Does Rewarding Quality Improve Behavior in a Competitive Pharmaceutical Production Environment? - A Serious Gaming Approach 2: Tournament

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Abstract

Background: It has been suggested that rewarding quality through acknowledgment will improve manufacturers' compliance with current good practices. In a previous study a serious game was used to show quality rewards may increase ethical decision-making. However, these results neglected competition among players and loss potential. Here the study is repeated in the presence of these constraints to investigate if previous results hold.

Methods: College students were recruited to participate in a tournament with a first and second place reward of $100 and $50 respectively. An entry fee of $27.88 was required to ensure players had incurred monetary risk. The tournament was held for three days at the University of Kentucky's Esports Lounge. Players were given the first day to practice before observations began. This allowed players to learn and grow comfortable with the game mechanics. Players accessed BigPharma (one piece of the serious game) via PCs through Steam, an online video gaming distribution service. The python 3 shell, which coupled with BigPharma to provide additional human activities to the virtual environment, was integrated using Jupyter Notebooks. Players were required to play three games (entitled prompt 1, 2, and 3) with varying objects. The first game motivated players to maximize profit, the second quality points, and lastly both.

Results: Players under competition and potential loss constraints performed similarly to players free of these constraints. Players were found to make unethical worker-level decisions only when solely motivated by profit. Interestingly the overall average shell score (SS) for the prompt 1 tournament game was 5.5. Similar to the pre-tournament average overall SS of 5.75. However, the pre-tournament median shell score was 7 compared to the tournament median SS of 5.5. Suggesting that the constraints of competition and possibility of loss did not necessarily increase the frequency of worker fraud. But, instead resulted in more players participating in worker frauds when motivated by profit. Furthermore, players were more risk averse when under competition and loss potential constraints. Indeed, riskier actions such as price gouging decreased in the tournament environment compared to the pre-tournament results.

Conclusions: Data suggests that rewarding quality may work to motivate some players to increase ethical decision-making even under competition and potential loss constraints. Further it was thought that under these constraints, players would shy away from high-risk unethical actions. The current observations lend themselves to this idea. Indeed, when comparing the unethical management-level actions taken by players in a non-tournament environment to a tournament setting, a decrease in attention-drawing activities such as price gouging and selling unapproved drugs is observed.

Keywords: serious gaming, game simulations, competition, counterfeit drugs, substandard medicine, pharmacy-level investigators.

Introduction

Counterfeit, adulterated, and misbranded medicine (CAMM) are threatening the pharmaceutical supply chain (PSC) (Campbell and Lodder 2021b, 2021a). Indeed, pharmacy-level testing flagged approximately 10% of all drugs screened as substandard (Valisure 2021). Further, the complex nature of pharmaceuticals makes it challenging to identify defects. Unlike fruits and similar food items, there are often no rules of thumb or sensory cues to guide customers to ensure they are purchasing high-quality medicine. Instead, low-quality medicine often requires specialized equipment coupled with advanced analytical methods to be identified (Drennen and Lodder 1990; Galante et al. 1990). It has been suggested that pharmacy-level investigators (PLIs) such as Valisure and the University of Kentucky (UK) Drug Quality Study (DQS) could provide a much-needed on-the-ground (OTG) quality inspection for customers. However, PLIs OTG status typically means working with limited equipment and staffing resources. Making scanning every single drug product infeasible. Currently, a scoring system coupled with batch testing techniques helps to decide what to test now(Campbell and Lodder 2021b). But this does not help decide what should be tested in the future. Further, these systems can only predict what they have been trained on. Making them incapable of providing unforeseen ways drugs could be tampered with. This means PLI's and regulators alike are always one step behind.

