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Research Article

Socially-Oriented Persuasive Game to Promote Disease Awareness and Prevention

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Persuasive games are widely implemented in the health domain to promote desirable behaviour change. Previous research shows that using persuasive games employing various strategies results in increased motivation and awareness that led to a positive change in behaviour. This paper investigates the efficacy of a competition-based persuasive game at creating awareness and motivating people to adhere to COVID-19 precautionary measures. To achieve this goal, we developed and evaluated a competition-based persuasive game to promote the awareness and adoption of COVID-19 precautionary measures. The results of our pretest and posttest study ($N = 67$) followed by a semistructured interview of 18 participants show the efficacy of the game with respect to promoting a positive change in attitude, intention, self-efficacy, knowledge, and promoting motivation and positive player experience among participants. The qualitative results provide insight into how and why persuasive games promote desirable behaviour. The paper contributes to the knowledge of how emerging technologies in the form of persuasive games can be designed and used to contribute to solving problems in our society.

1. Introduction

Due to the fun attribute, ability to engage people, and the motivational pull of digital, it has become one of the popular leisure time activities in our society today. Tapping into the increasing popularity and penetration of digital games into our daily lives, researchers and practitioners have focused on designing and using digital games for purposes other than entertainment [1–4]. Persuasive games are games designed to assist and motivate people to adopt behaviours that are beneficial to them and their communities using various strategies [2, 5, 6]. Persuasive games have been used in various domains to achieve diverse objectives. One application area that has gained attention is persuasive games for health and wellness, which aims to motivate and assist users to adopt healthy behaviours and avoid risky behaviours [7–9]. Persuasive games for health have been applied in motivating people to increase their physical activity [10–15], reduce medication misuse [16, 17], comply with blood glucose monitoring [18], promote personal wellness, manage diseases, engage in preventive behaviours [3, 19, 20], reduce stress and anxiety [21], and avoid risky behaviour [22, 23]. In the area of disease awareness and prevention, research has shown that games can be an effective tool for example, in the area of sexually transmitted diseases [24] and diabetes awareness and management [25].

A recently emerged area of focus of health intervention is the COVID-19 awareness and prevention. The COVID-19 pandemic affected the world, causing devastating impacts on public health services and the global economy. To curb the rapid spread of coronavirus, most countries around the world imposed strict public health guidelines and restrictions such as lockdowns and social isolation. In addition to this, World Health Organization (WHO) and the Centers for Disease Control and Prevention (CDC) also defined safety and precautionary measures [26, 27] to avoid contracting the COVID-19 and also reduce its spread. Existing research [28], which consists of participants from all around the world, also shows that following recommended precautionary measures (such as practicing social distancing, wear-

ing face masks, and washing hands with soap/sanitizer) is an essential behavioural intervention for controlling the spread of COVID-19.

Although persuasive games have been applied in the area of disease awareness, their effectiveness in creating awareness about COVID-19 and promoting the adoption of precautionary measures have not been fully explored. This is important considering the peculiarity of COVID19 and association precautionary measures. For instance, it is probably the first time that most of us witnessed a pandemic that necessitated a global lockdown. Additionally, the level of controversies, conspiracy theories, and misinformation surrounding the pandemic especially during the first and second wave, when this study was conducted, is probably as never witnessed before [29, 30]. Hence, making it possible that digital interventions that worked in other domains may not work for COVID-19. Again, the mandatory social isolation necessitated by the COVID-19 made people look for other avenues to socialize with others. Hence, a competition-based game that creates opportunities to compete with others in the game, hence, making it socially oriented, may appeal to people, create awareness, and promote the adoption of COVID-19 precautionary measures among individuals.

Previous studies have shown the effectiveness of persuasive games in promoting the desired behaviour in different health domains such as physical activity [31, 32], healthy eating [33, 34], and smoking cessation [35]. However, based on our literature review, there is limited research evidence and existing knowledge gap on how to design and the effectiveness of socially-oriented persuasive games targeted at infectious disease in general and COVID-19 in particular. Also, previous research has shown that the effectiveness of persuasive strategies may vary across domains [36, 37]. To advance research in this area, this paper aims to answer the following research questions:

RQ1: how effective is a competition-based persuasive game with respect to promoting positive change in attitude, intention, self-efficacy, and knowledge towards adopting COVID-19 precautionary measures?

RQ2: how effective is a competition-based persuasive game with respect to the motivational appeal?

RQ3: how effective is a competition-based persuasive game with respect to eliciting a positive user experience?

To explore these research questions, we developed a persuasive game called COVID Pacman-C. We developed the game using competition/comparison and self-monitoring strategy, targeting the goal of creating awareness and promoting the adoption of COVID-19 precautionary measures. To evaluate the game, we conducted a pretest and posttest study of 67 participants followed by a semistructured interview of 18 participants to investigate the effectiveness of the persuasive game. Our results show that the COVID Pacman-C was effective at promoting awareness and adherence to COVID-19 precautionary measures, and it is found appealing. We reflect on our findings and offer design implications for future research in the area of persuasive games. The qualitative study revealed that playing the game led to actual behaviour change in the lives of players in the real world and made them reflect on their behaviour.

The paper contributes to by shedding light on how emerging technologies in the form of persuasive games can be designed and used to contribute to solving problems in our society with a focus on disease awareness and prevention and specifically promoting COVID-19 awareness and adoption of the precautionary measures.

2. Background and Related Work

Persuasive games are designed as interventions with the primary purpose of encouraging healthy behaviour change [3]. Previous studies have shown that persuasive games are effective in motivating desired behaviour change in a variety of health domains such as physical activity [38, 39], healthy eating [2, 40], smoking cessation [41], and general wellbeing [42]. However, there is very little research on designing and evaluating a persuasive game targeted at infectious disease specifically COVID-19. Research has suggested that the effectiveness of persuasive strategies and the resulting intervention may vary across problem domains [43, 44]. Research has also shown that the COVID-19 and associated precautionary measures took a toll on people's mental health [45] and games provided "dreamlands for the players to temporally escape from the cruel reality" and "a perfect social platform to keep social interaction with others to get rid of the loneliness" [46]. Therefore, this study focuses on designing and evaluating COVID-Pacman-C, a competition-based persuasive game for creating awareness motivating people to adhere to the COVID-19 precautionary measures.

In this section, we review our theoretical foundation, we also review work on persuasive strategies and deconstruct how they have been applied in persuasive games design, and comparative effectiveness of strategies in persuasive interventions across domains.

2.1. Persuasive Strategies. A fundamental feature of behaviour change games is the use of persuasion to influence or reinforce behaviours, attitudes, feelings, or thoughts [47]. Persuasion is achieved by implementing various persuasive strategies. Persuasive strategies are techniques that can be employed in behaviour change games for promoting desirable behaviours or attitudes. Over the years, many researchers have proposed multiple persuasive strategies, for example, Fogg's 7 persuasive technology tools [5], Cialdini et al.'s 6 principles of persuasion [48], and Oinas-Kukkonen and Harjumaa's 28 persuasive strategies [6]. Previous studies [2, 4] have identified that competition, comparison, and self-monitoring are among the most commonly employed persuasive strategies in the games for behaviour change. For our work, we are targeting these three persuasive strategies. Table 1 shows the definition of these three persuasive strategies adapted from [2].

