Plagues and People: Engineering Player Participation and Prevention in a Virtual Epidemic

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ABSTRACT

In this paper, we report on the study of a new virtual epidemic called the *Dragon Swooping Cough*, a newly designed virus unleashed on the youth virtual world of Whyville.net in two stages during December 2015 and April 2016. Our overall goal in this study was to design experiential learning of infectious disease in a safe but epidemiologically and educationally sound way. The virtual virus targeted personal, social, and economic aspects of online life in Whyville in order to mirror real-world viruses and to trigger player emotions. Our analysis of pre/post surveys and online behavior log files for survey (N = 747) and non-survey (N = 3348) participants revealed that the virtual epidemic promoted participation, primarily through engagement in prevention against the virtual virus, that increased in the second outbreak. Furthermore, emotional engagement played an intriguing role in both behavioral and information-seeking behaviors. In the discussion we address what we learned about opportunities and challenges in designing a virtual epidemic for educational engagement.

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1 INTRODUCTION

Virtual worlds, whether designed as a game (i.e., *World of Warcraft*) or more as a social space (i.e., *Second Life*) hold tremendous creative and research potential from their massive size and population, their unique forms of communication and interaction, and the opportunities for players to design personalized homes, avatars, and other virtual artifacts [2, 18]. In particular, they provide a unique opportunity to engage and study players in experiential learning of issues that pose societal-level challenges, such as economics, health issues, or environmental concerns [4, 5, 11]. These types of problems are not caused by and cannot be resolved by a single person's or small group's actions but rather require a massive response from a community to tackle them. Virtual worlds provide a means to simulate such issues at the scale of a massive community with relatively little harm to participants (i.e., from health problems). Not only this but virtual worlds can provide vast, "societal level" data allowing for research on player activities that provides an authentic means of assessing changes in behavior to these sorts of problems [10, 35].

Given these attributes it makes sense to utilize virtual worlds to engage children and youth in experiential learning about an important topic that is difficult to cover in more traditional educational settings: *epidemics*. Prior research shows that while children begin to develop concepts of germs, disease,

and infection spread early on, they struggle to understand other aspects of infectious disease that are more relevant on a larger scale, such as the role of probability in spreading infections [1, 23, 29, 32, 33]. Through virtual epidemiology, youth can become emotionally invested in the topic, study live experiences in more systematic ways, and develop better insights into the relationships between infection parameters and social dynamics—the very same questions that interest real-world epidemiologists [30]. This approach thus turns players into epidemiologists, and provides learners with "epistemic frames" [31] as they engage emotionally, socially, and intellectually in complex activities.

Hints of the potential for virtual epidemics to engage players are found in the unintentional *Corrupted Blood* epidemic that ravaged the *World of Warcraft* where players exhibited new behaviors that epidemiologists had not previously thought of, such as taking risks to explore the disease [25]. Research on a more intentionally created epidemic in a virtual world for youth, Whyville.net, showed that the epidemic generated high emotions from players who changed their information seeking and problem solving behaviors as a result [21]. Yet in both of these epidemics players were severely limited in their abilities to fight the disease. The virtual epidemics allowed only for information sharing, not actual action against or deeper exploration and testing of the diseases. There is room for better design of virtual epidemics to allow for connections to actions that could be taken in the real world to fight disease.

In this paper, we report on the study of a new virtual epidemic called the *Dragon Swooping Cough*, a newly designed virus unleashed on the virtual world of Whyville.net in two stages during December 2015 and April 2016. The virtual virus targeted personal, social, and economic aspects of online life in Whyville in order to mirror real-world viruses and to trigger player emotions. We designed the *Dragon Swooping Cough* (DSC) to solicit player responses and actions, seeking to research the different ways that players were affected. Unlike prior virtual epidemics, we also designed actions that members could take to better investigate and fight against the virus. After all, virtual epidemics have the potential to not only simulate the spread of a virus but also the containment of a virus, if a community can respond enmasse in such a way as to reach, for instance, herd immunity—the percentage of people needed to be immune (i.e., vaccinated or recovered) in order to disrupt the chain of infection. Further, we designed two outbreaks of the virus in order to provide multiple opportunities for players to experience it and to build on their earlier learning about the virus.