Current scoring systems and traditional modeling can only predict based on history, where even the most sophisticated models are using data from days or weeks ago with tremendous human interference (Westman 2020). As a result, current modeling methods (including most AI models) often fail in the face of unexpected events such as COVID-19 (Heaven 2020). Indeed, COVID-19 exacerbated any pre-existing issues in the PSC and identified further vulnerabilities in drug development models, supply inventory models, and others (Adhikary et al. 2021; Buntz 2021; Jarrells et al. 2021; Miller et al. 2021). Given these models are critical to keeping the PSC running smoothly (e.g., avoiding drug shortages, ensuring high-quality medicine), it will be vital to improve on past mistakes. Several potential solutions have already been posed to solve structural vulnerabilities in the PSC. For example, reshoring at least some drug production to avoid unforeseen cutoffs of medicine due to travel and export bans (Socal, Sharfstein, and Greene 2021). However, there has been a notable lack in improving the behind-the-screens models, which can produce equivalent amounts of risk to the PSC as structural vulnerabilities. For example, drug shortages can come as the result of either or a mix of structural and model failures. A natural disaster at the only global supply site of a certain drug product or drug ingredient (i.e. a lack in diversity of regional production) is a structural design flaw that could result in drug shortages (Ball 2021; Lee Ventola 2011). But a quick shift in demand, which a supply model does not foresee, can provide just as much damage. Typically supply models provide manufacturers with a good estimate of what and how much people will be buying. This helps the manufacturer avoid costs attributed to unsold inventory. However, as Amazon and others learned in the face of COVID-19, unexpected events can alter people's purchasing quickly. Indeed, in less than five days of COVID-19's impact, Amazon's top 10 searched items all shifted in most developed countries (Westman 2020).

Most vendors on Amazon opt for Amazon to control delivery and logistics of their merchandise and typically are rewarded the top search spots in return. However, the sudden shift caused overwhelming demands on Amazon warehouses. As a result Amazon opted to alter their algorithms to lending top search slots to vendors who took responsibility for their own deliveries among other alterations (Comrie 2020;

Westman 2020). Since Amazon is often looked at as a gold standard for logistical operations, COVID-19 made clear that our current models are not ready for the unexpected (Bhaskar et al. 2020; Ioannidis, Cripps, and Tanner 2020).

Current models fail when unexpected events occur partly because they lack the human element (creativity, imagination, emotion, etc.). Gaming models bridge this gap (Campbell and Lodder 2021b). Indeed, games are well equipped to capture human behavior (Parsons and Wooldridge 2002). As Naciri describes, this is because games (more specifically serious games) allow for capturing the human decisions as "they are made rather than how they should be made" (Naciri, Yoo, and Glardon 2013). That is serious games allow for human decisions to be captured in order for more reliable models to be constructed. For example, Ford Motor Company has utilized an interactive virtual operations simulation to capture manager strategies around unplanned maintenance to identify ways to improve throughput (Robinson et al. 2005). Others have developed an interacting virtual emergency hospital unit to further understand physician decision-making in the context of trauma triage (Mohan et al. 2014). In this study, physicians interacted with the virtual emergency unit and made decisions under varying cognitive loads. It was found that physician's performance, and decision-making were consistent with their real-life actions. Further, the study found the game could manipulate cognitive load successfully and with increased cognitive loads, the players' (physicians') use of heuristics increased. A result predicted by cognitive theory (Mohan et al. 2014). In a study by Campbell and Lodder, it was shown that a serious drug quality game (DQG) can be used to provide insights into unethical behavior as it relates to the PSC (Campbell and Lodder 2021b). In this study, players interacted with a virtual pharmaceutical manufacturing business (PMB) (See Figure 1). Representative tasks were given, and players could act in both ethical and unethical ways. Through a series of three games, players' actions were captured while being first motivated by in-game profit, second by quality, and lastly by both. The study provided evidence that rewarding quality can promote ethical worker- and management-level decision-making. However, the study lacked human vs. human or real-life competitor effects and did not apply real-world losses to players' actions. Because of this, it is thought that players may have taken riskier actions than if these constraints were otherwise present. This paper addresses these limitations by repeating the study in a real-life tournament format.

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Figure 1: Representative BigPharma virtual pharmaceutical business. Includes marketing, processing, and research elements. Processing area shown.

The next section will illustrate the importance of competition and nothing to lose effects on behavior. A description of the tournament setup and purpose is then given. Before a brief description of the metrics used is provided. Results follow prior to addressing the study's current limitations. Future research opportunities are then provided before concluding.

