Point of Contact: Investigating change in perception through a serious game for COVID-19 preventive measures

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COVID-19 has exposed the need to identify newer tools to understand perception of information, behavioral conformance to instructions and model the effects of individual motivation and decisions on the success of measures being put in place. We approach this challenge through the lens of serious games. Serious games are designed to instruct and inform within the confines of their magic circle. We built a multiplayer serious game, Point of Contact (PoC), to investigate effects of a serious game on

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perception and behavior. We conducted a study with 23 participants to gauge perceptions of COVID-19 preventive measures and quantify the change after playing PoC. The results show a significant positive change to participant's perceptions towards COVID-19 preventive measures, shifting perceptions towards following guidelines more strictly due to a greater awareness of how the virus spreads. We discuss these implications and value of a serious game like PoC towards pandemic risk modelling at a microcosm level.

CCS CONCEPTS • Human-centered computing~User studies • Applied computing~Computer games

Additional Keywords and Phrases: serious games, covid-19, game transfer phenomena

ACM Reference Format:

Joshua Hill, Edward Corke, Mubarak Salawu, Ethan Cotterell, Matthew Russell, Joshua Gibbons, and Abhijit Karnik. 2021. Point of Contact: Investigating Change in Perception through a Serious Game for COVID-19 Preventive Measures. In Proceedings of the ACM on Human-Computer Interaction, Vol. 5, CHI PLAY, Article 274 (September 2021), 19 pages, https://doi.org/10.1145/3474701.

1 INTRODUCTION

COVID-19 pandemic has impacted the lives across the world. Health authorities in most countries have adopted a variety of preventive measures to safeguard the population. However, the compliance of the public to these preventive measures is inconsistent. Studies show a variation in compliance across demographics of gender, age and socio-economic status [1]. A common theme to higher compliance is individual's perception of infection risk and a better understanding of the preventive measures [21]. Encouraging safer behavior in line with scientific advice requires overcoming the barriers of people's perceptions and beliefs [35]. There is a positive correlation between increased perception of being personally affected and compliance with health advice [43]. However, a positive response to preventive measures is complicated by the nature of COVID-19 which can manifest both as a symptomatic and an asymptomatic infection. Furthermore, the complications due to impact on macro-level economy and individual livelihoods [8] presents a significant barrier to behavioral compliance due to a perceived lack of visible risk.

We propose to address these challenges viz., lack of compliance and awareness of risk balanced against economic hardship by attempting to improve the perception of COVID-19 preventive measures through a serious game. In this paper we describe the design and evaluation of Point of Contact (PoC), a multiplayer serious game, designed to improve the perception of players towards COVID-19 preventive measures. We are motivated by the fact that WHO identifies young adults to be the least compliant to preventive measures [7]. This age group is known to spend time playing video games and thus are familiar with video games as a medium of interaction. At the same time, the concept of using single-player games to influence behavior for better health outcomes is not new [3, 14, 37]. The challenge is to understand how the serious game design can introduce perception change in a non-intrusive way. How can the game-play help the players relate to the measures outside of the magic circle of the game? What can we learn from the players' behavior within the game when they work as a group? How can the game design model the transmission of the infection in a realistic way within the game?

We used PoC as a part of a study to capture pre-existing perceptions of COVID-19 preventive measures and investigate the ability of the game to change these perceptions. Our results show a positive shift in the perception of COVID-19 preventive measures in the sample population. We explore the conflict of economics of livelihood versus health risks due to increased contact with other individuals. We see an interesting shift in the perception towards safeguarding health over economy as a result of the game-play. We also found that the perceived risk of catching or passing the infection is underestimated by the participants. We show that PoC, as a multiplayer serious game, can be a useful tool in the fight against a pandemic like COVID-19.

2 BACKGROUND

2.1 Challenges of COVID-19 pandemic

The COVID-19 pandemic is an unprecedented event that has impacted almost all communities around the world. Health authorities have pushed large amounts of information aim at the public, such as how the virus spreads and guidelines detailing preventive measures to combat spread [11, 12]. This information is carried in all traditional mediums like news broadcasts, websites, and even social media. The information is jargon-rich and has to compete with the misinformation infodemic [6], thus making the effort to required comprehend the evidence-based information off-putting to sections of the population, especially younger people [44]. The COVID-19's spread is further enhanced because the infection manifests as an asymptomatic infection in many individuals. This lowers their risk perception as well as compliance to preventive measures.

If we view the underlying problem from a pedagogical lens, the issue is that transforming complex COVID-19 information into perception-altering knowledge. Constructivism learning theory [46] highlights that knowledge is created through experience whilst exploring and performing activities. It emphasizes that guidance or information is important for novices, but first-hand experience is even more crucial. In case of a disease like COVID-19, we need a safe but relatable virtual medium to construct the experience of how COVID-19 infection transmission occurs. Ortiz de Gortari and Griffiths [29] have already shown that virtual experiences are transferable to the real world through Game Transfer Phenomena (GTP). This allows us to address the challenge presented by COVID-19.