Our overall goal in this study was to design experiential learning of infectious disease in a safe but epidemiologically and educationally sound way. To do this we built a partnership of the designers of Whyville (Numedeon), educational researchers, and a professional epidemiologist to create an authentic virus that reflected real-life features of infectious viruses that are particularly dangerous in the real world, like Ebola. By bringing the mindset and tools of epidemiologists to a virtual epidemic [12, 26, 28], we offer a viable approach for youth to become engaged in learning about infectious disease and provide them with new ways to create linkages to real world behavior. Below we explain the background of virtual epidemics before sharing our own design for two versions of the *Dragon Swooping Cough.* Our research addressed the following two questions: (1) What factors (including emotion) impacted players' online participation behaviors and engagement in health prevention and protection measures? (2) Did a repeated outbreak of the virtual epidemic change players' participation and use of preventive measures? To address these questions, we examined and compared self-reported behavior and feelings recorded in surveys with actual behavior observed in log file data. In addition, we examined justifications provided by players explaining their behavioral choices. In the discussion we address implications for design and research.

2 BACKGROUND

Our design and study of a virtual epidemic is situated within the particular context of understanding learning about infectious diseases, or epidemics [e.g., 14, 32]. A spate of recent outbreaks of measles in Disneyland, Ebola in Africa, and Zika in Latin America illustrates that epidemics are far from being events of the past but continue to pose significant risks in the present. Virtual epidemics are massive-scale simulations running real-time in online communities and impacting players' key behaviors and interactions with others. They can also influence players' emotional engagement in the game, which has the potential to further players' learning. For instance, observations of *Corrupted Blood,* an unintended virtual epidemic outbreak in *World of Warcraft*, illustrated their potential as a context for generating real life-like emotions of grief as players' avatars perished as well as a tool for studying behavioral patterns of avoiding or even seeking contact relevant to epidemiology [25].

Similarly, in our own previous work with a virtual epidemic, we examined this potential by designing and releasing the *WhyPox* virus into a tween virtual world called Whyville [21]. Unlike the *Corrupted Blood* outbreak where players' avatars died, the virus was only active for several days with relatively mild symptoms, but with dramatic impacts on participation. For instance, analysis of chat records revealed that the epidemic became a frequent topic of conversation [17]. Movement patterns on the site shifted with more players visiting the virtual CDC (Center for Disease Control) to find out about the community's infection status while others opted to forgo online visits in fear of infection [21]. Hundreds of players also used simulators at the CDC to research the spread of small-scale virtual epidemics with the precision of their predictions improving over time [13]. All of these actions were associated with heightened emotions regarding the disease [21]. Further, in associated classroom discussions, we saw how students and their teacher successfully drew parallels between the virtual and real life epidemics [27] and developed scientific arguments to support their reasoning about the causes and effects of the disease [22].

However, we noted some opportunities for better design of the *WhyPox* virus experience. For instance, in the *WhyPox* epidemic, information was scantily available only in a

community infection graph and simulators in areas not often visited by players. Further, except for a limitedly available vaccine, the design provided few opportunities for engaging in preventive behaviors other than avoidance (i.e., not logging in for several weeks). Despite these limitations, players sought ways to fight the virus, for instance by putting player-design scarf on their avatars (which has absolutely no effects on infection). In response we decided to design a new virus that provided better opportunities for players to take action against the disease.

In the current study we introduced a new virus called the *Dragon Swooping Cough* (DSC—for more detail see next section) while also offering several preventive measures as potential indicators of mass community participation. The introduction of these measures sits at the critical nexus between individual actions (e.g., engaging in preventive behavior) and community impact (e.g., developing herd immunity) [26]. Our designs were both epidemiological—mirroring real-life virus infection qualities as well as the economics of preventive measures available—and also educational—with the goal of engineering mass community participation to support large numbers of players in not only finding out information about the disease but also engaging in prevention and protection [28]. Both of these behaviors are important in stopping an outbreak of a virtual as well as real life epidemic. We also realized that a one-time exposure to an epidemic outbreak might not be enough to change players' behaviors, thus we planned the re-appearance of the virtual epidemic after a brief respite. This repeated implementation also allows us to examine consistency and changes in behavioral and emotional responses. Because research has shown that large gaps exist between reported and actual behavior, [e.g., 7, 34], we also captured player behaviors in different ways: comparing self-reports from surveys with actual activities and use of prevention measures through log file data. Below we report on the design of the virus and preventive measures as well as our research methods.