Competition and Nothing to Lose Behaviors

Depending on the viewpoint, competition can act as a motivator or a pressure. In specific scenarios, competition can motivate us to work harder, achieve more, and be more efficient (Bloom et al., 2013; Bracha and Fershtman, 2013).Indeed, competition has been shown to drive firms to improve relative efficiency, especially in highly competitive markets (e.g., Bertrand competition with a homogeneous product) (Hay and Liu, 1997). On the other hand, competition can act as an external pressure that fosters an environment in which humans suffer and behave unethically (Gilbert et al., 2009; Rigdon and D'Esterre, 2014). When considering what must be present for humans to partake in fraudulent behaviors, competition emerges as a potential trigger. According to criminology's Fraud Triangle Theory, three elements- pressure/incentive, rationalization, and opportunity- are required for fraud to occur (Cressey, 1973). Naturally, competition has been shown to fulfill the theories pressure element (Mackevičius and Giriūnas, 2013). An example of competition playing this role can be seen in some political elections. Indeed, the introduction of competitive candidates to political elections has been linked to electoral fraud. To the extent that the primary distribution of fraud was shown to, geographically redistributed to the central provinces, the elections took place in one Latin American study

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(Lehoucq, 1999). In this scenario, the incumbent has his or her political power in jeopardy while the contender has nothing to lose (i.e., everything to gain). So, it seems that in addition to the extent of competition, the resultant human behavior may heavily rely on what there is or is not to lose. Indeed, it has been suggested that players may participate in jeopardizing behaviors in video games because there is nothing real to lose (Lodder, 2020).

Players may take part in risky behaviors in video games because there is nothing real to lose. In its simplest form, risk may be defined as the probability (of an unwanted event) multiplied by the loss (connected to the event's occurrence). Using this definition, it is easy to see why people would be willing to partake in highly jeopardizing behaviors when loss is zero (i.e., having nothing to lose). Take, for example, if you were given the opportunity to own a highly volatile stock for free. Chances are, you will be much more willing to own the stock as opposed to if you had to purchase the stock with your own funds. A similar line of thought can be used when assessing risky behaviors in video games. For example, in first-person shooters, players often run into a field or room of armed foes with bullets flying everywhere. Player's probably feel confident in doing this because they know their avatar can take a few hits (often measured by an avatar's health metric) and if they were to "die" in-game they would be regenerated (though total recklessness that results in death is often discouraged in games through forcing players to defeat foes again, repeat missions entirely, and other undesirable tasks). All in all, the player does not have all that much to lose for risky behavior. But it is probably safe to say that most of the players playing out such action would take a safer approach if the avatar were near death or could only take one bullet. Along the same line of thought, it is suspected that players of the previous DQG study may have behaved riskier than if potential loss and competition were present.

Given the above, one may infer that repeating the DQG in a tournament with a required entry fee will result in a reduction in risk-taking behavior among the players. In the next section, a quick description of the serious gaming system, tournament setup, and games played are presented.

Tournament Setup and Purpose

How can one make video games simulate real-life better? Players can take what would be otherwise considered crazy risks within single-player video games because there is nothing real to lose and no human competition. In a tournament, players have real entry costs to lose, real cash prizes to gain, and real humans to compete against. In the previous DQG study, a non-tournament environment exposed players to a virtual pharmaceutical manufacturing business. Comparing a series of three games with different objectives suggested that players often behave more ethically when rewarding quality points (points earned through completion of good practices). However, even with the improvement, players were observed to actively engage

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in what the study called management frauds (decisions typically made at a management level). Further players were readily acting in ways that could be considered highly risky. That is, the probability of them getting caught (in real-life) would be high. The most notable action observed was players' decisions to set their prices unethically high for drugs they were selling sub-potently. Though selling sub-potent drugs may be considered low risk, due to a low probability of detection (remembering pharmaceuticals' complex nature). Price hiking drugs immediately draw attention. A lesson Martin Shkreli (aka pharma bro) found out after raising the price of Daraprim from $13.50 to more than $750 (Luthra 2018).

In this study, a Tournament was held to determine rather the introduction of competition and real-life loss constraints alters what was observed in the absence of these real-life constraints. The games played by the players were the same as before. Rules and objectives were presented in the same manner through digital prompts. Prompt 1 (or game 1) was profit-focused and sought to test the hypothesis that when players are not rewarded for quality they would act unethically. Prompt 2 shifted players' motivations to collect quality points. This prompt encouraged players to ignore money and sought to test the hypothesis that when players are rewarded for quality, they would act more ethically. Lastly, Prompt 3 reintroduced the profit motive and encouraged players to maximize both quality points and in-game revenue. This prompt sought to test the hypothesis that when players are rewarded for-profit and quality, they would continue acting ethically. Furthermore, players were told that they were approved to make one and only one injectable high-quality drug as they were cast into the role of an injectable drug manufacturer in these games.