2.2 Serious games mediated GTP

Game Transfer Phenomena (GTP) is described as transference of virtual experience to real world actions. As per Ortiz de Gortari [23], the transference to real world actions can manifest as altered behavior and is one of the three ways in which GTP is experienced. Serious games are defined by Abt [45] as games with a carefully thought-out educational purpose, but not lacking entertainment value. The role of a serious game is two-fold. First, it is designed with a learning objective in mind. Second, it is designed as a game, relying on established game-frameworks that maximize engagement. GTP is generalized to all types of games including serious games. A well-designed serious game leverages GTP to trigger a change in perception or heightened awareness towards targeted real-world activities. We see this GTP in action from examples like DrLudens [19], Re-mission [40] and Corrupt Kitchen [3]. DrLudens is designed to encourage adoption of preventive measures against spread of tropical diseases. In-game actions include removing infected dogs and drying water puddles to reduce sandflies. This translates to a perceived need to perform similar actions in real life. Similarly, it can motivate players to continue performing activities which have a favorable but deferred outcome. Re-mission [40], a game that mimics chemotherapy by shooting lasers at cancer cells, motivates the players to persevere with chemotherapy. GTP can also invoke moral emotion as shown by Flintham et al. over compliance to hygiene practices through their game Corrupt Kitchen [3]. Serious games can also encourage preventive actions while alleviating the perceived burden or boredom of such actions [14].

2.3 Design of serious games

The efficacy of a serious game in delivering its purpose is not a foregone conclusion. Mitgutsch and Alvarado [28] state that the good intentions need to be met in terms of the game's design. Research has focused on identifying design elements that work in favor of the learning goal of a serious game [13]. Game elements [17] like avatars, hints, points systems and teams along with design elements like feedback [34], cooperation [33], soundtrack [38] can enhance the players experience and engagement with the game. There is no single recipe for a successful serious game. However, enjoyment is at the heart of any game [36] and thus the design needs to incorporate all the expected design elements that contribute towards this enjoyment. The challenge is to use the correct transformation of learning goals, allowing them to be embedded into the elements of game-play.

3 DESIGN

Keeping the design challenges discussed above, we explored the design for PoC through the lens of target demographics, existing offerings and design requirements tied to the learning goals.

3.1 Target audience

The proposed target audience age of PoC is 19-25 years. This group experiences a significantly lower COVID-19 death rate [9] and are less engaged with traditional mediums for health messaging. This demographic is most likely to experience GTP [29] and to undergo changes in perceptions of real-world behaviors. A serious game would provide this audience with an innovative approach for learning COVID-19 safety measures in a more accessible and engaging manner.

3.2 Design ideation

Ideation for PoC occurred in three phases, each exposing different design challenges and solutions. The initial idea was developed during a UN Sustainable Development Goals springboard event prior to the COVID-19 pandemic. The participants, including epidemiologists and health policy makers, discussed the need to model behavioral responses to pathogens through simulated experiences. One participant mentioned, "*I'd like to have the ability to see and influence a player's behavior in their natural surroundings where they are likely to be infected rather than burden the player with just the science behind infection.*" This observation helps identify the objective of focusing on the localized, personal effects emerging from a pandemic and learn from the player's behavior. The most vocal critic (a game designer) of addressing this challenge with a serious game mentioned, "*What if I want my character to have big boobs?!*" This provides a critical insight into the design of our game. The serious game's design needs to balance the anthropomorphic relatability to the player's in-game avatar against the distraction caused by providing high fidelity aesthetics like customizing the character.

Further informal discussion with game design experts identified the dominant prevalence of the Z-Man Games offering called "*Pandemic*" [41] as the serious game solution to any pandemic related challenges. "*Pandemic*" is designed to operate at a macro-level, i.e. the magic circle constitutes a world map. The game-play is complex and long [15] requiring a high level of mimicry and immersion. While this game is likely to engage interested players, we see an opportunity to create a complementary offering which is fast-paced, with light-weight complexity of rules and more relatable to an individual's normal life. By building the magic circle [4, 22] around a very familiar and relatable location from the person's life, we aim to increase the chances of GTP positively influencing the individual's perception towards preventive measures applied to that familiar location at a later point in time. Prior research [18, 20, 26, 30] shows that location is a known trigger for GTP, when in-game elements relate to day-to-day context. Intentional design aimed at mapping objects or events portrayed in the game to real-world activities would thus benefit from the associated location based GTP.

The final phase of ideation focused on familiar game-play. We focused on identifying a game which our target demographics was likely to be aware of, found entertaining and which required minimal learning of basic mechanics. We identified InnerSloth Entertainment's offering "*Among Us*" [16] as a suitable candidate due to its new-found popularity in 2020. "*Among Us*" is a multiplayer social deduction game. Four to ten players complete a series of simple tasks set in a small area to complete the game. Some of the group members, termed as imposters, secretly work against the team. We retain the collaborative play, fast pace of game-play and the mechanics related to map-navigation and task-completion for PoC. "*Among Us*" also uses a relatable avatar design with minimal customization. As a part of the re-design process, we eliminated irrelevant game-play elements (viz. imposters and the social deduction aspects) and replaced them with elements that are relevant to a pandemic-themed serious game. The resulting game, PoC, is a cooperative game where all players must work together to complete tasks whilst preventing the spread of the virus, which will spread if players do not play safely. Simulation and cooperation are the explicit strategies employed in PoC. These strategies belong to the collection of strategies [25] known to help achieve the objective of being a game for change (see gamesforchange.org).

3.3 PoC's elemental tetrad

To expose the game design of PoC, we present the game through the lens of Schell's Elemental Tetrad [39] consisting of Technology, Story, Mechanics and Aesthetics.