3 THE *DRAGON SWOOPING COUGH* DESIGN

3.1 Virus Design

Our study took place in 2015-2016 in collaboration with Numedeon, Inc., the company that hosts Whyville and collected the tracking data and online surveys for us. Whyville.net is a massive, free virtual world (in 2016, at the time of our study, it had over 5.7 million registered players) that encourages youth ages 8-16 to play casual science games in order to earn a virtual salary (in "clams"), which they can then spend on buying and designing parts for their avatars (virtual characters), projectiles to throw at other players, and other goods such as cars and plots of land [18]. The general consensus among Whyvillians (the citizens of Whyville.net) is that earning a good salary to spend on face parts or other goods is essential for full social participation in Whyville. Avatar appearance also demonstrates a player's tenure on Whyville and experience level; new players have fewer clams, and their looks show this because cheaper face parts are perceived as less attractive.

Building on insights gained from the *WhyPox* outbreak [e.g., 21], we designed the *Dragon Swooping Cough* virus (hereafter: DSC). There are dragons in Whyville: players breed them in order to study genetics. Thus it was not a far stretch to imagine that a virus might move from a dragon to a player (as some viruses move from pigs or birds to people). The design of the virus reflected real-life features of infectious viruses that are particularly dangerous in the real world, like Ebola, especially in the proportions of time allotted for the incubation, latent, infectious, and symptomatic periods. The *incubation period*, the time between infection and becoming infectious was intentionally short (days 1-2) while the *latent period*, the time between infection and showing symptoms, was long (days 1-5). This allowed the virus to spread quickly as players could be infectious before showing symptoms, unknowingly spreading the virus around the virtual world. Indeed, many Whyvillians complained that while they used preventive measures to avert infection, they still caught the disease, something entirely possible. We also chose a long *infectious period* (days 3-9) so that the virus would spread widely, with a *symptomatic period* (days 6-10) where the ratio of the latent period to symptomatic period was greater than one (in this case 7:5; important from an epidemiological perspective as again, players are infectious longer than they are symptomatic).

To begin the epidemic the designers infected a set number of Whyvillians (100), a number chosen by Numedeon based on prior experience with infections, on the first few days of the virus and then let the virus run. Logging in when the virus was active created a chance of infection and spreading the virus. To keep brand new users from being discouraged from or confused by visiting Whyville, at the designers' request we did not infect users whose accounts were less than 4 days old.

3.2 Symptoms

Drawing on earlier findings that emotional engagement was key in triggering participation, we designed symptoms that affected the things Whyvillians cared about the most—avatars, socializing, and money—and targeted those with disruptive symptoms. We also sought for the symptoms to show a visible display of disease progress (the infection vector), so each symptom either increased in visibility or appeared as a sign of progress of the disease. We affected avatar appearance by putting dragon scales on their bodies; the scales grew over the course of two days (with three days of the worst scales) and then dissipated (see Fig. 1). During the worst days of infection the scales also shed as avatars flew around the screen, providing the idea that the scales could infect others. For chat, we interrupted player conversations by inserting the words "rawrr...cough cough rawrr" into chat (see Fig. 1) at random intervals. On the three days of the worst symptoms (days 8-9 of infection) we also added visible movement with avatars swooping and circling around the screen. This added to the visibility of the disease (players swooping around the screen are hard to miss) and the playfulness of the disease. Swooping while roaring seemed a very "dragon-y" thing to do. In addition, we stopped salary deposits during the three worst days of infection (see Fig. 2).

This had parallels to real life where a virulent disease could cause people to be unable to work, with potential effects on their financial income. Earlier *WhyPox* infections had targeted appearance and chat (but without movement). The addition of the visible movement and financial impact were chosen to increase the drama of the disease.

Figure 1: The *Dragon Swooping Cough* design: Scales and cough.

Figure 2. Complaints about salary loss during DSC.