Using these games, players were recruited for an in-person tournament. Entry fees equivalent to the cost of the BigPharma game ($27.88) were required to ensure the players had “skin in the game” (i.e., incurred a monetary risk). A 1st, 2nd, and 3rd place reward were offered as $100, $50, and $30 respectively to provide a real-life reward. Where the player who earned first place had gained the most in-game revenue post the subtraction of worker task costs. Recruitment occurred for two weeks through stationery and social media (Twitch) advertisements targeted towards college students. Nevertheless, recruitment was low with N=2 such that the rewards required adjustment via dropping the 3rd place position. The low turnout was thought to be a result of the University’s virtual learning status as well as the state and federal social distancing guidelines at the time of the tournament. Though the cost of entry may have provided another hurdle for some to participate.

The tournament was held for three days at the University of Kentucky’s Esports Lounge. Players accessed BigPharma via PCs through Steam, an online video gaming distribution service. The python shell, which coupled with BigPharma to provide additional human activities to the virtual environment, was integrated using Jupyter Notebooks. Players were required to play all three games (prompt 1, 2, and 3). Once starting a gaming session players played uninterrupted. Data was collected on these games through screen recordings and script outputs. Furthermore, players were given the opportunity to practice the first and into the second days of the event. This was to ensure all players were familiarized and comfortable interacting with the gaming environment.

Metrics

Behavior was first categorized at worker or management level. Worker-level fraud was defined as unethical decisions made when prompted to complete tasks via the python shell and reflect decisions made by general workers. Worker fraud was quantified through a shell score (SS). Player SS corresponds to the total number of worker tasks (seven) ethically completed. Hence a SS of 0 indicates a player took every shortcut possible. Where an SS of 7 indicates, all tasks were completed ethically. When calculating the SS where applicable, unprompted tasks (null) are assumed to be ethically performed. This is justified given children tasks were unprompted if and only if the parent task were ethically completed. Further, overall SS were calculated as the average and median of the players' SS across prompts. On the other hand, management fraud is described by ethical scores (ES) and categorical descriptors. Management fraud can be thought of as decisions primarily performed by management personnel. For example, choosing to conceal negative clinical results are typically out of the hands of workers. ES provides a description and distinction of the various players’ management strategies and describes just how ethical each player was or was not. ES were designated through reviewing players' specific actions (See Supplement-Ethical Timetables). Using ethical timetables, players' overall management strategies were described and compared against an ethical scale (see supplement-Ethical Scale) to assign the players earned ES. ES ranged from 0 to 5. An ES of 0 indicated the player was completely unethical (followed no rules or objectives). Where an ES of 5 represents a completely ethical management strategy. That is, the player followed all guidelines perfectly which in this case meant manufacturing a high-quality injectable drug. For more details, see (Campbell and Lodder 2021b).

Results

In the previous DQG study, the current serious gaming system was shown to be capable of simulating real-life humans and their actions in a pharmaceutical manufacturing setting. Through a series of three games, the study suggested that rewarding quality could improve players’ behavior in both work and management-level decision-making. Indeed, worker frauds were zero in the presence of quality rewards, and the frequency of management frauds decreased compared to profit motivated play. Despite the observed decrease in worker and management unethical decision-making, players readily partook in highly risky activities. For example, players frequently sold their drugs at unethically high prices while also selling those drugs

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sub-potently. A phenomenon that interestingly reflected well with observations seen in the DQS (Campbell and Lodder 2021b). Nevertheless, the question has been asked -how can this serious gaming system simulate human behavior better? It has been suggested that the lack of competition and possibility of loss in the previous study may have fostered an environment of unrealistic comfort for players partaking in highly risky activities. To address these limitations, the study has been repeated in a real-life tournament that required an entry fee and provided rewards that could be won based on performance. In this way, the previous study is now constrained by competition and the probability of loss. The results of this study are presented below, beginning with Figure 2, which summarizes the in-game revenue earned by players through the course of all three games (termed prompt 1, 2, and 3).