3.3.1 Technology

The context of preventive measures is directly linked to interaction with individuals and can benefit from teamwork and collaborative thinking [31]. Multiplayer design adds to the social dimension of interaction [32] and creates more realistic situations than those achieved by AI-controlled non-player characters (NPCs). The multiplayer aspect requires a minimum of four players and a practical maximum of seven players. At the same time, real-life social distancing precludes board-game type implementation. The game thus needs to be accessible online and to maximize reach, platform-independent and playable with minimal hardware. The graphics and cross-player communication need to be light-weight to minimize dependence on high performance GPUs and high-speed networks. This also informs certain choices of aesthetics, mechanics and finally implementation.

3.3.2 Story

The story element of PoC follows the high-level theme of "Among Us" involving micro-tasks distributed across the game-map. For the PoC prototype, we chose an office setting wherein the player plays the role of an office worker performing tasks commonly carried out in an office. Other settings like a restaurant and supermarket were also considered as equivalently viable options but left for future implementations that include in-game level-ups. The game-map comprises of many rooms connected via corridors (see Figure 1), reflecting a typical real office with storerooms, work-areas, and cafeterias. The tasks require the players to move around on the map similar to the movement of office-workers during a normal workday. Additional tasks are included to model COVID-19 preventive measures. The story-arc sets an objective of completion of tasks which contribute towards communal economy scores, mimicking a commercial operation. The players only encounter other players in-game and there are no NPCs in the prototype. The conflict element of PoC is created using the concept of 'patient zero' similar to 'Plague Inc.' [27] where one employee comes to work infected. The infection spreads among the players based on their decisions and actions. The players can relate to this setting within the real-world where they are forced to balance '*lives versus livelihood'*, thus establishing the reflective learning aspect of the serious game. If less office tasks are completed, the economy score falls. If more players get infected, the health score falls. The players must collaboratively decide and act on how to balance the game outcome in terms of the two scores through the optimal use of preventive measure tasks.

Figure 1: Game-map for Point of Contact showing multiple work-areas and narrow corridors connecting them.

3.3.3 Mechanics

The extrinsic and intrinsic rules of the game are guided by the following mechanics:

Infection probability mechanics: PoC uses a probabilistic approach to determine the successful transmission of the disease to a person. For each action or event that can be considered a transmission opportunity, we assign a probability of transmission when that action is performed, or the event occurs. The choice of the actions is guided by understanding of COVID-19 transmission as of November 2020. For example, close contact with an infected individual is known to increase chances of infection. Each player has a personal space (2m) and a smaller intimate space (1m). If an infected player enters either space of an uninfected player, the event is considered as a close contact and the uninfected player may catch the disease too. We assign probabilistic weights (20-40%) to the distance between the players and compute an outcome (infected/not infected) for each game-tick of a close contact event. Similarly, objects handled by an infected individual can host an infectious viral load. We model this by assigning a status (infected/not infected) to the task again based on probability. If a non-infected player performs an 'infected' task, again the probability function determines if the player gets infected or not. Finally, we model the effect of COVID-19 on an infected individual, which can be symptomatic or asymptomatic. In PoC, infected players will be either symptomatic (20%) or asymptomatic (80%). Symptomatic players see their avatar move with a 60% reduction in speed and making it obvious to other players that they are infected. Asymptomatic players are provided with no obvious feedback to indicate that they are infected.

Infection opportunity mechanics: The office workspace is designed to mimic real world scenarios. This allows us to create situations with higher opportunities for infection transmission. For example, the narrow corridors connecting office locations force players to pass by each other in close proximity, breaking social distancing guidelines (See Figure 2a). Players must make conscious decisions to wait for other players to pass or risk infection.

Similarly, each player has a limited field of view and can only see players within a small range. This prevents the player's ability to see around corners or past large obstacles (See Figure 2b). This mimics the real-world scenario where an individual does not necessarily have full situational awareness of individuals around them. Certain tasks are positioned close to each other. This is similar to real-world situations where co-workers carry out related tasks in close proximity. These tasks have to be executed within cramped working quarters (See Figure 2c) and thus preventing meaningful social distancing. This mechanic also aims to make social distancing a conscious decision.

Preventive measures mechanics: We designed for the preventive measures as established by the UK Government through the *"Hands. Face. Space."* [11] campaign. The guidance mentions regular sanitization of hands (washing or alcohol-based sanitization), covering of face with a suitable mask and maintaining social distancing of more than two meters. These are implemented through the 'optional tasks', which are not mandatory and do not contribute to the economy score. However, when tasks related to preventive measures are carried out, the probability function includes an opposing weight towards the outcome of a successful transmission. Using a hand sanitizer reduces the chances of a player being infected from a task by 10%. Face masks reduce the chance of transmission from the player wearing the mask to another player by 20%. Opening a window reduces the air-borne transmission chance in the surrounding area by 10%.

Economy task mechanics: Economy tasks are mandatory tasks which contribute to the economy score. These tasks were designed to be self-explanatory (see Figure 2c). They are simple and intuitive and do not require any prerequisite understanding of how the game works. This flattens the learning curve for the target audience as well as future audiences who may not have much gaming experience. The tasks are assigned to players in a random, never-ending order to ensure there are always tasks to complete.