3.3 Preventive Measure Design

Seeking to provide opportunities for action to Whyvillians, we created several protective and preventive measures that worked to varying degrees. Drawing on knowledge of virtual and real world economics, we created preventive measures at various costs. The most expensive of these was an expensive biohazard umbrellas (see Fig. 3) with a roughly 95% chance of protection when worn that would intentionally cost the middle 50% of Whyvillians their entire savings to purchase (11,000 clams). In addition we designed scale block lotion (15% chance of protection if used once per day, 30 clams), and washing hands, a carryover from recent *WhyPox* infections, (10% chance of protection if used very frequently (i.e., when someone coughed), free). "Cover," another carryover from *WhyPox* infections was deemed ineffective to prevent DSC since the latter was skin- (or rather scale-) based. As a preventive measure, players could purchase face masks for 1 clam, but these only lowered the chance of contagious individuals infecting others, a subtlety many Whyvillians did not catch, especially in the first round[1].

3.4 Information & Tests for Infection

In addition to the symptoms and preventive measures we also sought to provide a way to allow players to test for infection. This had three main purposes. First, it allowed players to actively

Figure 3. Biohazard umbrella in use (left), User comments on her mask (right).

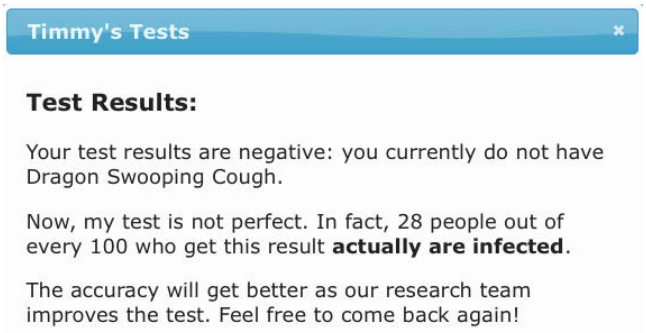

Figure 4. Test results from "Timmy" showing a negative test result and the likelihood of a false negative.

respond to the disease by seeking out personal information on their own infection status. Second, the test enabled players to explore the possibility that they could be infected even when they were not showing symptoms, a quality of the most virulent epidemics in the world today. Third, knowing that youth struggle with understanding probability in the science of epidemiology, we designed the tests to have false positives and negatives, and reported these to the players at the time of the testing. For instance, Timmy, the NPC provider of the infection tests told players, "I'm happy to give you my test for the Dragon Swooping Cough. Before I do, keep in mind that it's not perfectly accurate. No test is. We're still working on it." After the test the actual percentages of the false positives or false negatives were provided to player (see Fig. 4).

We also provided several forms of information about the disease in a few key areas of Whyville. First, the home page provided information throughout the course of each version of the epidemic. In the beginning this took place as the form of "rumors" about the disease in the area that provided rotating current news about Whyville. Eventually more information was offered as a pop-up window on the front page of Whyville (see Fig. 6), including information about preventive measures (what each one was useful for and what it cost), links to a virus status graph that showed how many people in Whyville were current infected (see Fig 5), and links to *The Whyville Times* articles that a few players wrote.

3.5 Version 2 of the *Dragon Swooping Cough*

With many viruses (i.e., chicken pox), repeated infections are possible, so to mirror this and to provide further experiences to players, we ran two instantiations of the DSC. The second (DSC2) was a minor mutation of the original and had similar symptoms (this time with red scales and animated fire-blowing coughs) and identical infection characteristics (i.e., latent period, infectious period). If players had been previously infected by DSC, they contracted the second version with the red scales and flaming coughs. If players were infected for the first time, then they received the original version of the virus with the grey scales. To support Whyvillians' learning we made three small changes surrounding the conditions of the outbreak. First, about two weeks before the second virus was released, the homepage publicized that the DSC might come back. Second, a fundraising drive was begun to collect money toward research on a vaccine[1] for the DSC. This was highly successful, raising 2,072,000 clams from 890 players in 14 days with hundreds of players subsequently purchasing and using the vaccines made available part-way through the second DSC outbreak [see 19 for more details on the vaccine drive). Third, we re-organized the informational pages to be more intuitive. One goal of these changes was to make information more easily readable and available and to provide a new form of player agency in the form of the vaccine drive and vaccine use. We turned to the research to see what effects a repeated instantiation of the virtual epidemic had on player emotions and behaviors.