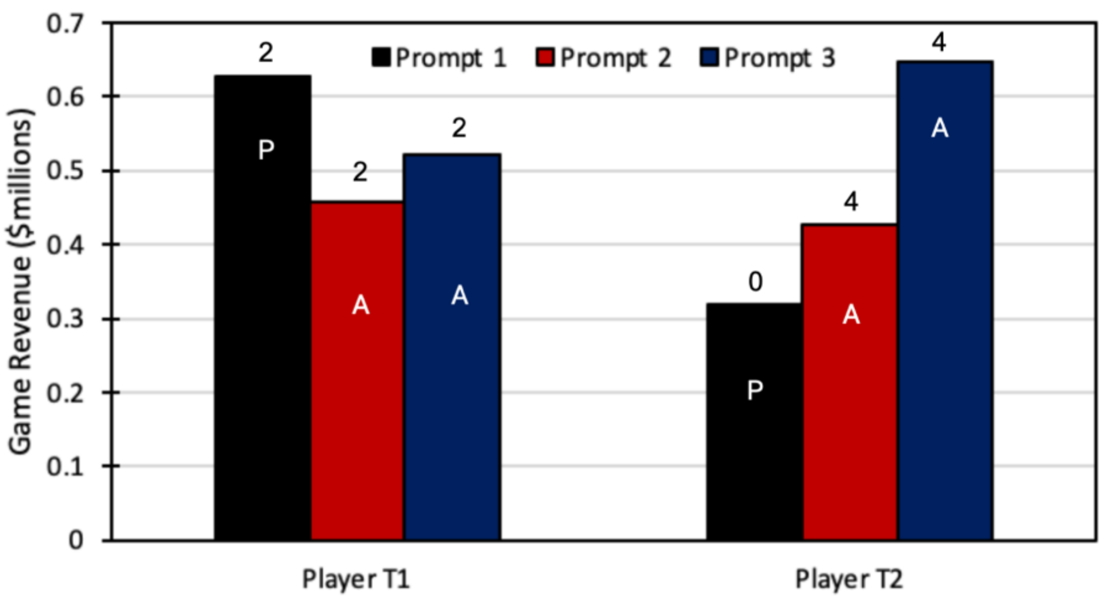

Figure 2: Summarizes the in-game revenue gained by players. Where numerical values above the bars are the players earned ethical score (ES). Within the bar text indicates the presence (P) or absence (A) of worker fraud.

Figure 2 shows that both players performed relatively well in terms of in-game revenue, with Player T1 winning first place with a total of $1,605,846, gaining $214,440 more than Player T2. Further, both players participated in worker fraud exclusively in prompt 1. This resulted in average and median overall SS equaling 7, in Prompts 2 and 3. Agreeing well with the pre-tournament overall shell scores of 7 (average and median) in prompt 2 and a 6.75 average, 7 median in prompt 3. Suggesting that once quality rewards were introduced, players in both non-tournament and tournament settings improved worker level decision-making. Taking a closer look at Prompt 1's worker-level decision outcomes (see Table 1), we see that the overall average SS is 5.5. Similar to the pre-tournament average overall SS of 5.75. However, the pre-tournament median shell score was 7 compared to the tournament median SS of 5.5. Suggesting that the constraints of competition and possibility of loss did not necessarily increase the frequency of worker fraud. But, instead resulted in more players participating in worker fraud when motivated by profit.

Table 1 Summary of decision outcomes in worker-level tasks in a tournament environment. Where red indicates an unethical approach and green indicates an ethical approach to completing the task. Blue indicates the task was unprompted.

Player	Player T1	Player T2	
Prompt 1	Profit Focus		
Task 1	(+)	(+)	
Task 2	(+)	(+)	Shell Score Average: 5.5
Task 3	(+)	(+)	Shell Score Median: 5.5
Task 4	(-)	(-)	
Task 2.1	null	(-)	
Task 2.2	null	(+)	
Prompt 1.2	Quality Focus		
Task 1	(+)	(+)	
Task 2	(+)	(+)	
Task 3	(+)	(+)	Shell Score Average: 7
Task 4	(+)	(+)	Shell Score Median: 7
Task 2.1	null	null	
Task 2.2	null	null	
Prompt 1.3	Profit and Quality Focus		
Task 1	(+)	(+)	
Task 2	(+)	(+)	
Task 3	(+)	(+)	Shell Score Average: 7
Task 4	(+)	(+)	Shell Score Median: 7
Task 2.1	null	null	
Task 2.2	null	null	