Conflict/Resource mechanics: To add further realism and conflict within the game-play, we provide additional actions associated with COVID-19. Players can get tested to check if they have COVID-19. This task takes 5 seconds to complete and can only be used three times in a game. At the time of creation of this game, the gold-standard test was a lab-run PCR test which takes significantly longer than 5 seconds. The concurrent government guidance was to self-isolate till the test-results were returned. However, to match the game-play situated within a single work-day, this is modeled as a self-administered test with a quick response. The design shifts focus from the mechanics of the test to the resulting experience that intentionally forces the player to be non-productive during this time and places resource constraints to mimic limited resources in real life. Players can be voted into a quarantine area where they cannot infect others, nor contribute to the economy. A player can only be quarantined if 50% of the non-quarantined players vote for them. This is intended to force a reflection on ethical and moral implications of more stringent preventive measures.

End-game mechanics: PoC has two primary performance metrics - economy and health scores. The health score is the percentage of players that did not contract COVID-19. The economy score is tied to the number of assigned tasks that were completed by the players. Players must decide how they balance completing as many tasks as possible whilst minimizing transmission risk. From a gameplay perspective, success could be considered as achieving the highest possible health and economy score simultaneously. We aim to trigger reflection and better awareness of preventive measures (See Figure 2d). With subsequent iterations of game-play, this could result in higher number of optional tasks completed, a lower number of infected players and lower amounts of personal contacts between players. This is counter-balanced with the pressure of maintaining a viable, if not maximum, economic output.

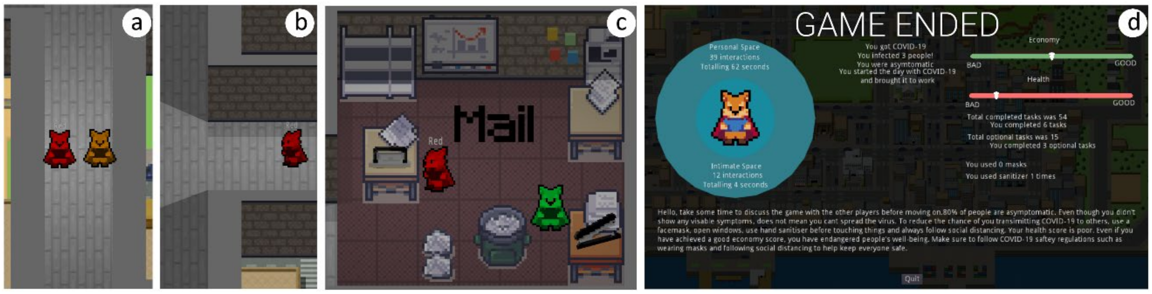

Figure 2: Game Mechanics a) Narrow corridor prevents social distancing; b) Limited view around corners; c) Mail-room as a cramped location where players perform office tasks like using copier or stapler; d) End-game splash screen showing economy and heath scores on right and infection outcome for the individual player.

3.3.4 Aesthetics

Aesthetics of PoC are light-weight in terms of graphics. The player always has a top-down view of a part of the map. The character representing them is an anthropomorphic gender-neutral figure which cannot be customized, thus taking away the distractive elements of character customization. The aesthetics are intentionally minimal to support deployment on a wide range of devices.

4 IMPLEMENTATION

4.1 Game engine

We implemented PoC using the Godot engine. Godot is a completely free game-engine which is published under the MIT license [44]. The engine allows HTML export for browser games. With cross-platform compatibility, this allows PoC to reach the widest audience possible. Browser games are easy to distribute which is vital due to COVID-19 restrictions on gatherings. The probability function was implemented as a random n-sided die roll with a successful outcome defined as a rolled value less than the probability weight assigned to the event.

4.2 Game distribution

PoC is hosted on Gotm.io, a free to use hosting website specifically tailored for Godot web-games [44]. Gotm.io also supports Godot's multiplayer API, adding support for lobby-based games. Using Gotm.io allowed game lobbies to be accessed over a WAN and maximize availability to the player-base.

5 STUDY

We conducted a study to investigate the effectiveness of PoC in achieving its stated aim of improving the perception of COVID-19 preventive measures. The study was a mixed methods study relying both on questionnaires and quantitative data from game logs.

5.1 Hypotheses

We expected that the players would be positively influenced towards safer behavior through adoption of preventive measures after playing the game (H1). This would result from heightened awareness of the players towards COVID-19 transmission risk in everyday interactions in real life (H2). We also expected that the players would alter their game play over iterations of the game to reflect heightened awareness of risky behavior during game-play (H3).

The counter-hypothesis was that the game be ineffective as a serious game and we would not see a positive shift in the perception of the players even after repeated failed plays.

5.2 Measures

The participants filled out a pre-study questionnaire aimed at assessing the participants' knowledge of COVID-19 preventive measures before entering the study. We provided the participants with a list of preventive measures and asked them to select the ones they were aware of. After this, they were asked to rank the importance of each preventive measure on a 5-point Likert-style scale. We also asked participants about their willingness to voluntarily wear masks. The post-study questionnaire repeated all the pre-study awareness and ranking questions to measure any changes in the perceived importance of the preventive measures. Additional questions were included on the post-study questionnaire to identify if the player's actions were representative of how they behave in the real-world and an opportunity to provide open-ended feedback. The participants filled an additional perception questionnaire after each iteration of the game (see Procedure for further details). This questionnaire contained reflective questions referencing the concluded game and related to the role of the player in the transmission of COVID-19. The game was instrumented to save the game-logs. This was used as a correlating factor to compare against the participants' responses to the questionnaires. It also allowed us to compare the perception of what the participants thought they did versus what they actually did during game-play.