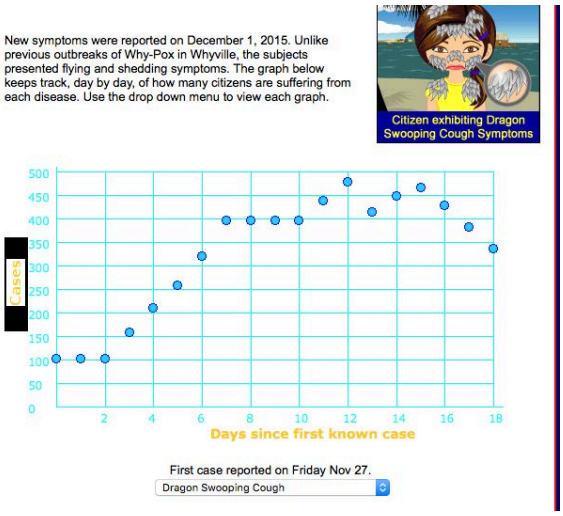

Figure 5. Example of the virus infection graph reporting how many players in Whyville were infected with the Dragon Swooping Cough.

[1] We had determined earlier that providing too much information during the first infection outbreak could create "cognitive overload" for players, and so did not provide vaccines at that time.

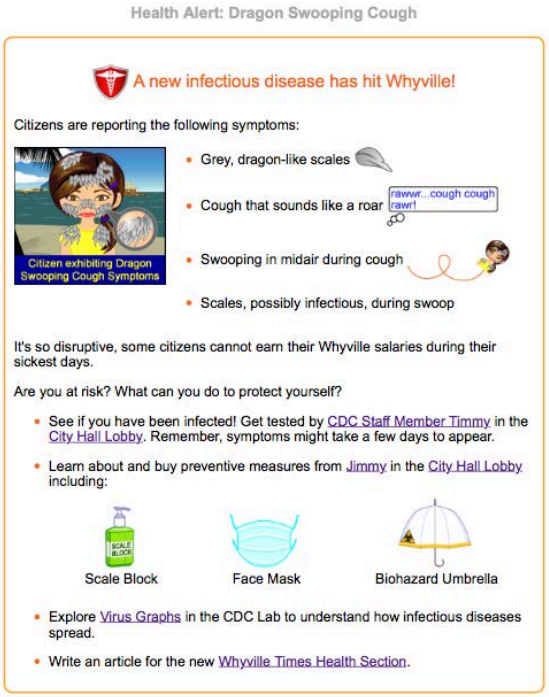

Figure 6. Pop-up information about the Dragon Swooping Cough available on the homepage of Whyville.

4 METHODS

4.1 Data Collection

The DSC affected all of Whyville. Any citizen who logged on during the outbreaks was vulnerable to the disease. We collected two primary sources of data to examine how the DSC viruses affected players' self-reported responses and actual behavior. First, we recruited participation in two post-surveys through advertisements on the homepage and ymail (private messages) to users who had completed previous DSC surveys: a post-survey after the first iteration (DSC1, N = 412), and a post-survey after the second iteration (DSC2, N = 335), with largely different participants. These surveys inquired into Whyvillians' feelings and self-reported actions about the DSC. To assess their emotional responses about DSC, participants were asked 'What did you think of the Dragon Swooping Cough?' and were given three response choices: I liked it; I neither liked it nor disliked it (neutral), and I did not like it (dislike). In terms of behavioral responses during DSC, participants indicated whether they used preventive measures; looked up information online about real life epidemics, infections, diseases, or DSC; avoided chat; avoided sick users; logged onto a different Whyville account; or purposely got infected. In addition to these self-reported measures, log file data were also used to complement some of these behaviors (i.e., checking for infection, using preventive measures, and using umbrellas).

The survey samples were representative of the overall distribution of age and gender on Whyville: 78% were girls, and the mean grade level was 9.33 (roughly aged 14-15 years).