2.2. Operationalization of Persuasive Strategies in Behaviour Change Games. Our review of related work reveals various ways in which persuasive strategies were operationalized in behaviour change games across multiple domains. In the following section, we describe how researchers implement the three strategies considered in this paper for behaviour change games in the health domain.

Table 1: Definition of the persuasive strategies.

Persuasive strategy	Definition
Competition	This strategy allows the users to compete with each other to perform the desired behaviour
Comparison	Provide a means for the user to view and compare his/her performance with the performance of other user(s)
Self-monitoring	Provides means for users to track their own progress or performance while performing the behaviour

2.2.1. Persuasive Strategies in Behaviour Change Games for Health Domain. Several persuasive games have been implemented for promoting healthy behaviour among individuals. Examples of such behaviours include promoting physical activity [39, 49], healthy eating [40, 50], discouraging risky behaviour [51], smoking cessation [41], and disease management [52]. For example, TreeCare is a persuasive mobile game for promoting physical activity and reducing sedentary behaviour [39]. In this game, the growth of a tree is tied to the player's physical activity in the real-world. They employed self-monitoring as a daily step counter for the player and competition/comparison as leaderboard. Another example is LunchTime, a slow casual game for motivating healthy eating [40]. Lunchtime employs competition and comparison strategies. In this game, players play the role of a restaurant visitor, and the goal is to choose the healthiest option from the list of food choices. Players are awarded points for making healthy food choices, and every player is allowed to view and compare (competition and comparison) their points with other players. Right way café is another persuasive game to promote healthy eating and physical activity [53]. This game provides healthy eating suggestions based on the player's avatar physical attributes (age, gender, and physical activity). The player who best managed their avatar's health with a daily diet wins the game (competition). Another game called Bronki the Bronchiasaurus is a persuasive game that helps young children with asthma in monitoring their self-management skills [54]. The players must protect their in-game characters from dust and smoke while they go on a quest by measuring and monitoring their breath strength (self-monitoring). The good health outcome of the in-game character makes the player win the game (competition).

The examples of the games discussed above show how game interventions can be implemented using persuasive strategies to motivate preventive health behaviour and disease management.

2.3. Comparative Effectiveness of Persuasive Strategies across Domains. Previous research has highlighted the fact that the effectiveness of persuasive strategies could be influenced by many factors including the choice of persuasive strategies and their operationalization in the persuasive intervention [43, 44]. Below, we review the effectiveness of persuasive strategies across different domains based on existing literature. Strategies perceived to be effective by the participant are highlighted with "+" sign in Table 2, while strategies found to be not effective are highlighted with "-" sign. Table 2 compares the effectiveness of the five persuasive strategies used in this research across multiple domains.

As shown in Table 2 above, the effectiveness of persuasive strategies varies across domains. For example, employing competition/comparison as a leaderboard was found to be effective in promoting physical activity [36], E-commerce [34], sustainable energy consumption [58], disease management (for patients with chronic heart disease) [63], and healthy eating [62]. However, according to Baskerville et al. [31], competition/comparison was not effective in promoting smoking cessation as the participants preferred their progress to be private and anonymous. Ferron et al. [59] also found leaderboards as one of the reasons for the participants' demotivation and quitting the game. The implementation of self-monitoring strategy as tracking the behaviour of the people and allowing them to visualize their progress was effective in promoting physical activity [55], healthy eating [56], disease management (for HIV patients) [57], smoking cessation [31], sustainable energy consumption [58], sustainable transport and mobility [59], and e-commerce [34]. However, in weight loss [60] and overall health and wellness [61], domain self-monitoring was found to be ineffective. Other related studies in the domain of disease awareness include [33, 64, 65].

Therefore, the effectiveness of the persuasive strategies seems to be domain dependent. In other words, the effectiveness of persuasive strategies varies across domains. Therefore, there is a need to study and evaluate the effectiveness of persuasive strategies in the domain of infectious diseases, specifically COVID-19 which has not been investigated by any research to the best of our knowledge.

2.4. Behaviour Change Theory. Various behaviour change theories have been applied by persuasive technology researchers to determine the motivation and measure the change in behaviour of individuals. Theory of planned behaviour (TPB) [66] is one the popular and successful theory employed by previous researchers [2, 67] to measure the motivation as well as change in individuals' desired behaviour. The TPB postulates that the likelihood of an individual engaging in behaviour depends on both motivation (i.e., individual's intention to engage in the behaviour) and ability (i.e., individuals' perception that the behaviour is within their control). It is comprised of the following constructs that determine individuals' actual control over their behaviour:

(i) *Attitude*. Indicates beliefs about behaviour. It refers to individuals' favourable or unfavourable evaluation with respect to performing the behaviour of interest

Table 2: Comparing the effectiveness of persuasive strategies across domains.

Persuasive strategies	Author	Domain	Effectiveness
Self-monitoring	Munson and Consolvo [55]	Physical activity	+
	Hsu et al. [56]	Healthy eating	+
	Schnall et al. [57]	Disease management (for HIV patients)	+
	Baskerville et al. [31]	Smoking cessation	+
	He et al. [58]	Sustainable energy consumption	+
	Ferron et al. [59]	Sustainable transport and mobility	+
	Nkwo and Orji [34]	E-commerce	+
	Burke et al. [60]	Weight loss	-
	Orji et al. [61]	Overall health and wellness	-
Competition/comparison	Almutari and Orji [36]	Physical activity	+
	Toscos et al. [62]	Healthy eating	+
	Zechmann et al. [63]	Disease management (for patients with chronic heart disease)	+
	Baskerville et al. [31]	Smoking cessation	-
	He et al. [58]	Sustainable energy consumption	+
	Ferron et al. [59]	Sustainable transport and mobility	-
	Nkwo and Orji [34]	E-commerce	+

(ii) Behavioural Intention. *T*he motivational factors that influence a given behaviour

(iii) Subjective norms. *B*eliefs about others' attitudes towards a behaviour. It refers to individuals' belief about what people who are important to them or peers think with respect to whether they should perform the behaviour of interest or not

(iv) Perceived Behavioural Control. *I*ndividual's perception of how easy or difficult it is to perform the behaviour of interest

The TPB has shown validity in several health-related contexts, including physical activity, healthy eating, safe sexual behaviour, and exercise [68–70]. For instance, Orji et al. [2] measured change in attitude, intention, and self-efficacy in their evaluation of a persuasive game to determine the behaviour change towards healthy eating among participants. Similarly, Ndulue [67] also designed and evaluated a persuasive game to measure the change in attitude, intention, self-efficacy, and knowledge of young Africans towards risky sexual behaviour. Kharrazi et al. [71] introduced a serious game for chronic patients based on the theory of behaviour change. The study involves two parts: one to increase compliance to treatment, while the other is to reduce severe driving consequences. The results demonstrated that designing persuasive games for healthcare based on behavioural models can increase usability and effectiveness in promoting desired healthcare outcomes. Researchers have also used the TPB in other domains, such as sustainability. For instance, Rai and Beck [72] used the TPB as a theoretical model to assess the impact of serious games on behavioural antecedents towards solar energy in residential energy customers. To evaluate whether games influence the determinants and the intention itself. Most previous research found the theory of planned behaviour as a useful model for designing serious games and gamification solutions.