5.3 Participants

PoC is a multiplayer game and we planned to recruit participants through an open call within <anonymized for review> university while following UK government guidelines. However, due to COVID-19 lockdown restrictions (starting 5th November 2020), the participants could only be recruited from the same household bubbles as the authors. The study was carried out as best as possible to recreate in-lab conditions. 23 participants (16 male, 7 female) were recruited in total. All participants were within the age range 19-25 years. 20 participants claimed to play games (computer, console, mobile) for at least one hour per week, with 13 participants stating that they played games for more than 4 hours per week. Most of the participants had considerable gaming experience. We carried out the study in 3 groups of 5 participants and 2 groups of 4. The study was carried out after following standard procedure for ethical approval within the university.

5.4 Procedure

Participants used their own PC or laptop to play PoC. Before the study, participants were shown a presentation to familiarize them with the controls and game-play. Next, they individually filled up the pre-study questionnaire. The participants then played the game together as a group once, each iteration lasting four minutes to ensure a fast-paced game experience. After completing the game, each participant filled up the post-game questionnaire. The steps of playing the game and filling the post-game questionnaire were repeated two more times. This was followed by the post-study questionnaire. The participants could leave the study at any time. Since the participants were from the same household bubble, their identities were not masked within the group. The participants were not compensated for their time in any form and participation was voluntary with informed consent. Each group-session lasted half an hour including game-play and responding to the questionnaires.

5.5 Results

5.5.1 Awareness of Preventive Measures

The pre/post study questionnaires contained one question about awareness of a list of preventive measures. This was followed by Likert-style questions about importance of these measures and grouped into 4 categories. These categories were: Original 'Hands. Face. Space.' (HFS, 5 questions), Updated guidelines (UG, 1 question), Group size restrictions (GSR, 3 questions) and Restrictions on movement (RoM, 4 questions).

The pre-study questionnaire indicated the level of awareness for the preventive measures. All participants were fully aware of HFS measures with all responses (excluding 5 out total 115) rating all measures as 'important' or 'very important'. The UG category included the new measure of opening windows and increasing ventilation (released on 18th November 2020) [12]. This measure showed lower awareness, wherein 6 out 23 (>25%) were unaware of it. The responses to its perceived importance showed a normal distribution (low skew and kurtosis). While the Wilcoxon signed rank tests on pre/post study responses did not reveal a statistically significant shift in perception of importance for UG category, we saw a large increase in participants rating it 'very important' (from 3 in pre to 12 in post-study). For GSR and RoM, again we saw high awareness in pre-study responses. For testing perception of importance, we constructed scales using the underlying questions in each category and separately for pre-study and post-study. We found high internal reliability (Cronbach Alpha > 0.7 in all cases) for scales. Once again, Wilcoxon Signed Rank tests did not show statistically significant differences but showed the average shift towards 'very important' for each category. One possible reason is that most participants rated all the measures in these categories as 'important' or 'very important' from the outset, providing limited scope for further improvement.

5.5.2 Trust in Preventive Measures

The pre-study asked about the perceived effectiveness of preventive measures. 43.4% of participants felt less confident in the effectiveness of COVID-19 preventive measures in reducing the spread of the disease. The participants felt well-informed about COVID-19's transmissibility. The post-study responses revealed that participants learned that the preventive measures were not a guaranteed safeguard against contracting the disease, but only lowered the probability. 87% of participants indicated intentions to be more careful in following COVID-19 preventive guidance.

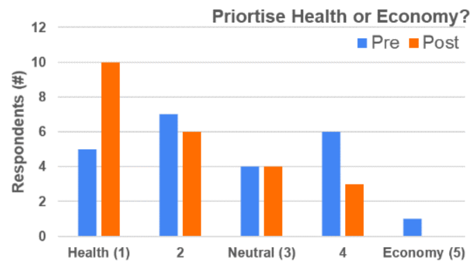

Figure 3: Pre-study versus post-study attitudes for health vs economy. Priority: 1=Health, 5= Economy *(n=23).*

5.5.3 Economy versus Health

The real-life challenge of balancing economy against health risk was one of the mechanics implemented in PoC. To gauge the response to this, we initially asked their preference for prioritizing economy or health in real life. The pre-study responses were favorable towards preserving the economy, though only 4.3% chose an absolute focus on economy preservation. We once again ran Wilcoxon signed rank test for the pre/post responses. We saw a statistically significant shift towards prioritizing health and away from economy (z=-2.74, $p<0.01$). A possible explanation for this shift is the game-play wherein participants identified with their avatars getting infected. The histograms of the responses are shown in Figure 3. We expected a fall in economy score, computed using the number of mandatory tasks (Econ tasks), as people prioritized tasks related to preventive measures (PM tasks). We saw a statistically significant increase in the number of PM tasks (Repeated measures ANOVA, $F_{(2,19)}=15.413$, $p<0.001$, significant pairwise interactions across all game-iteration pairs) per game iteration. However, there was not a similarly significant fall in Econ tasks (see Figure 4). This can be explained due to the game-play balance which did not stress the players enough to make an either-or choice between the two types of tasks.