Second, we examined log file data on actions that took place in Whyville to study how the DSC viruses affected players' actual online behavior. This data included those who participated in the surveys (N = 747) and a subset of non-survey players randomly selected by Numedeon (N = 3348).

4.2 Data Analysis

Analyses focused on describing players' emotional, behavioral, and cognitive (information seeking) responses to DSC1 and DSC2 (via surveys), and the connection among these self-report responses and actual behavior (via log files).

Descriptive and correlational analyses were conducted for all major variables. Using average per week activities in log file data, we also compared actual behaviors amongst survey versus the non-survey participants across four time periods: pre-infection (time 1 or T1), DSC1 infection (T2), non-infection period between the viruses (T3) and DSC2 (T4). A series of 4 (time) x 2 (survey) mixed design analyses of variance were conducted to examine differences in checking for infection, use of preventive measures, and umbrella use. In addition, multivariate analysis of variance grouped players into three emotional response groups (dislike, neutral, and like) to examine differences across four log file behaviors per week (checking for infection, use of preventive measures, umbrella use, and login frequencies). Lastly, we also conducted a comparative analysis of open-ended survey questions where Whyvillians were asked to explain why they liked, disliked, or felt neutral about the DSC. Two researchers developed an initial coding scheme, revised it, then tested it with Dedoose software for inter-rater reliability amongst two independent coders on 10% of the sample (0.91 on Cohen's kappa).

5 FINDINGS

5.1 Participatory Responses to the *Dragon Swooping Cough*

The *Dragon Swooping Cough* elicited multiple responses among Whyville citizens across the two infection periods. During the first DSC period, survey results showed that players actively tried to avoid the disease. For instance, they reported avoiding chat (34%) and avoiding infected users (40.8%) as they assumed that (like many real-life diseases) this would prevent infection. They also reported using preventive measures (41.3%). The disease also prompted players to seek out information about the disease with similar levels of activity. For instance, players reported going to the Whyville DSC information page (40.8%), the Whyville CDC (35.7%), Whyville forums (31.3%) or otherwise seeking information across the Whyville website (25.5%). Given that Whyville is an informal virtual space where members may log on infrequently or irregularly, we consider this level of involvement strong, especially compared to prior rates of visiting places such as the CDC (a place rarely if ever visited by Whyville players). Report of these activities in surveys increased slightly during DSC2, showing a similar level of overall engagement with the disease, at least in regard to self-perceived behaviors.

Analyses of log files (of weekly averages) amongst survey participants also show engagement with the disease. During the first infection period, 16.3% of all survey participants checked for infection per week, 33% used preventive measures, and 10.5% used an umbrella as the most expensive preventive measure. During the second DSC, weekly averages of survey participants show that checking for infection doubled (34.5%), while use of preventive measures remained stable (34.9%) and umbrella use decreased (7.8%). How did these activities relate to each other?

In general, the trends within self-reported and actual activity (via log file data) amongst survey participants were correlated. Those who tended to use preventive measures were more likely to avoid others and seek out information about the disease. For example, in DSC1 (but not DSC2), actual use of preventive measures correlated with increased self-reported use ($r = .231$, $p < .001$), avoiding sick users ($r = .121$, $p = .016$) going to the Whyville CDC ($r = .145$, $p < .01$, and visiting the forums ($r = .152$, $p < .01$). In other words, players who used preventive measures were consistent in their efforts to get information about and avoid the disease.

Comparing survey and non-survey participants' actual behavior across time, only significant interactions effects and follow-up analyses will be reported for brevity. The figures on the following page display the results (see Fig. 7, Fig. 8, and Fig. 9), most importantly that checking for infection, using umbrellas, and using preventive measures were strongly tied with the presence of DSC and almost non-existent in between infectious periods. Further there were some changes amongst both survey and non-survey participants between DSC1 and DSC2: checking for infection more than doubled in DSC2; using umbrellas as a preventive measure stayed consistent; and using preventive measures (not including umbrellas) dropped during DSC2.

