a few levels only. The ASD for this group was 3.27 in the easy category, 3.12 in the moderate category and 2.65 in the hard category. This metric was calculated from in-game analysis.

5.3.2. **Evaluation as a User-centered Game**

**University students** (17-21 years): The overall results of the MEEGA+ model can be seen in Fig. 11, and the comparative analysis between the MEEGA+ model results and the in-game statistics can be seen in Fig. 10. The findings for the factors and the sub-dimensions under the MEEGA+ model have been stated below:

1. **Usability:**
   (a) **Aesthetics:** 51% of the players felt that the game was attractive and contained well-blended text font and colors.
   (b) **Learnability:** Using the in-game analysis, we have found that 85.71% of the players cleared the levels 0 and 1 in the first attempt (Fig. 10). From the MEEGA+ model results in Fig. 11, 55% of the players felt that the game was easy to learn. The percentage of players who have learned the game quickly is more than the percentage of players who agree that the game was easy to learn. Although a majority of the MEEGA+ responses hold when compared to the in-game analysis, it can be seen that some of the players either could not realize that the game was easy to learn or did not report their experience. From this result, we can say that the game is easy to learn and has a good learnability factor.
   (c) **Operability:** From in-game analysis, it was found that 68.01% of the players cleared levels 1, 2, and 3 in the first attempt itself (Fig. 10). Since most of the players were able to clear levels 1, 2, and 3 in the first attempt, we can say that the game is easy to play and has a good operability factor. Later, when players were asked if the game was easy to play (operability), 58% of them agreed that the game was operable, and if we compare this with our in-game analysis, we can see that 68% of the players cleared levels 1, 2, and 3 in the first attempt (Fig. 10). The number of players who cleared levels 1, 2, and 3 in the first attempt is more than the number of players who agreed that the game was operable. Hence, it can be said that the game is operable and easy to use.
   (d) **Accessibility:** 48% of the players agreed that the game was accessible as it allows for customization of font and text according to their preferences. We can say that the game is moderately accessible as the number of players who agreed to the accessibility of the game was less than 50%.
   (e) **User Error Protection:** From in-game analysis, it was found that the average percentage of sanitizer usage was 73%, and 61% of the players exceeded the average sanitizer usage throughout gameplay (Fig 10). Also, 54% of the players agreed that the game provided them a mechanism to recover from an error. Since most of the players who used sanitizers greater than the average usage and felt that the game had the means to rectify the mistakes, we can say that the game has a good user error protection factor.

2. **Player Experience:**
   (a) **Confidence:** 57% of the players felt confident and had a feeling of mastery after playing the game, which indicates that the game induces confidence among most of the players.
   (b) **Challenge:** Using the in-game analysis, we found that the average overall success rate was 36% and 43% of the players had a success rate less than the average success rate (Fig. 10). Since most of the players have a success rate greater than the average, we can say that the game is not very challenging to the players and might have found it to be of moderate difficulty. From the state anxiety questionnaire results, we can see that there has been a slight increase in the average state anxiety scores after the game compared to the pre-game state anxiety scores. The average score for the pre-game questionnaire was 48 out of 60, and the average post-game anxiety score was found to 50 out of 60. Although, in the MEEGA+ model, 55% of the players said they found the game challenging. We can infer that 12% of the players, although cleared most of the levels successfully (having high success rates), felt that the game was slightly challenging to clear.
   (c) **Satisfaction:** 55% of the players felt satisfied with the game and had a feeling of accomplishment of learning some information. Since most of the players felt satisfied with the information provided, we can say that the game has a good player satisfaction factor.
   (d) **Fun:** 46.75% of the players found the game to be fun to play. The number of players who found the game to be fun is slightly less than 50%. Hence, we can say that the game has a moderate level of fun factor.
   (e) **Focused Attention:** 48% of players said they were so immersed while playing the game that they lost track of time.
   (f) **Relevance:** 52% found the game to be relevant in solving their problems, and they preferred learning through the game-based method rather than the traditional COVID-19 Awareness platforms. We can say that the game is relevant and is in line with the problem statement.

3. **Learning Outcome:** A detailed account of the game as a learning tool for the players was given earlier. But, when we asked the players if they gained knowledge throughout the game, 56% of the players felt that the game, Unlock Me, helped them learn about COVID-19 and 57% of the players felt that the game helped them remember information related to COVID-19.

When we took the average of the scores for all sub-dimensions under the MEEGA+ questionnaire, we found that 52.40% of the players found the
game to be usable, had a good player experience, and felt that the game, Unlock Me helped them gain awareness about COVID-19.