According to the theory of planned behaviour, intention is the most proximal predictor of behaviour. Moreover, it also states that cognition that affects specific intention are attitudes and self-efficacy. Attitude is important determinant as it guides the thought and behaviour. Also, self-efficacy is another important determinant as it refers to one's competence or future behaviour, and it has been adopted by previous studies [33, 73]. Therefore, in our evaluation, we are measuring change in attitude, intention, self-efficacy, and knowledge of the participants as a precursor of actual behaviour change regarding the adoption of COVID-19 precautionary measures.

2.5. Our Research Objective. Despite this alarming spread of COVID-19 around the world and wide applications of behaviour change systems and persuasive games in health domains, there is little knowledge on how these persuasive games can motivate people to adopt the COVID-19 precautionary measures. Our research study addresses this gap with the design and evaluation of COVID Pacman-C: a competition based persuasive game to promote the adoption of COVID-19 precautionary measures. To evaluate the game, we used pretest and posttest study design to examine the relationships between the baseline versus target change in attitude, intention, self-efficacy, and knowledge among participants.

3. Methodology

This section covers the game design, game play, implementation, study design, and data analysis techniques used in the research.

3.1. COVID Pacman-C Game Design. COVID Pacman-C is an interactive two-dimensional maze arcade game aimed at creating awareness and promoting the adoption of

COVID-19 precautionary measures. The game was designed following an iterative design method and frequent feedback from potential users. The game design process was divided into three stages. In each stage, the game was evaluated and refined by 13 and 6 persuasive researchers (in stages one and two respectively). The researchers are experts in the domain of persuasive game design and potential users. In stage one, the game was evaluated for the basic game mechanics and narratives. As a result, we improved things like player movements in the game, the functionality of powerups (e.g., hand sanitizer, face masks, and hand gloves), and elements in different game levels such as appearance of the avatar, functionality of the COVID monsters in the game, and adding game sounds, including game tutorial section. In stage two, six persuasive researchers were asked to play the improved version of the game for two days (10 mins per day). After two days, we collected and analyzed their feedback regarding their thoughts on the implementation of persuasive strategies. The feedback from this stage enabled us to improve the implementation of employed persuasive strategies including the look and feel. In stage three, the game was finally evaluated for feedback on user interface (UI) elements. We presented the final version of the game to 13 researchers who are domain experts. The feedback helped us refine the positions of some UI elements, colors to make the game more appealing, change the size of the buttons, and improve the sound associated with collecting the powerups in the game. The final game designed after this iterative design process was the COVID Pacman used in this study.

3.2. COVID Pacman-C Game Play. COVID Pacman-C was designed to increase awareness and teach individuals about COVID-19 precautionary measures. Research has shown that games can be effective learning tools [74]. The COVID Pacman-C is designed mostly for learning purposes. Thus, we designed this game using some of the principles and mechanisms of game-based learning [75]. Based on a literature study, Perrotta et al. [75] suggested a set of principles (i.e., underlying assumptions and concepts) and mechanisms (i.e., processes that help us understand how games can, in theory, assist the pursuit of educational goals). The study suggested the following principles: intrinsic motivation, learning through fun and enjoyment, authenticity, self-reliance, and experiential learning. Our proposed game was designed according to three principles: learning through fun and enjoyment, the authenticity, and experiential learning. The learning through fun principle suggests that games can be a tool for engaging individuals in a "flow" (a state of consciousness during which individuals are in control of their actions and completely absorbed in the task at hand) [75]. This principle is important in our game because the goal is to get users in control of their actions with respect to adopting the precautionary measures while keeping them engaged using the fun aspects of the game. The second principle, authenticity, means a concern for the real nature of learning, which is supposedly different from the "artificial" or decontextualized forms of learning. COVID Pacman-C follows the authenticity and experiential learning principle as it provides a means for individuals to practice the COVID-19 precautionary measures and see the consequences in a safe environment, based on self-motive rather than forceful adherence to the government's policies. The game also employed three mechanisms: progressively difficult levels, uncertainty, and unpredictability. It is worth to mention that these mechanisms were selected among others because they are the most relevant and applicable in the context of Pacman-C. However, other mechanisms can also be examined in this context, and this creates *n* opportunity for future work.

The following sections describe the implementation of the game components, including simulation of infection spread in the game and explanation of the preventive measures that are implemented in the game.

3.2.1. Infection Spread Process in COVID Pacman-C. The main objective of the game is to create awareness and motivate people to keep the COVID-19 precautionary measures such as avoiding getting close to the COVID-19 virus and other humans like avatars who are potentially infected, by making sure the player's avatar maintains social distance from them, while the Pacman goes about carrying the game task of picking coins. To complete a level and progress to the next level, the player must move around in every corner of the maze to collect coins and the powerups (which are COVID-19 safety and precautionary measures, e.g., hand sanitizer) while maintaining the distance from the virus and other infected humans. This creates an engaging experience as the player has to constantly protect his/her avatar from catching the infection while carrying out the game task of picking coins. Moreover, the movement of the COVID-19 virus in the game is uncertain and unpredictable. This is in line with the uncertainty and unpredictability mechanism of game-based learning [75] and also in line with how COVID-19 infection spreads in the real world.