Notably, survey participants were much more active in the behaviors listed above than the players who did not participate in survey. It is not too surprising that survey participants tended to show higher usage of preventive measures, umbrella use, and checking for infections; players who respond to a survey solicitation are likely to be among the more involved users of a site compared with the broad population. Amongst the non-survey participants, there were lower rates of checking for infection, using preventive measures, and using s during both non-infection periods. Still, overall these activities were tied with the presence of the virus, demonstrating the type of engagement we sought to design for in this virtual world.

5.2 Players' Emotional Engagement with the *Dragon Swooping Cough*

5.2.1 Changing Emotions. Knowing that emotions played a role in prior epidemics such as *Corrupted Blood* and *WhyPox*, we further investigated emotional responses to the DSC and whether those were linked with any behavioral activities. Intriguingly, emotional reactions changed after the second iteration of the DSC. While neutral responses dominated feelings

in the first round, both negative and positive responses grew in the second round, with neutral responses diminishing (see Table 1). Of note, these were largely different survey takers, so we cannot make claims that individuals' feelings changed. However, the proportional responses to the disease changed, at least as evidenced in those who chose to take the surveys. What does it mean that emotions about the virus increased?

In contrast, the substance of neutral feelings did change in the second round. In DSC1, neutral responses appeared to be largely due to players not knowing what DSC was or not caring because they did not experience it personally. Fifty-two players in the first post-survey claimed a complete lack of knowledge about the virus, saying, "I don't know what it is." A similarly large number (36) of survey takers said that they were not around enough for the virus, either not logging in or not going to chat rooms (instead doing more individual activities on Whyville). In the second round neutral feelings dissipated considerably and analysis suggests that lack of knowledge or experience of DSC dropped considerably the second time it appeared. For instance, after DSC2 only 14 users claimed that they did not know what the *Dragon Swooping Cough* was, a significant decrease from 52. Similarly, only 28 Whyvillians

Like negative responses, the positive responses to DSC also increased during DSC2, but unlike the negative responses there was a small change in the substance of the emotion. Positive responses generally focused on how the virus was "cool," "fun," and "interesting." These users enjoyed the symptoms of the disease, especially the funny movement and "spitting fire." While these notions continued in the second round, a new expression of the value of the virus as "a shared communal experience" began to appear. As one user described, the *Dragon Swooping Cough* "felt like an actual event ...and made chatroom

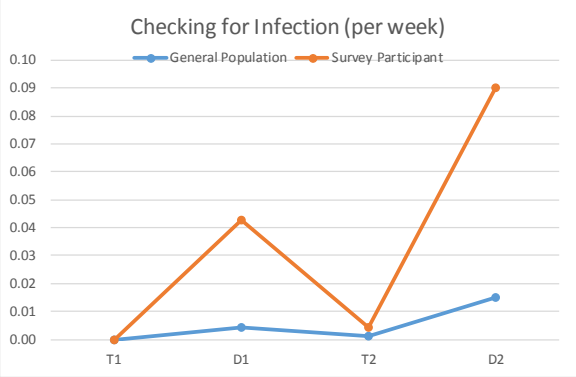

Figure 7. Checking for infection before DSC1 (time 1: T1), during DSC1 (D1), between infections (T2) and during DSC2 (D2).

	Survey	Time	Interaction
F-value	139.455***	154.436***	80.690
Partial η2	.061	.067	.036

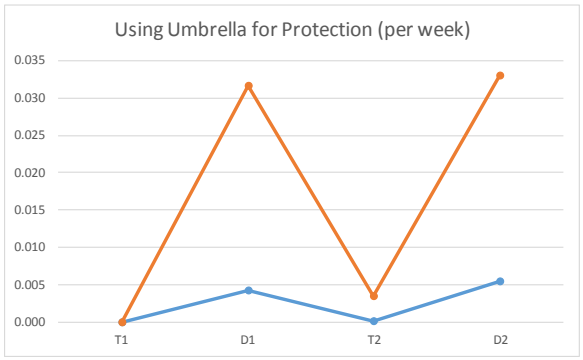

Figure 8. Biohazard umbrella usage before DSC1 (T1), during DSC1 (D1), between infections (T2) and during DSC2 (D2).