Additionally, from Table 1, we see that Player T2 earns an ethical score (ES) of zero for their strategy within the Prompt 1 game. Though this quickly increases to an ES of 4 in prompts 2 and 3. Interestingly this occurred in the pre-tournament results as well. Suggesting when profit motivates, some players may be more willing to prescribe their own set of rules (i.e., transform the presented game into a novel game). Indeed, the transformation of games based upon an individual's motivational profile has been previously observed. Merrick and Shafi, for example, show how classical games such as the prisoner's dilemma can be transformed into novel games by differences in individuals' motivational preferences (Merrick and Shafi 2013).

Table 2 presents the occurrences of management frauds by prompt. From Table 2, it is observed that the frequency of management fraud decreases in the presence of quality rewards—six occurrences in prompt 1, to 4 in both prompts 2 and 3.

Table 2 Occurrences of management frauds in Tournament per Prompt.

Fraud	Prompt 1	Prompt 2	Prompt 3
Sold unapproved drug	1	0	0
Sold subpotent drugs	1	2	2
Used cheap/unapproved material	2	1	1
Conceal negative clinical results	1	0	0
Price Hike by tournament median	1	1	1
	6	4	4

Further comparing the pre-tournament frequency of management frauds to the tournament in Table 7.3. It is observed that the top two most used management frauds change from price hiking and selling subpotent drugs in the pre-tournament environment to selling subpotent drugs and using cheaper materials. Indeed, the frequency of selling subpotent drugs (to be considered low risk due to the difficulty in detection) increased 25% in the Tournament setting. Likewise, the use of cheaper materials (also considered a low-risk action due to the difficulties in detection) increased 25% as well. This provides evidence that under the constraints of competition and the possibility of loss players stray from riskier behavior in-game. As both selling subpotently and using cheaper materials have a lower risk of detection compared to price hiking. Further from Table 3, it is observed that in a Tournament, the frequency of selling entirely unapproved drugs dropped 33%. This fraud is arguably the riskiest due to the high possibility of detection and high penalties associated with the deed. Indeed, at the time of this writing, two executives of a generic drug company face indictment arising from the distribution of 383,000 bottles of unapproved hydroxyzine between 2011 and 2013 (Crandall 2021).

Table 3 Frequencies management frauds took place in pre-tournament and tournament environments.

Fraud	Pre-tournament	Tournament
Sold unapproved drug	50%	17%
Sold subpotent drugs	58%	83%
Used cheap/unapproved material	42%	67%
Conceal negative clinical results	0%	17%
Price Hike	83%	50%

Lastly, a comparison of players ES' is provided in Table 7.4. Given ES' are a reflection of the players' management strategies. In both pre-tournament and tournament settings, we see the emergence of consistent player scores, suggesting players form a strategy within the game and stick to that strategy moving forward (forming a habit). The habit phenomenon in games has caught the attention of researchers; however, there is still a lack of literature concerning this topic (Schaekermann 2016). Nevertheless, this may suggest that training people correctly and ethically early in their work-life is important. It seems that it may be worth wild for future research.

Table 4 Summarizes the ethical scores earned in Prompt 1, 2, and 3. Players A, B, C, and D results are from the pre-tournament sessions. While Player T1 and T2 results are from the tournament sessions.

	ES-Prompt 1	ES-Prompt 2	ES-Prompt 3
Player A	5	3	3
Player B	0	3	3
Player C	1	1	1
Player D	4	4	4
Player T1	2	2	2
Player T2	0	4	4

Limitations and Future Research

Limitations of the current study include the constraint the BigPharma environment places on playable actions. Indeed, the game provides many realistic options but limits players' creativity in unethical pathways (Ditum 2016). Though in one respect, this is a good way of steering the player's interaction with the virtual environment into rational and realistic scenarios and actions. However, it may also be considered hindering to the players' ability to develop novel

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and unforeseeable ways of cheating the PSC. To address this limitation, the authors have floated the idea of using Unity (a game engine) to develop a novel base for this serious game (See Figure 3). A previous version of the game shown in Figure 3 can be played at- https://play.unity.com/mg/other/pharmaceuticals.