3.2.2. Preventive Measures Aspect in COVID Pacman-C. At the start of the game, the player gets a default healthy human-like avatar (see Figures 1 and 2) representing the player. As the player moves around the maze picking the coins and powerups, they need to continuously observe the precautionary measures including social distancing, wearing face mask, and hand sanitizing to protect their avatar against COVID-19 infectious which are randomly spreading throughout the game environment. The player must follow social distancing measures and avoid getting closer to other humans in the game and the virus. If the player encounters the virus, the player's color turns to green showing that he or she is now infected with the virus. In addition to the COVID virus, there are other system-controlled human-like avatars in the game which represent other people in players' community, just as in the real world. The player must maintain distance from these other people's avatars to avoid being infected or transmitting the infection to others. The player can collect the powerups in the maze (e.g., hand sanitizers, face masks, hand gloves, and tissues) to increase their protective strength. The game is designed with three levels, each equipped with different powerups (different tools for preventive measures against COVID-19)

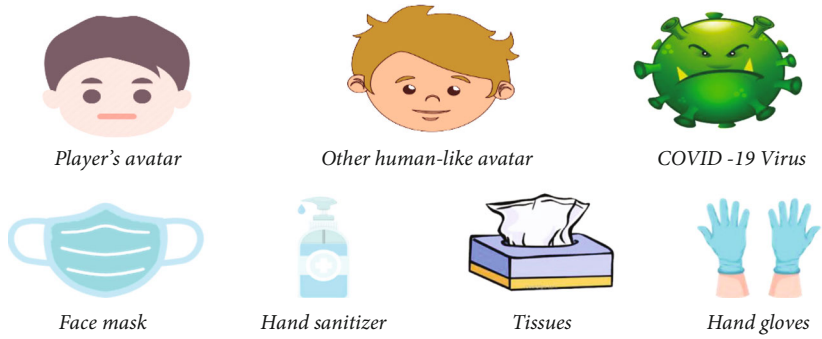
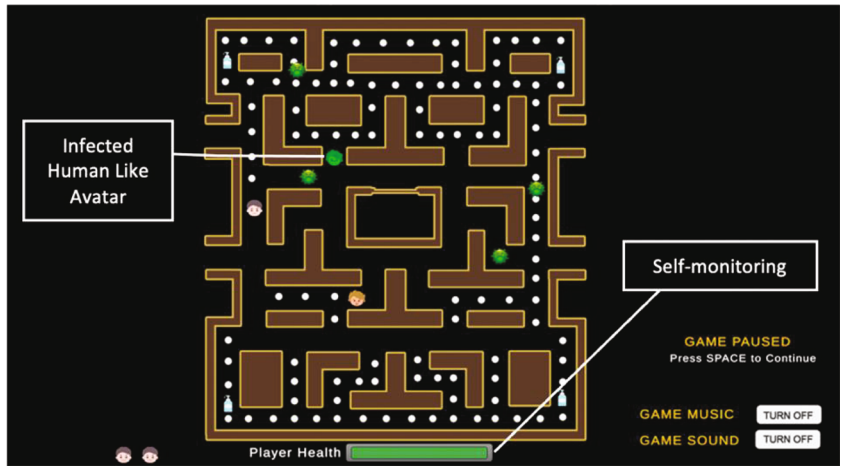


Figure 1: Game characters and powerups.



(a)

(b)

Figure 2: COVID Pacman-C game screenshots. (a) Implementation of self-monitoring components. (b) Implementation of competition component.

to prevent the player's avatar from catching the infection. To win the game, the player must defeat other players and complete the three levels. The game difficulty increases as they progress in level since the number of viruses and humans to avoid increases and uncertainty increases too. The game is designed to be played on desktop and laptop devices (including both Windows and macOS). The game was developed using the Unity game engine [76].

3.3. Deconstructing COVID Pacman-C. In this section, we deconstruct the persuasive game highlighting the design components.

3.3.1. Game Characters and Powerups. To simulate the real-world, COVID Pacman-C consists of human-like avatar for player and other humans in the game. Also, the monsters from the traditional pacman were improvised to look more

like the COVID-19 virus. The game consists of four powerups in total: hand sanitizer, face masks, tissues, and hand gloves as shown in Figure 1. The primary task of the player is to move around the maze using the arrow keys collecting all the coins and powerups while maintaining the physical distance from the virus and other potential infected individuals. Figure 1 below shows the screenshot of player's avatar, other human-like avatar, and powerups used in the game.

3.3.2. The Persuasive Strategies. In order to motivate people (or players), we implemented persuasive strategies COVID Pacman-C. Particularly, we used different implementations of two well-known persuasive strategies, competition/comparison and self-monitoring. The competition/comparison strategy allows the users to compete with each other to perform the desired behaviour and provide a means for the users to view and compare their performance with the performance of other users (s). On the other hand, the self-monitoring strategy provides means for users to track their progress or performance while playing the game. The selection of these strategies was based on previous studies, which suggested that these two strategies can motivate people with different behaviours [58]. Besides, competition and self-monitoring allow people to view their progress and provide social influence factors, which is helpful in the context of the Pacman-C game.

We designed the game to motivate people to adhere to COVID-19 precautionary measures while creating opportunities for players to feel some sense of social connection using the competition feature. Previous studies [58, 77] have shown that individuals who strive for competition to bring out a change in their behaviour need some external reinforcement and a way to track their progress towards their goals. Hence, they are motivated to continue the healthy behaviour by using strategies that allow them to view their progress and some social influence factors [58, 77]. To accommodate this need, we implemented self-monitoring in addition to competition/comparison persuasive strategies in the game.

Table 3 summarizes our implementations of both persuasive strategies in the Pacman-C. As the table shows, we implemented self-monitoring as a health bar that shows how healthy/unhealthy the player is. At the same time, we used the Leaderboard feature as an implementation of the competition/comparison strategy. Figure 2 show the self-monitoring and competition strategies and the other game elements in the Pacman-C game. In this game, when a player collects the powerups (hand sanitizer, face masks, hand gloves, and tissues), the player's health is increased in the health bar by 10%, and when the player gets closer to virus or infected people, the player's health is decreased in the health bar by 10%. Moreover, the players can see and compare their performance with other players playing the games from the leaderboard, along with monitoring their health status from the health bar.

3.4. COVID Pacman-C Game Implementation. COVID Pacman-C was developed using the Unity game engine and C# programming language and photoshop. The reason for choosing the Unity game engine was due to its robustness and compatibility with C#. We also used photoshop for editing assets and exported them as png images. In the implementation of COVID Pacman-C, the first step we took was to identify the characters, elements, and assets we needed in the game. We created and edited most of our assets in photoshop including the game logo, buttons, and icons. We also sourced few open access assets like player avatar, powerups, and COVID virus using the keyword searches on the internet. After editing these assets according to our game requirements, we exported them into png image files. Further, we imported these files into Unity and converted them into sprites while those assets that needed collision were given rigid bodies and polygon colliders. After developing both versions of the game, we used the inbuilt unity packages to generate the build for both Windows and macOS.

3.5. Study Design. Our study was divided into four stages: (i) first, we conducted a pretest study to collect the participant demographics and identify their baseline for attitude, intention, self-efficacy, and knowledge for adhering to COVID-19 precautionary measures. (ii) Second, participants were sent the web link of the game and asked them to play the game for at least 10 mins daily for the period of 10 days. We also tracked the average time spent in the game to ensure participants completed the game. (iii) Third, we conducted a post-test study to identify the participants' change in attitude, intention, self-efficacy, and knowledge for adhering to COVID-19 precautionary measures. For our pre- and post-study, we adapted question from [2]. We used the online survey as the data collection tool for our study. Our survey was designed and hosted on Opinio [32], and all the data collected was stored in the University's online server. (iv) Finally, we conducted a one-to-one interview with 18 participants to get more insights.