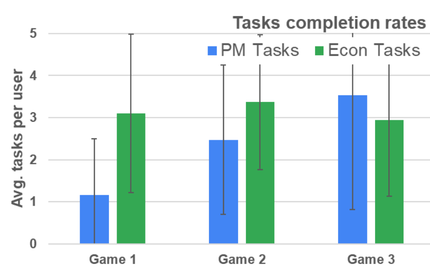

Figure 4: In-game tasks completed. Preventive measures (PM tasks) and economy related tasks (Econ tasks). *(n=19).*

5.5.4 Face Masks

One binary choice question focused on voluntary usage of face-mask. The overall willingness to voluntarily use masks was consistently high 87% (pre-study, 20 participants) and 95.7% (post-study, 22 participants) and thus would not show a statistically significant shift. However, we don't see this reflected proportionately in the game logs (NB: Due to a technical issue, game-logs of one group of 4 players were lost). From the available data, only 36% used a mask in every game, 15.7% never used a mask. However, the outcome of note is that the number of mask users increased from 9 users in first iteration to 15 users in the last iteration. The in-game mask mimicked real-world behavior of requiring periodic replacement to remain active and effective. 47.8% believed they used the in-game face mask correctly, i.e., always having an active face mask. 30% believed that their mask-usage was not proper and the rest were unsure. Based on the overall number of masks used (46) and the number of players who used more than one mask in any game (31.5%), we see that the participants overestimated their ability to use the masks correctly.

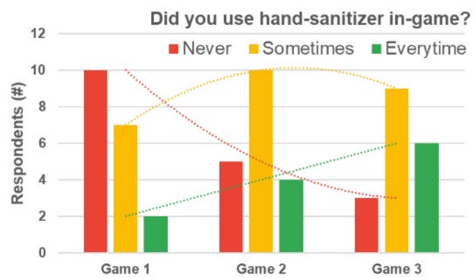

Figure 5: Self-reported usage of hand-sanitizer in-game. *(n=19)*.

5.5.5 *Hand Sanitizer Usage*

Participants were also asked how often they used hand sanitizer in public (1: Never, 5: All the time) in the pre-study questionnaire. All participants excluding one (4.3%) reported high usage (*avg.*: 4, *s.d.*: 1). This correlates with the perception of hand sanitizer being the most important safety precaution under the HFS category of responses. The post-study question around usage asked if participants would increase their usage of hand-sanitizer in public. 82.6% of the participants (including the one who reported no usage previously) indicated that they would consider increasing usage. This was a desirable positive shift in perception. The post-game questionnaires show an increasing trend towards self-reported usage of hand-sanitizer (See Figure 5). The game-logs showed that the number of players using of hand-sanitizer showed comparable trends (See Figure 6) when we looked at actual number of times a player used hand-sanitizer in-game. This provides an insight on how participants self-report their involvement in adhering to the preventive measure.

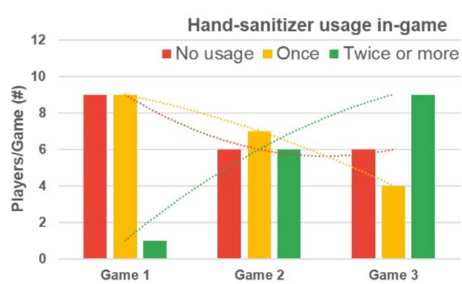

Figure 6: Logged usage of hand-sanitizer in-game. *(n=19)*.

5.5.6 *Social Distancing*

We asked participants in the pre-study questionnaire how well they complied with the guideline on social distancing in real-life. Only 8.7% reported a high degree of non-compliance. We collected reasons for breaking guidelines as an open-ended question. The reasons were very diverse. The matching post-study questionnaire asked how strictly they were likely to comply with guidance going forward. 78.3% participants reported an intention to follow the guidelines more strictly than before. Overall, participants described social distancing as “critical” and “vital” in stopping COVID-19 spreading, and that the game encouraged them to properly distance from others when possible. Participants felt that the biggest challenge to them in the game was primarily social distancing.

We also asked the participants to estimate the number of times they broke social distancing per game. The game-log stats recorded the average number of contact violation per person per game. While we see a falling trend of number of contacts (both reported and actual) over game iterations (See Figure 7), the statistical tests only showed significant difference for self-reported numbers (Repeated measures ANOVA, $F_{(2,19)}=3.56$, $p<0.05$, pairwise significance between the last two iterations) and not the actual in-game data ($p>0.05$). There was a large difference (5x-10x) between the self-reported numbers of contact violations and the in-game logs of contact violations. This is a likely explanation for many infections through lack of social distancing both in-game and real-life.

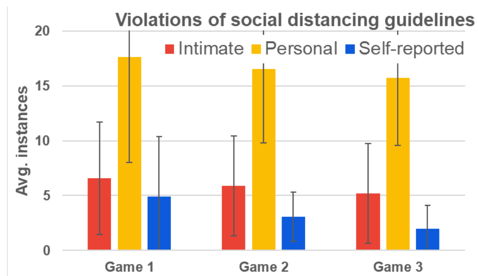

Figure 7: Social distancing violations. Logged (first 2 series, *ns) and self-reported (*sig.). *(n=19)*. *NB*: Truncated error bars.