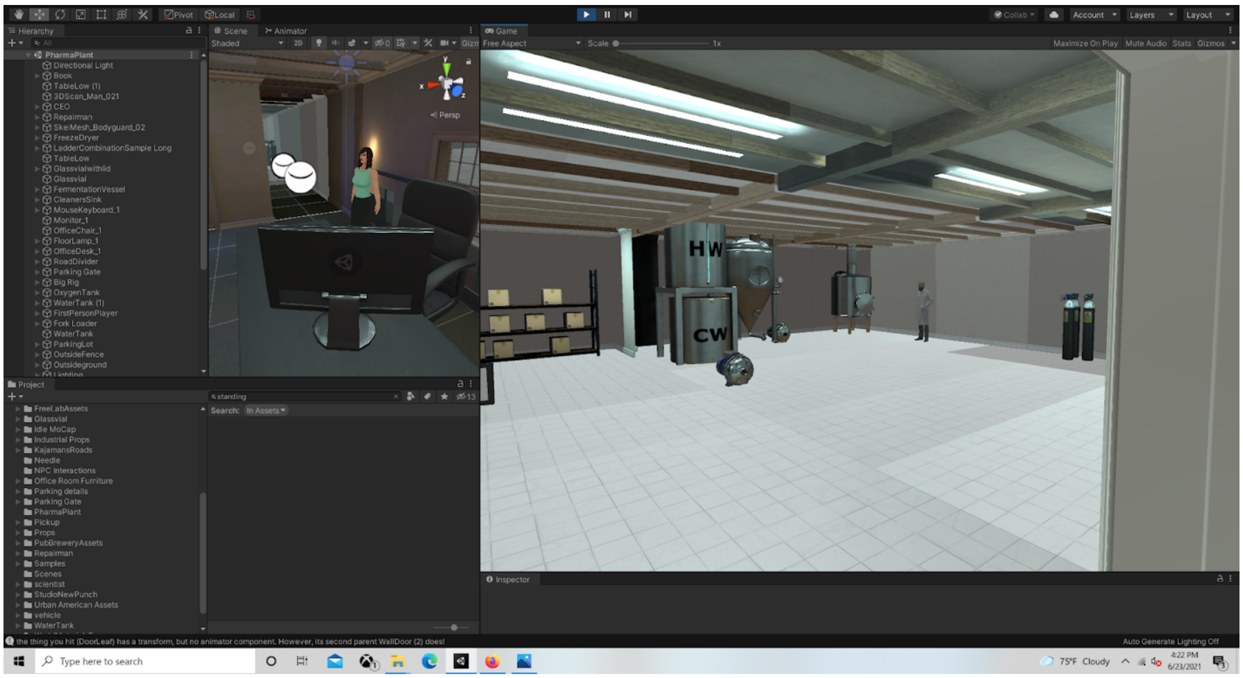

Figure 3 Representative scene from investigators novel series game development. Performed in Unity.

An additional limitation was the small sample size. Rendering statistical approaches insignificant. Though trends did emerge- encouraging for future research to scale the study. It is thought that targeting online BigPharma game forums may be successful in achieving this. Indeed, targeting this audience would result in players who are already familiar with the game mechanics of BigPharma, and such players could participate remotely. Further, it is thought that holding online tournaments which players must pay to enter with entry fees going into a pool for rewards may increase participation as pools can grow increasingly large. However, there may be legal hurdles in developing such a system (GS 2021). Further play order effects were not explored. Future research should swap the order of quality and profit motives. Despite these limitations, the study provided results reflective of results seen in the DQS as well as results that align with current theory and literature.

Conclusions

The above study sought to repeat the experiment described in (Campbell and Lodder 2021b) under the constraints of competition and non-zero probability of loss. It was thought that under these constraints, players would shy away from high-risk unethical decisions. The observations presented above lend themselves to this idea. Indeed, when comparing the unethical management-level actions taken by players in a non-tournament environment (Campbell and Lodder 2021b) to a tournament setting, we see a decrease in attention-drawing activities such as price hiking and selling unapproved drugs. On the other hand, we see an increase in actions that are considered harder to detect, such as selling subpotent drugs or cheap/unapproved materials. Furthermore, when comparing these results to those seen in (Campbell and Lodder 2021b), players tend to form in-game strategies that they stick to. Suggesting players may form habits in virtual environments. Though this study is limited in sample size, it does align well with the limited amount of literature available. Offering promising trends for future research.

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