3.5.1. Data Collection. We conducted an online survey involving participants recruited from advertising to the public using various channels such as social media and the university's emailing list. We also used word of mouth and snowball sampling techniques that allowed participants to recruit more people. For our presurvey hosted on Opinio [32], there were four sections. In the presurvey, the first section contains the demographic-related questions such as participants' age group, gender, marital status, and education qualifications. In the second section, we asked participants about their gaming background, such as how often they play games and their most preferred platform where they play games. The third section of the survey includes 32 questions related to attitude, intention, and self-efficacy adapted from [2, 66]. Final section of the survey includes 8 questions for testing participants' knowledge on COVID adapted from reliable sources. The postsurvey of our study consisted of questions measuring change in attitude, intention, self-efficacy, and knowledge which are same as used in presurvey. It also contains 12 ARCS motivation questions for measuring the games motivations appeals—attention, relevance, confidence, and satisfaction [78]. Additionally,

Table 3: Summary of persuasive strategy implementation for COVID Pacman-C.

Strategy	Implementation
Self-monitoring	Health bar of the player to represent how the infection or powerup is affecting the player's health.
Competition and comparison	Leaderboard to compare the scores and compete with other players playing the game.

Table 4: Participants' demographic information.

	Total participants = 67
Age	18-25 (60%), 26-35 (27%), 36-45 (9%), over 45 (4%)
Gender	Male (58%), female (42%)
Marital status	Single (82%), married (18%)
Education	High school or equivalent (17%), college diploma (6%), bachelor's degree (57%), master's degree (19%), doctoral degree (1%)
Gaming frequency	Many times a day (25%), every day (36%), many times a week (20%), once or twice a week (13%), once or twice a month (4%), once or twice a year (2%)
Preferred gaming platforms	Mobile phone (iOS or android) (45%), desktop or laptop (windows or macOS) (45%), Play Station (5%), Xbox (5%)

we adapted questions from [2] for measuring play experience—enjoyment, invested effort, usefulness, perceived competence, and tension to examine player's experience. Participants were also asked to provide a justification for their ratings in the survey to collect some qualitative data. Finally, we conducted one-to-one interviews online with 18 participants who played the game and completed the survey. Each interview lasted for about 20 mins. We audio-recorded all 18 interviews with the participant's permission. This semistructured interview helped us to collect rich qualitative feedback from the participants about their experience with the game, its impact on their behaviour with respect to promoting adherence to COVID-19 precautionary measures, what they like/dislike about the game, their thoughts on the persuasive features used in the game, and any suggestions for improvements in the game.

3.5.2. Participants' Demographics. We included a total of 67 responses in our analysis, having removed incomplete responses from our survey. Our participants were adults (18 years or above) and proficient in English. We target adults in this study for three major reason: one, it is in compliance with the study ethics approval. Two, most minors are under the control of adults and tend to believe or adhere to whatever a trusted adult tells them. For example, parents who adopt the precautionary measures are more likely to instill that in their kids and dependents, the opposite is not necessarily true. A kid may have a hard time convincing an adult. Again, parents who do not believe in the precautionary measure may not grant the person needed for a minor to participant in this type of study. Finally, most precautionary measures are required for adults but not for kids people. Generally, our participants were diverse in terms of age, gender, marital status, education, gaming background, and their stages of behaviour change (see Table 4). As the table shows, 67 participants played the game for at least 10 days and completed the quantitative study. While 18 participants who played the game also participated in the one-on-one interview. The sample size is adequate for studies of this nature that involves repeated game play over a period, quantitative, and qualitative studies. Also, in comparison to previous studies who evaluated serious games with an average 58 participants, our sample size is adequate [35, 37, 79, 80].

3.6. Data Analysis. To analyze the quantitative data and answer our research question, we used well-known analytics methods via IBM's SPSS. We conducted a paired t-test of the overall participants' responses ($n = 67$) to answer research question RQ1—change in participant's attitude, intention, self-efficacy, and knowledge. We ran a one-sample t-test to answer RQ2 and RQ3. To analyze the qualitative data, first, we transcribed all the interviews. After that, we performed thematic analysis separately on survey comments and our interview transcription. While performing thematic analysis, we reviewed each comment by clustering the similar comments together to form a theme. Specifically, we followed the approach proposed by Braun and Clarke [42] which has been highly adopted: (1) becoming familiar with the data, (2) generating initial codes, (3) searching for themes, (4) defining themes, (5) iteratively reviewing themes, and (6) writing up the results.

4. Results

In this section, we present the results of our paired t-test comparing the baseline and poststudy changes in participant's attitude, intention, self-efficacy, and knowledge towards adopting COVID-19 precautionary measures. This is followed by the result of the motivational appeal of the game and the play experience. The reliability analysis showed that all the scales demonstrated internal consistency, with Cronbach's alpha values above 0.70.

4.1. Change in Attitude, Intention, Self-Efficacy, and Knowledge. To investigate the changes in behaviour as a

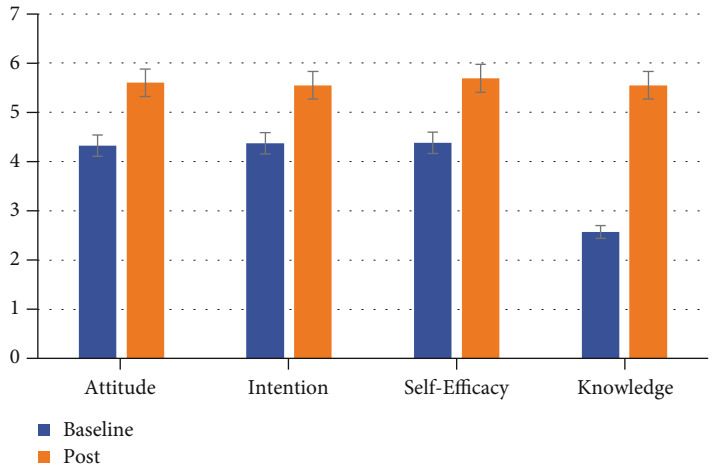


Figure 3: A bar graph showing the paired means of attitude, self-efficacy, intention, and knowledge ratings over time—baseline and post. Error bars represent a 95% confidence interval.

Table 5: Descriptive statistics (mean and standard deviation) for attitude, intention, self-efficacy, and knowledge change.

Measures	Mean	SD
Pre-attitude	4.32	1.25
Post-attitude	5.60	1.27
Pre-intention	4.37	1.36
Post-intention	5.55	1.46
Pre-self-efficacy	4.38	1.23
Post-self-efficacy	5.69	1.36
Pre-knowledge	2.57	2.54
Post-knowledge	5.55	2.53

result of playing the persuasive games, we performed a paired-sample t-test on the data to determine if the mean of baseline attitude, intention, self-efficacy, and knowledge (before playing the game) differ significantly from the mean of post attitude, intention, self-efficacy, and knowledge (after playing the game). The results show there is significant difference in all measures: attitude ($t(66) = -22.31$, $p < 0.001$), intention ($t(66) = -16.74$, $p < 0.001$), self-efficacy ($t(66) = -19.79$, $p < 0.001$), and knowledge ($t(66) = -7.58$, $p < 0.001$). The summary results are presented in Figure 3 and Table 5.