School Children(10-16 years): The major results of the evaluation with school children have been presented in 12. Using the in-game analysis, we have found that 56.12% of the players cleared level 0 and 1 in the first attempt. From the MEEGA+ model results, 50% of the players felt that the game is easy to learn. Thus, the results of in-game analysis and MEEGA+ responses are comparable. Similarly from in-game analysis, it was found that 47.71% of the players cleared levels 1, 2, and 3 in the first attempt itself. From the MEEGA+ questionnaire, 53.86% of the players agreed that the game was operable. With regard to the user error protection factor, 48.22% of the players used sanitizers more than the average usage whereas from the MEEGA+ 41.02% players agreed that the game provided user error protection. The in-game analysis revealed that 48.93 % of the players faced challenge whereas only 30.96% players self reported that they faced challenge.

The results of this have been presented in Fig. 12.

Working Professionals(30-40 years) and Elderly(41-50 years)

Figure 13 shows the results. The learnability and operability of this group was less compared to the first two groups. The user error protection was also less thus explaining that these users did not use sanitizers effectively. The challenge was more than the other two groups. This directly relates to the fact that participants in this group have less experience of playing video games hence might have found it difficult to cope up with the increasing difficulty of levels. Additionally, there was only one elderly person who reached up to the last level.

6. Discussion and Future work

In this section, we discuss the limitations of our work and discuss the possible approaches that could be used to address these limitations in the future. We also describe the lessons learned from the entire research study and the ways in which this study can be helpful for other researchers.

Unlock Me, a single-player game, was developed by considering the parameters like fantasy, mystery, goals, stimuli, challenge, and control.
However, social interaction can be considered in the future to encourage coordination among other players digitally. For implementing social interaction, we can add a multiplayer mode. A study conducted on a serious game in both multiplayer and single-player modes indicates that the multiplayer game had a high player engagement rate compared to the single-player mode (Gitarana et al., 2020). Introducing a multiplayer mode would engage the players extensively and induce a competitive spirit among each player to compete against the other player.

Currently, we have evaluated the game over a short time to test the COVID-19 learning of the player from the game. The average scores of the pre-game questionnaire were compared with the in-game questions based on easy, medium, and hard difficulty levels. The results for 17-21 years age group show an increase in learning by 53% over a short period of the experiment. However, to evaluate the long-term learning of the player, we can conduct another quiz with the same set of participants after a few weeks. The quiz can be conducted in the form of a simple online questionnaire. Then we can measure the overall memorability of the COVID-19 content among the players over a long period.

**In-game analysis:** Authors in Kiili et al. (2018) have used in-game metrics for measuring overall game performance and maximum level reached. They have inferred the playing behaviour with an objective to measure the game’s effectiveness in improving the learning on rational numbers. While calculating the MEEGA+ factors through the in-game analysis, we have used the gaming behavior of the players to make an indirect inference. Quantitative measurement of these factors has not been done before. However, we attempted to empirically represent the factors of the MEEGA+ model through in-game analysis. We could not calculate all the factors and sub-dimensions mentioned in the MEEGA+ model. Currently, we were able to use our in-game analysis on three out of five sub-dimensions under usability, one out of six sub-dimensions under player experience, and one out of two sub-dimensions under learning outcomes (Table 6). We are working on providing specific heuristics to evaluate the remaining sub-dimensions as well.

We extensively compared the results of MEEGA+ and in-game analysis in the first evaluation phase. In the second evaluation phase, we could get only limited time to interact with the participants. Nevertheless, in-game analysis proved helpful in evaluating player experiences.

Additionally, we have used in-game analysis to improve the game design. As indicated in Table 1, we have used this technique to understand game progression and analysis of the difficulty curve, which leads to game balancing. This technique is instrumental when the players are remote and direct observation is not feasible. It can reduce the time and effort of evaluating the user experience. In the future, to complement our study of the sub-dimensions under player experience, we can record the user’s affective state with physiological signals.

**Tutorial:** Through our study, we have realized that the game’s tutorial plays a crucial role in creating the desire for the users to play. It also helps the less experienced game players to master the game. At the same time, it turned out to be annoying for more experienced game players because they thought it was too simple. Most users reported that the tutorial was straightforward compared to the levels. We made the tutorial after most levels in the game were complete. Level 10 in Unlock Me is a survival mode that is different from the rest of the levels. The current implementation of Unlock-Me does not have instructions to clear level 10 in the tutorial. The knowledge of PLAY and GAP (Game Approachability Principles) can prove useful to design effective tutorials (Desurvire and El-Nasr, 2013). Think aloud technique works with a small set of users. In our case, most of the users were remote; hence we relied on in-game analytics, which has the added benefit of being an unobtrusive measurement. *Role of game in learning*

The players get a sense of accomplishment upon completing levels in the game. The user receives both auditory and visual stimuli, which are far better than reading a piece of text in an article or a form. The player engrossed in the game pays more attention to anything that appears on the screen even if it is useless as (example ad) this can be used to communicate important things. Games have a positive impact on problem-solving skills and overall attentiveness. There are various peripheral activities associated with playing a game like pace, flow, immersion, engagement, game mechanics, sound track, sound effects, camera angle, narrative, and emotional connection.