5.5.7 Infection Analysis

Due to the probabilistic nature of infection transmission, the qualitative analysis is not straightforward. Based on the logs of the 12 games (4 groups x 3 iteration), we observed a total of 35 in-game infections of which 27 were asymptomatic and 4 resulted from task-related transmission (not due to close contact with another individual). We gathered feedback from participants about the perception of their own behaviors and actions as well as that of others within the game. They were encouraged to reflect on the impact of the game-play on their real-life behaviors. Over a third of the participants expressed surprise by the end-game statistics (refer Figure 2d) with respect to being infected. They found COVID-19 spread more easily than they had expected. The participants exhibited less careful behavior due to the assumption that neither they nor other players were infected with the disease since they did not exhibit any symptoms. Participants felt that they were mainly infected or they infected others through lack of social distancing and didn’t consider transmission through infected items as important. In one iteration, one participant went around intentionally attempting to infect others. Their logic was that they wanted to trial an alternative play style to just explore and see what happens. Other participants reported a change in their game strategy over iterations. The most popular responses included using more frequent use of optional PM tasks (refer Section 5.5.3), spreading out players across the map, using sanitizer stations more often (refer Section 5.5.5) and getting tested immediately before starting any tasks. The effectiveness of PoC in shifting perception is best explained through one of the feedback comments, "*Opened my eyes as to how easily COVID can spread from one person's minor mistake*."

5.5.8 Game-play Feedback

The data analysis of the results of the study show that PoC achieves the goals of a serious game to act as a tool for education and perception change. PoC avoids the issues arising from disparity between traditional and serious games [14, 24] by using established game-models, and familiar mechanics to improve entertainment and engagement. The open-ended player feedback from participants indicated that the game was "*engaging and fun to play*" and that they would play again outside of a study. Participants suggested extending game time, increasing "*a sense of completion*" and improving the interface. Participants commented that PoC is "*unique*", "*the social element is more engaging*" and "*fun to play with friends*", supporting our expectations that a multiplayer game would be an effective approach to changing perceptions and raising awareness.

6 DISCUSSION

6.1 Study results

6.1.1 Game-play and GTP

Perception towards preventive measures progressed with iterative game-play. Due to the prevalence of public messaging, the participants already had the knowledge associated with most of the preventive measures (excluding the UG category). They potentially comprehended the importance of the preventive measures but without a personal stake or engagement with the measures. Only when the participants experienced the situations, during game-play that ended with them getting infected or even passing the infection on, did they start to perceive the preventive measures in an applied context. PoC increases positive perception towards preventive measures and also increases the acceptance towards an approach that prioritizes health over economy. After viewing their game results, participants stated they were going to follow the guidelines more strictly, use face masks and hand sanitizer more frequently and favor safety over the economy. Their perception of importance of COVID-19 prevention measures greatly increased along with their insight regarding how easily the virus can spread, which was also frequently commented on. These observations show that the participants may increase compliance or at least demonstrate a higher level of risk-awareness. The evidence suggests that we validated our hypotheses.

6.1.2 Limitations

The long-term impact of PoC and actual influence on real-life behavior is harder to quantify without a longitudinal study. We do not claim a persistent change in behavior either, in line with the limitations noted by prior studies of similar kind [3]. Due to the lockdown restrictions of COVID-19 during this study, we could not run controlled studies in a lab environment. Instead of a wider population to sample from, we were forced to rely on participants belonging to the same household bubbles as the authors. The household bubbles resulted in a population sample consisting of university-going students, studying towards undergraduate degrees, and living together in a single house. There is an obvious likelihood of introducing participant bias regarding the quality of the game due to this sampling approach. Since we do not formally evaluate the game itself beyond feedback on playability, the associated biases are less likely to affect the overall results. The familiarity with preventive measures guidance (e.g. HFS) is accounted for in the lack of drastic shifts of perception towards these measures. The intrinsic mechanics, for e.g., the infection probabilities, are difficult to manipulate through conscious bias intentionally and consistently. The trends within self-reported behavior versus logged in-game behavior provide no indication that participant bias affected the observed outcomes. Due to the experimenters' familiarity with the participants, experimenter bias is another factor to consider. This was mitigated using a fixed protocol for conducting the studies and replicating in-lab conditions as best as possible. We do not recommend that future studies use a similar recruitment pattern unless constrained by restrictions like the ones imposed by the Covid-19 pandemic.

6.2 Design Recommendations

PoC demonstrates a positive shift in perception and better awareness towards the topic it tackles. While the choice of Covid-19 as a subject for serious game design may seem opportunistic, the design journey for PoC started prior to Covid-19. Reflecting on this design journey, we identify elements that can benefit future designers of serious games. However, we concede that the selection of Among Us as a template for implementation is rather serendipitous. The game's new-found popularity during the Covid-19 pandemic and adaptability to PoC's objective provides an interesting observation. Instead of designing a game from ground-up, there's benefit in exploring if an existing and currently popular game offers the magic circle that is amenable to *low-effort adaptation*. The reliance on an established template can help avoid pitfalls that may only become evident after considerable design or development effort has been expended. It also reduces the player learning time required to grasp the fundamental mechanics of game-play. The re-design should also *balance* the use of intrinsic *mechanics* versus explicit actions towards the learning goal. In PoC, the infection mechanics intentionally provide limited immediate feedback while the preventive measures mechanics are explicit in terms of actions that the player can perform.