4.2. Motivational Appeal of the Persuasive Game. We evaluated the motivational appeal of the game using the ARCS model, a well-known and widely used motivational model [78, 81]. It highlights attention, relevance, confidence, and satisfaction as the four qualities that a system needs to have in order to motivate [73]. The ARCS motivation model has been used as a scaffolding tool for persuasive and behaviour change systems [82–84]. The result of a One-Sample t-test shows that the game is effective with respect to the overall motivational appeal, obtained by aggregating the four motivational dimensions: $t(66) = 7.344$, $p < 0.001$. It is equally effective across the four motivation dimensions: attention ($t(66) = 7.822$, $p < 0.001$), relevance ($t(66) = 6.777$, $p < 0.001$), confidence ($t(66) = 7.558$, $p < 0.001$), and satisfaction ($t(66) = 7.038$, $p < 0.001$). Overall, the COVID Pacman-C game is effective with respect to motivational appeal. The summary results are presented in Figure 4 and Table 6.

4.3. Play Experience from Playing the Persuasive Game. To understand the experience of our participants from playing COVID Pacman-C, we employed the popular intrinsic motivation inventory (IMI) scale [85] to assess participant experience after game play on a 7-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree). We collect play experience across the five dimensions of experience according to IMI: interest and enjoyment, perceived competence, effort and importance, pressure and tension, and value and usefulness.

To analyze the play experience data, we conducted a one-sample t-test with an optimistic neutral point/midpoint of 4 in a 7-point Likert scale. The results show that players had significant positive experience playing the game: interest and enjoyment ($t(66) = 6.44$, $p < 0.001$), perceived competence ($t(66) = 9.53$, $p < 0.001$), effort/importance ($t(66) = 8.13$, $p < 0.001$), and value/usefulness ($t(66) = 9.49$, $p < 0.001$). However, it was also clear from the results that the game induced significantly low pressure and tension ($t(66) = -9.90$, $p < 0.001$). Figure 5 and Table 7 present the descriptive summary of the results.

Moreover, we also received comments from the survey to support our quantitative results. For example, participants who played the game found the features important to keep them motivated to follow precautionary measures. This was also clearly reflected in our interview comments:

"I was really engaged to save my player when my health was down. I think it is important to have health bar in such type of games." (P12).

"It was constantly in my mind that I don't want to lose the health of my player and adhering to this I was following best practices to stay safe." (P13).

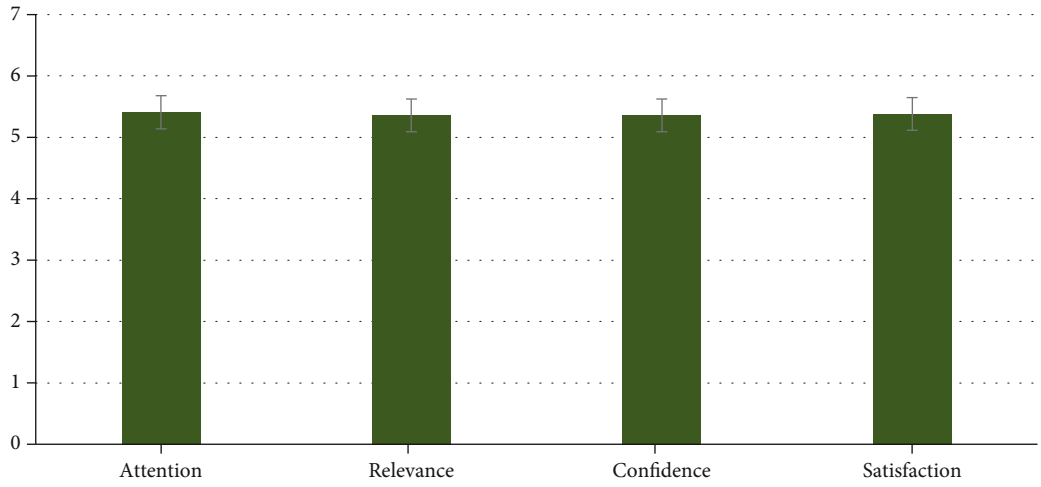


Figure 4: Motivational appeal of the persuasive game for the motivation dimensions on a scale ranging from 1 to 7. The horizontal line indicates the neutral score of 4. Error bars at 95% confidence interval.

Table 6: Mean (M), standard deviations (SD), mean difference (MD), t-values (t_2), and significance levels on a scale from 1 (low) to 7 (high) of the persuasive game's motivational appeal.

Motivation dimensions	$N = 67$				
	M	SD	MD	t_2	p
Attention	5.41	1.48	1.41	7.822	<0.001
Relevance	5.36	1.63	1.35	6.777	<0.001
Confidence	5.36	1.48	1.36	7.558	<0.001
Satisfaction	5.38	1.60	1.38	7.038	<0.001

"It really made me stick to the game as I wanted to be the person who is always on top." (P10).

"As I mentioned earlier, I wanted my player to be on top of leaderboard and hence I feel it was important." (P11).

These results show that the game significantly led to positive changes attitude, intention, self-efficacy, and knowledge to adopt the COVID-19 precautionary measures. This was also effective with respect to the motivational appeal and also to a positive play experience. These results answer our research questions RQ1, RQ2, and RQ3.

4.4. Thematic Analysis from Survey Comments and Interviews. For collecting the qualitative comments from the survey, we asked the participants to provide justifications/comments about their experience with the game and to justify their ratings. Table 8 presents the themes identified in the thematic analysis of the survey comments along with the sample comments from the participants.

After all the participants completed the COVID Pacman-C and responded to the postsurvey, we interviewed 18 of them one-to-one to collect more qualitative insight about the game and their experience. This provided deeper insights that support our findings. Table 9 presents relevant identified themes and sample comments from one-to-one interview.

In summary, thematic analysis results are in line with our quantitative results of the game. The feedback demonstrates that the game created awareness and motivated participants to adhere to the COVID-19 precautionary measures. Moreover, the comments from the participants also portrayed positive learnings from the game, positive impact on their behaviour, and corroborates that the persuasive strategies used in the game are important, useful, and effective.

5. Discussion

Research has elaborated the importance of including competition elements in digital games to improve enjoyment [86]. Our research investigated the hypothesis that a competition-based persuasive game will bring a positive change in attitude, intention, self-efficacy, and knowledge towards disease awareness and prevention. Specifically, we investigate the efficacy of the competition-based persuasive game to create awareness and promote the adoption of COVID-19 precautionary measures. We also investigate if the competition-based game will lead to a positive play experience. In our study, we designed and implemented a COVID Pacman-C game to create awareness and promote the adoption of COVID-19 precautionary measures employing the competition strategy as the key strategy to engage the users, facilitate social interaction, and promote desirable behaviour.