### 7. Conclusion

We have designed and developed a freely available COVID-19 based mobile awareness game to help educate people about the virus. We have conceptualized our game, Unlock Me by adapting a user-centered methodology. This methodology includes defining the problem.
DeSmet, A., Van Ryckeghem, D., Compernolle, S., Baranowski, T., Thompson, D., DeLeeuw, K.E., Mayer, R.E., 2011. Cognitive consequences of making computer-based learning activities more game-like. Computers in Human Behavior 27 (5). https://doi.org/10.1016/j.chb.2010.11.001

Boyle, E.A., Hainey, T., Connolly, T.M., Gray, G., Earp, J., Ott, M., Lim, T., Ninaus, M., B, S., T, R., A.E, D., P, C., 2013. eVision: A Mobile Game to Improve Environmental Awareness. Lecture Notes in Computer Science. Springer. https://doi.org/10.1007/978-3-319-03161-3_28

Bingham, P.M., Lahiri, T., Ashikaga, T., 2012. Pilot trial of spirometer games for airway mutation-vaccine. 2013. Accessed: 2020-10-05 https://www.vox.com/22866696/omicron-covid-19-variant-virology-mutation-vaccine

de Freitas, S., 2006. Learning in immersive worlds: a review of game-based learning. WorkingPaper:This is an Open Access report distributed under the terms of the Creative Commons Attribution Non-Commercial No Derivatives License (http://creativecommons.org/licenses/by-nc-nd/3.0/), which permits users to copy, distribute and transmit the work for non-commercial purposes providing it is properly cited.

DeLeeuw, K.E., Mayer, R.E., 2011. Cognitive consequences of making computer-based learning activities more game-like. Computers in Human Behavior 27 (5). https://doi.org/10.1016/j.chb.2010.11.001

DeSmet, A., Van Ryckeghem, D., Compernolle, S., Baranowski, T., Thompson, D., Crombez, G., Poels, K., Van Lippevelde, W., Bastiaensen, S., Van Cleemput, K., Vandenbosh, H., De Bourdeaudhuij, I., 2014. A meta-analysis of serious digital games for healthy lifestyle promotion. Preventive Medicine 69. https://doi.org/10.1016/j.ypmed.2014.08.026 https://www.sciencedirect.com/science/article/pii/S009174331400317X

Desvignes, P., El-Nar, M.S., 2013. Methods for game user research: studying player behavior to enhance game design. IEEE computer graphics and applications 33 (4), 82–87.

Devey, J., 1986. Experience and education. The educational forum, Vol. 50. Taylor & Francis, pp. 241–252.

Drachen, A., El-Nar, M.S., Canossa, A., 2013. Game Analytics: Maximizing the Value of Player Data. Springer.

Erlin Cunningham, 2021. Pandemic has severely impacted human rights of millions around the world, says Amnesty. Accessed: 2021-04-07 https://www.washingtonpost.com/nation/2021/04/07/coronavirus-covid-live-updates-us/

Gang, C., Nihufar, B., Abdolhossein, S., Chris, M., Steve, M., Gudrun, C., 2011. Designing games to educate diabetic children. Proceedings of the 23rd Australian Computer–Human Interaction Conference. Association for Computing Machinery, New York, NY, USA. https://doi.org/10.1145/2071536.2071546

Garrir, R., Ahlers, R., Drikkell, J.E., 2002. Games, motivation, and learning: A research and practice model. Simulation & Gaming 33 (4). https://doi.org/10.1177/1046878102238607

Gian, P., von Wangelin Christiane, G., Ferretti, B.A., 2016. Meega+: An evolution of a model for the evaluation of educational games.

Ghara, G.R.E., Fithrath, C., Muis, A.N., Darmakusuma, R., 2020. Analysis and evaluation of player engagement in serious education game using game refinement theory case study: Arithmatopia game. 2020 6th International Conference on Interactive Digital Media (ICIDM), pp. 1–5. https://doi.org/10.1109/ICIDM48920.2020.9390087

Harvard Medical School, 2021. Preventing the spread of the coronavirus. Accessed: 2021-04-07 health.harvard.edu/diseases-and-conditions/preventing-the-spread-of-the-coronavirus

Johnson, D., Gardner, M.I., Perry, R., 2018. Validation of two game experience scales: the player experience of need satisfaction (pens) and game experience questionnaire (geq). International Journal of Human-Computer Studies 118, 38–46.