The interplay of *choice* and *artificial conflict* has to contribute to the extrinsic end-game or objective of the game. As noted by Salen and Zimmerman [42], the players' choice to engage in the artificial conflict is central to the play. PoC establishes this conflict by limiting test-kit resources and creates a choice between health and economy scores in the end-game. The preventive measures mechanics are left as a choice for the player rather than an imposition. For PoC, this design decision prevents the game from enforcing didactic information nuggets and *avoids* producing a negative emotional response to a *forced choice game-play* where the end outcome can be predicted through obvious choices that lack meaning to the player. Experienced game designers may identify with some of these as fundamental aspects of game design, but the catch lies in the nuances of implementation.

PoC *supports the learning objective using a probabilistic model* instead of a deterministic one. Since a real-life close contact event does not definitely result in infection, we used a probabilistic approach to model infection transmission. We believe that this made the game more relatable by introducing the uncertainty experienced by individuals in real-life towards the transmission mechanics and simultaneously influencing their perception (GTP) that the infection is more transmissible than they previously assumed. The probabilistic mechanics can be applied directly to affect play associated with the learning or alternatively determining when play associated with learning emerges.

6.3 Generalization Beyond Study

The results from our study are encouraging and indicate that PoC can increase positive perception towards preventive measures. However, in the process of designing the game and running the study, we identify value in PoC through customization of the layout and game rules. Apart from identifying directions for future work for PoC, these customizations may benefit game designers aiming to create alternative serious game implementations for a similar objective.

6.3.1 Game-map Based Risk Modelling

We propose that PoC can serve as a valuable modelling tool within a microcosm of a single building structure or a small area within a city, e.g., a high-street. This is in contrast and complements the capabilities of other established serious games like Pandemic [41] which operate at a macro-scale. The game-map can be trivially redrawn to model a supermarket floor (which we considered initially) or even an airport. Restrictions for pedestrian flow direction can similarly be included without major difficulty. These customizations can let a policy maker, a business owner or even an epidemiologist identify the potential risks in the implementation of a mitigation plan against current and future pathogens. This can lead to better risk assessment towards achieving the "COVID Safe Workplace" status [10]. This is in contrast to post-hoc evaluation and analysis of outbreaks attempted at a microcosmic level by Lu et al. [5]. Birnir expands the analysis to three specific outbreak cases in an office building, a restaurant and a transit bus [2]. A tool like PoC can support pre-hoc risk analysis through deploying customized game-maps and inviting a targeted sample population to interact within it.

6.3.2 Rule-based Risk Modelling

PoC is based on probabilistic approach to transmission of infection. The probability parameters used in our study are modelled from published values and can be changed easily by an administrator of the game. This adds another useful dimension to the risk modelling process. Epidemiologists and policy makers can tweak these parameters to model the emergence of more virulent strains, without altering the game-play for the users. Building-level mitigations like air filtration/vents can be deployed through intrinsic game rules and contrasted against the available models of transmission probability. This can allow rapid exploration of impact of pathogen evolution.

6.3.3 Perception Modelling

PoC uses mini-tasks as a part of the game mechanics. These mini-tasks can be preventive actions which contribute to the health-score. Our implementation included mask-use, hand-sanitization and increasing ventilation through opening windows. These tasks are designed based on the current UK government guidance. Our results show that individuals become more receptive to the government guidance on preventive measures. PoC can help public health officials to explore the effectiveness of their messaging. As seen with the UG category of preventive measures, policy makers can evaluate the effectiveness and reach of their messaging. While the HFS measures were well-known and understood, the messaging related to ventilation was not seen to be as effective as the HFS messaging. New mini-tasks, like the "open-window" task, can be included to model the actions being promoted by the officials or even test the effectiveness of a public health message. The game-data and the questionnaires can then help identify the efficacy of this messaging in altering the perception of the sample population.

6.3.4 AI-driven Game Play

One potential draw-back to PoC as a research tool is the need for real people to interact and play with the game. However, it is possible to build a repository of play-throughs (i.e. traces) as individual behavior maps. This can then be utilized to populate NPCs (PoC currently has no NPCs) to augment the population density on the game-map. These NPCs can retrace the behavior of previous players to model different scenarios and even create conflicting interaction between populations following different safety measures. Another alternative solution is to collect a large corpus of player traces. Once available, machine-learning can be applied to these to build a human-behavior model. By tweaking probabilistic parameters and speeding up/down individual traces, a researcher can explore large number of alternative outcomes or even populate a macro-scale model of disease transmission.

7 CONCLUSION

We presented Point of Contact, a serious game that is designed to challenge and improve perceptions of COVID-19 preventive measures. Our design approach tackled the challenge of making a serious game successful in educating as well as being engaging. The results of the study indicate that the participants altered their perception towards COVID-19 preventive measures and that they would consider taking them more seriously. The method of using a serious game is more popular with the 19-25 demographic that was sampled in this paper than traditional methods. PoC and future iterations could be seen more than a tool for perception change and behavior monitoring just for COVID-19. This concept could easily be applied to other viruses due to its grounding in relatable real-world activity, trial new prevention measures for a virus-like situation with its own custom parameters for transmission and model newer preventive measures.

ACKNOWLEDGMENTS

We would like to thank the participants of the South East Asia GCRF Springboard (2017), especially Ben Taylor and Kamarul Imran, for the initial insights into the challenge of modelling behavior and perception for epidemiological purposes. We would also like to acknowledge the support from the staff, TAs, and other students of the class of SCC.402 in shaping the various aspects of Point of Contact.

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