Our results show that the game was effective, leading to significant changes in attitude, intention, self-efficacy, and knowledge towards adhering to the COVID-19 precautionary measures. These results are in line with previous research [87] which found that a mobile serious game was able to enhance users' adherence to precaution measures, such as wearing masks. The results also show that the game was effective with respect to the overall motivational appeal. Although we could not assess actually change in behaviour quantitatively, the qualitative study revealed that playing the game led to actual behaviour changes in the lives of

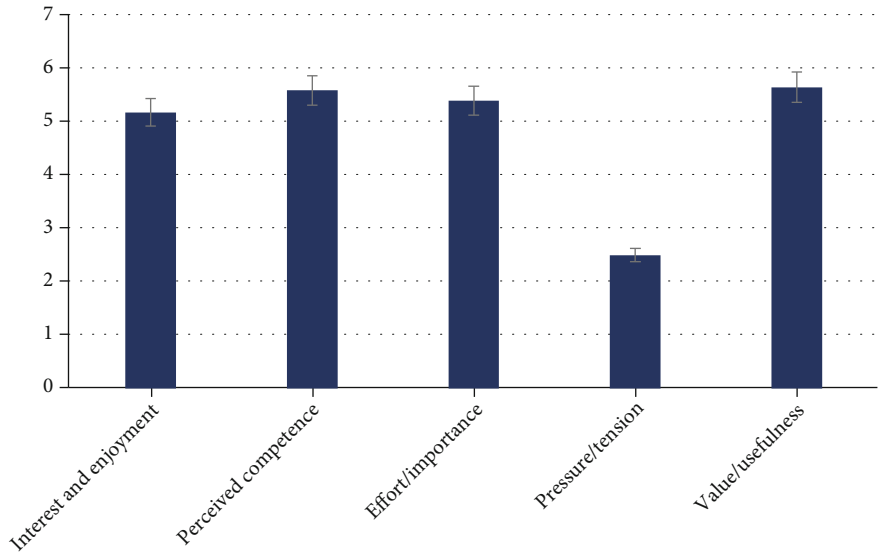


Figure 5: Play experience from playing the persuasive games on a scale ranging from 1 to 7. The horizontal line indicates the neutral score of 4. Error bars at 95% confidence interval.

Table 7: Mean (M), standard deviations (SD), mean difference (MD), t-values (t_2), and significance levels on a scale from 1 (low) to 7 (high) of the play experience.

	$N = 67$				
Dimensions	M	SD	MD	t_2	p
Interest and enjoyment	5.17	1.49	1.17	6.44	$p < 0.001$
Perceived competence	5.58	1.36	1.58	9.53	$p < 0.001$
Effort/importance	5.39	1.40	1.39	8.13	$p < 0.001$
Pressure/tension	2.50	1.24	-1.50	-9.90	$p < 0.001$
Value/usefulness	5.64	1.42	1.64	9.49	$p < 0.001$

participants in the real world and made them reflect on the behaviour as shown by sample comments below:

"After playing the game I try to sanitize my hands frequently and always wear a face mask." (P3).

"I became more aware not to visit crowded places nowadays and I follow social distancing." (P4).

"Earlier, I used to ignore but after playing the game it was clear that covid is a serious disease and we need to prepare ourselves for new normal" (P2).

"Until this game, I was following measures out of fear, but this made me realize that we should follow it to stay safe and it really takes less time and effort to involve this in our lifestyle." (P14).

"I realized my mistake of ignoring precautionary measures after playing the game. Seeing the infection spread made me aware of the problem and I will improve my habit for sure." (P5).

This is supported by our quantitative results which show that the persuasive game led to a higher increase in knowledge from (baseline to poststudy) compared to its effect on other behaviour measures (attitude, intention, and self-efficacy). This is probably because the realistic simulation used in the game created awareness and cleared many misconceptions about COVID-19, how it spreads, and the importance of adhering to precautionary measures. This highlights the importance of creating awareness by increasing people's knowledge in disease prevention intervention. Previous research has found that knowledge acquisition/content understanding is the most common outcome of serious games, which leads to affective and motivational outcomes [88]. Also, other tasks, such as changing attitude and behaviour, are known to be more challenging compared to increasing awareness and knowledge [89]. Hence, we suggest that persuasive game for disease awareness and control/prevention designers should focus on including mechanisms to impart knowledge about the disease, risk, and prevention as a way of promoting desired behaviour.

The game provided a simulated environment for players to experiment with many risky behaviours as it relates to noncompliance with the precautionary measures and also observe how the virus could easily spread. This was like a moment of awakening for some people. This highlights the power of digital game simulation at simplifying and conveying abstract/complex subjects in a relatable and comprehensible manner by allowing people to explore and visualize the choices and consequences of their behaviours in a digital and safe environment [5].

Our results also show that the game elicits a positive player experience with respect to the game enjoyment, perceived importance, effort, and competence. This is very important considering that although the game was designed to promote disease awareness and prevention, people may not play and keep playing it if they found it not fun. The primary reason people play games most time is to have fun. However, it is always challenging balancing the fun element and serious element of persuasive games. We were able to achieve this in the COVID Pacman-C by closely linking the players' performance with respect to learning COVID-19 awareness-related information and effectively observing the accompanying precautionary measures in the simulated

Table 8: Themes, descriptions, and sample comments from online survey.

1. Useful and relevant game content—participant found the game content useful and relevant with respect to promoting the adoption of COVID-19 precautionary measures. "This game is useful to me as it is regarding covid measures that everyone should follow." (P5) "The content of the game is relevant and makes sense to me as it provides the means to avoid the spread of the COVID." (P11) "The game displays and promotes useful and relevant content." (P40)
2. Creating awareness and impacting knowledge about COVID-19 precautionary measures—the game helped in raising awareness and impacting knowledge about COVID-19 precautionary measures. "Does a great job of creating Covid measures awareness." (P3) "The game would improve my awareness in the adoption of Covid precautionary measures." (P30) "I felt that the game was a good experience to play as it is raising awareness." (P46) "This game would be useful to me to increase my knowledge about COVID spread." (P6) "The knowledge regarding the COVID precautionary measures is presented in this game." (P22)
3. Easy to play and aesthetically appealing user interface (UI)—our participant found the game easy to play, and participants liked the user interface of the game and the overall pacman theme. "The UI of the game is quite compelling, and it reminds of the older games we played. So, it's good game to play." (P1) "The Pacman theme in itself is quite nostalgic and enjoyable." (P52) "The game was easy to understand and play." (P61)

Table 9: Themes, descriptions, and sample comments from one-to-one interview.