Kili, K., Moeller, K., Ninaus, M., 2018. Evaluating the effectiveness of a game-based national number training-in-game metrics as learning indicators. Computers & Education 120, 13–28.

Luz, S., Masoodian, M., Cesario, R.R., Cesario, M. 2016. Using a serious game to promote community-based awareness and prevention of neglected tropical diseases. Entertainment Computing 15. https://doi.org/10.1016/j.entcom.2015.11.001

Mehdi Khosrow-Pour, 2015. Gamification: Concepts, Methodologies, Tools, and Applications (4 Volumes). IGI Global. https://doi.org/10.4018/978-1-4666-6200-9

Oprins, E., Visschedijk, G., Roseboom, M.B., Dankbaar, M., Trooster, W., Schuit, S.C.E., 2015. The game-based learning evaluation model gem: Measuring the effectiveness of serious games using a standardised method. Int. J. Technol. Enhanc. Learn. 7 (4), Casco-Cardaballo, R.Y.-G., Sevilla, D., 2016. Academic methods for usability evaluation of serious games: a systematic review. Multimedia Tools and Applications 76. https://doi.org/10.1007/s11042-016-3845-9

Dörner, R., Göbel, S., Effelsberg, W., Wiemeyer, J., 2016. Serious Games Foundations, Concepts and Practice. Springer International Publishing. https://doi.org/10.1007/978-3-319-40612-1

Dowler, S., Sharp, M., Preece, J., 2002. Interaction design: Beyond human-computer interaction, Jon wiley & sons Inc.

Rosli, M.S., Manghor, N.A., Nur, S., Fikry, S.I., Ibrahim, Z., 2017. Educational game as interactive learning for hurricane safety. 2017 7th IEEE International Conference on System Engineering and Technology (ICSET). https://doi.org/10.1109/ICSET.2017.8123447

RIT International, 2020. RIT Surveyed 1,000 Americans about Awareness, Perceptions of COVID-19. Accessed: 2021-04-07 https://www.rit.edu/secure-area/coronavirus-unit-ed-states-survey

Shreyansh Anchila, 2021. Unlock Me. Square Dragon Gameshttps://play.google.com/store/apps/details?id=com.shreyansh.UnlockMe

Southik Biswas, 2021. Coronavirus update: India is facing a ‘severe, intensive’ second wave. Accessed: 2021-04-01 https://www.bbc.com/news/world/asia-india-65384620

Stern, R.M., Ray, W.J., Quigley, K.S., 2001. Psychophysiological recording. Oxford University Press, USA.

Umaris Irfan, 2021. What makes the omicron variant so strange and surprising. Accessed: 2021-12-27 https://www.vox.com/22866696/omicron-covid-19-variant-virology-mutation-vaccine

Venagilla, A.S.M., Vagavolu, D., Chimalakonda, S., 2022. Survivecovid-19-an educational game to facilitate habituation of social distancing and other health behaviors to enhance game design. IEEE computer graphics and applications 33 (4), 1046878102238607.

DeSmet, A., Van Ryckeghem, D., Compernolle, S., Baranowski, T., Thompson, D., Crombez, G., Poels, K., Van Lippevelde, W., Bastiaensen, S., Van Cleemput, K., Vandenbosch, H., De Bourdeaudhuij, I., 2014. A meta-analysis of serious digital games for healthy lifestyle promotion. Preventive Medicine 69. https://doi.org/10.1016/j.ypmed.2014.08.026 https://www.sciencedirect.com/science/article/pii/S009174331400317X

Desvignes, P., El-Nar, M.S., 2013. Methods for game user research: studying player behavior to enhance game design. IEEE computer graphics and applications 33 (4), 82–87.

Devey, J., 1986. Experience and education. The educational forum, Vol. 50. Taylor & Francis, pp. 241–252.

Drachen, A., El-Nar, M.S., Canossa, A., 2013. Game Analytics: Maximizing the Value of Player Data. Springer.

Erlin Cunningham, 2021. Pandemic has severely impacted human rights of millions around the world, says Amnesty. Accessed: 2021-04-07 https://www.washingtonpost.com/nation/2021/04/07/coronavirus-covid-live-updates-us/

Gang, C., Nihufar, B., Abdolhossein, S., Chris, M., Steve, M., Gudrun, C., 2011. Designing games to educate diabetic children. Proceedings of the 23rd Australian Computer–Human Interaction Conference. Association for Computing Machinery, New York, NY, USA. https://doi.org/10.1145/2071536.2071546

Garrir, R., Ahlers, R., Drikkell, J.E., 2002. Games, motivation, and learning: A research and practice model. Simulation & Gaming 33 (4). https://doi.org/10.1177/1046878102238607

Gian, P., von Wangelin Christiane, G., Ferretti, B.A., 2016. Meega+: An evolution of a model for the evaluation of educational games.