1. Self-realization on the importance of following the COVID precautionary measures—the game made the players realize how important it is to follow the precautionary measures via the simulation and narratives. "Earlier, I used to ignore but after playing the game it was clear that covid is a serious disease and we need to prepare ourselves for new normal" (P2) "Until this game I was following measures out of fear, but this made me realize that we should follow it to stay safe and it really takes less time and effort to involve this in our lifestyle." (P14) "I realized my mistake of ignoring precautionary measures after playing the game. Seeing the infection spread made me aware of the problem and I will improve my habit for sure." (P5)
2. Encouraged engagement in behaviours that are in line with the COVID-19 precautionary measures—playing the COVID Pacman-C game encouraged desired behaviours while discouraging others, in line with the COVID-19 precautionary measures. "After playing the game I try to sanitize my hands frequently and always wear face mask." (P3) "I became more aware not to visit crowded places nowadays and I follow social distancing." (P4)
3. Support for the self-monitoring strategy—the self-monitoring strategy which help participants track their health status using health bar helped to engage and motivate the participants. "I was really engaged to save my player when my health was down. I think it is important to have health bar in such type of games." (P12) "It was constantly in my mind that I do not want to lose the health of my player and adhering to this I was following best practices to stay safe." (P13)
4. Support for the competition/comparison strategy—participants highlighted the importance of competition/comparison strategy in the game in keeping them engaged as they compare their scores with others on leaderboard and try to stay on top. "It really made me stick to the game as I wanted to be the person who is always on top." (P10) "As I mentioned earlier, I wanted my player to be on top of leaderboard and hence I feel it was important." (P11)
5. Liking for overall game design and sound effects—participants portrayed liking towards game UI design and sound effects. "I enjoyed the simplistic design of the game." (P2) "I liked the UI and sound effects." (P10) "I liked the icons, and the way information was presented in an interactive way." (P3)
6. Suggestions for expanding scope of the game—participants suggested some improvements and future work including designing the game to accommodate multiple diseases and their prevention as different modes in the game. "I think the game can include multiple modes for different types of diseases but when it comes to covid game was sufficient." (P10) "Including another version for another COVID-19 strains when more information is available will be useful thing to add." (P1)

game environment. Hence, the fun and serious (learning) aspects of the game are closely integrated. In other words, the fun element is closely tied to the behaviour change objective which the game intends to achieve. This implies that designers can balance the fun element and serious element by closing linking the fun element to the game objective as opposed to including the fun element as an afterthought—-that is weakly integrated into the game main objective. This challenge is recognized by previous research which asserts that too much emphasis on learning tends to suck the fun out of games, and the opposite is also true; too much focus on game play sucks out the learning [90, 91].

This is supported by the comments:

"It really made me stick to the game as I wanted to be the person who is always on top." (P10).

"As I mentioned earlier, I wanted my player to be on top of leaderboard and hence I feel it was important." (P11).

"The content of the game is relevant and makes sense to me as it provides the means to avoid the spread of the COVID." (P11).

Our results also show that our participants did not feel pressure and tension playing the game. Although tension and pressure may be a necessary attribute for some persuasive games such as exertion games (e.g., exergames), we deemed it unnecessary for our game. As one of our design decisions, we decided to make our persuasive game a casual game and balance the difficulty level using incremental difficulty approach to achieve two major aims: one, make the game easy to learn and play, hence, attract a broader

audience and two, make it possible for players of varying ability to navigate through the game levels, and experience the persuasive contents (which facilities the desired behaviour change) with moderate effort. This decision was based on the findings of previous research, which confirmed that the success of serious games is affected not only by usability and learnability but also by the playability of the game [92]. That is, if the game is unplayable, then it is considered unsuccessful. Hence, we recommend that, although pressure and effort may be necessary for user experience, serious game designers should consider trading that off when necessary to ensure that users have the opportunity to be exposured to all the persuasive content for desired behaviour change. We recommend balancing game difficulty level via dynamic difficulty adjustment. Again, to attract a wider audience and reduce the learning curve, game designers should consider modeling their gameplay to resemble a popular existing game. This is supported by these comments:

"The UI of the game is quite compelling, and it reminds of the older games we played. So, it's good game to play." (P1).

"The Pacman theme in itself is quite nostalgic and enjoyable." (P52).

"The game was easy to understand and play." (P61).

In summary, our findings show that the persuasive game is successful at promoting awareness and motivating participants to adhere to COVID-19 precautionary measures. Again, the findings also provide support for the importance of digital interventions (such as digital games) as a tool for health promotion and disease prevention especially those that create opportunities to simulate and visualize the cause-and-effect linkage of unhealthy and noncompliant behaviours. This type of game is powerful and has the capability to persuade beyond what conventional health and risk communication intervention can afford using appealing visual cues that can be easily understandable by many. It allows people to rehearse and experiment with unhealthy behaviour and see the consequences in a safe space. Our results show that such experimentations such as breaking the social distancing rule and observing the consequences in the digital space are highly motivating: "I realized my mistake of ignoring precautionary measures after playing the game. Seeing the infection spread made me aware of the problem and I will improve my habit for sure." (P5). Finally, it was clear from the interview (see Table 6) that the persuasive features in the game especially the competition were important for facilitating the behaviour change.

6. Limitations and Future Work

There are some limitations of our study. Our study is limited to the context of persuasive games designed to promote disease awareness and prevention and should be extended to other domains. We measured attitude, intention, self-efficacy, and knowledge which are a precursor to actual behaviour change, although our qualitative study showed that the game led to actual behaviour change in the real world, future work should investigate actual behaviour change quantitatively. Although our study showed some interesting and significant findings, it also opens many research areas for other researchers in this domain. In the future, we plan to conduct a large-scale long-term evaluation using randomized control trials. We will also explore if our result generalizes across other domains.

7. Conclusion

Persuasive games that help people improve their lives are increasing in prevalence in many domains such as education, physical activity, healthy eating, disease management, and risky behaviour. This paper investigates the effectiveness of a persuasive game at promoting disease awareness and prevention. Specifically, this paper contributes to advancing the field of HCI and behaviour change by effectively answering the important research question: (1) how effective is a competition-based persuasive game for promoting disease awareness and prevention using COVID-19 as a case study?

To answer the research question, we conducted a quantitative study of 67 participants followed by interviewing 18 participants. Our pre- and posttest study uncovered that our persuasive game called COVID Pacman-C was effective at promoting awareness and adherence to COVID-19 precautionary measures. Specifically, the results show that the game promoted changes in attitude, intention, self-efficacy, and knowledge towards the adoption of COVID-19 precautionary measures. The results also show that the game was effective with respect to overall motivational appeal and play experience. The qualitative study revealed that playing the game led to actual behaviour change in the lives of players in the real world and made them reflect on their behaviour. The paper contributes to the current literature by shedding light on how persuasive games can be designed and used to solve problems in our society with a focus on disease awareness and prevention and specifically promoting COVID-19 awareness and adoption of the precautionary measures.

Data Availability

The data used in our study is not available to the public in compliance with the ethics approval.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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