	Survey	Time	Interaction
F-value	70.838***	50.401***	21.137***
Partial η2	.032	.023	.012

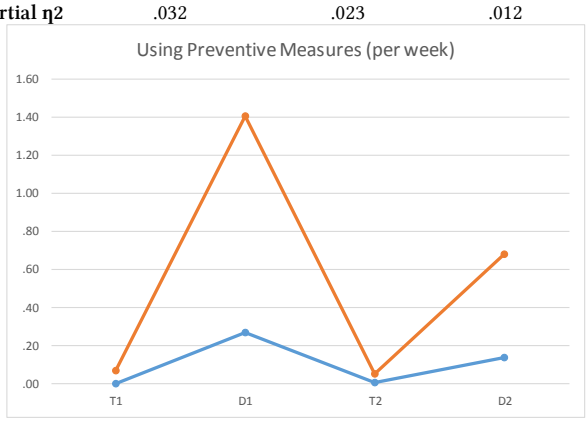

Figure 9. Preventive measure usage before DSC1 (T1), during DSC1 (D1), between infections (T2) and during DSC2 (D2).

	Survey	Time	Interaction
F-value	76.223***	78.171***	35.056***
Partial η2	.032	.036	.016

Table 1: Emotional responses in the two iterations of DSC.

DSC1 (N = 406)			DSC2 (N = 331)		
Disliked	Neutral	Liked	Disliked	Neutral	Liked
36%	49%	15%	40%	38%	22%

interactions more meaningful since you had a chance of becoming sick." Further, in the second round, as with the neutral responses, more of the positive emotional responses displayed a feeling that they learned something from the experience of the DSC and that it helped them in some way. For instance, one player wrote that the DSC was "very educational. I automatically assumed I would not catch it, Because I'm hardly on, and hardly in any chat rooms, but I did. It gave me a realistic perspective on the chances I have of getting the actual flu." DSC2. Noting the strong (and changing) emotional reactions to the DSC, we

investigated whether emotional engagement had any influence on activity, self-reported or actual.

5.2.2 Comparing Emotion and Activity. How did emotions relate to self-reported behaviors? First, the more players liked DSC1, the more they were likely to hang out on Whyville and even try to get the disease by hanging around with sick players and not using preventive measures. Statistically, liking the first iteration of DSC was significantly correlated with a self-reported increase in logging in ($r = .185$, $p < .001$), a decrease in avoiding chat ($r = -.229$, $p < .001$), trying to get infected ($r = .111$, $p < .05$) and a decrease in use of preventive measures ($r = -.132$, $p < .01$). Inversely, players who disliked the virus reported that they avoided Whyville and other players, tried to avoid infection and used preventive measures.

This trend was matched in a comparison of emotions and actual behaviors (via log files). For DSC1, MANOVA results show that players who disliked the virus were significantly more likely to engage in infection checking, preventive measure use, and umbrella use than the Neutral group (see Table 2). In addition, umbrella use was significantly lower for the Neutral group compared to both the Dislike and Like groups. This makes sense; especially given that players with neutral emotions in DSC1 expressed not knowing about or experiencing DSC. In DSC2, emotions seemed to play less of a role in prevention behavior (see Table 3). On the one hand, similar to the first iteration, liking the virus was correlated with the self-reported activities of logging in more often to Whyville ($r = .178$, $p = .001$), and not avoiding chat ($r = -.178$, $p < .01$). However, emotions were no longer correlated with trying to get infected or using preventive measures either by self-report or through actual activities. Further, MANOVA results only found that those who disliked the DSC were more likely to login to Whyville compared to Neutral players.

Table 2. Multivariate analyses of variance results predicting log file behaviors during DSC1

DSC1	Checking Infection	Umbrella Use	Preventive Measure	Logins
Dislike (n=142)	0.08_a	0.04_{ac}	2.27_a	10.61_a
Neutral (n=191)	0.04_b	0.01_b	0.60_b	4.80_b
Like (n=59)	0.06_{ab}	0.05_{ac}	1.98_{ab}	8.33_{ab}
F-value	3.217 *	6.951**	5.983**	7.511***
Partial η2	.016	.035	.030	.037

Column means with different subscripts indicate significant difference $p < .05$. Pillai's Trace = .066, F (8, 774) = 3.301, $p = .001$, partial η2 = .033

Table 3. Multivariate analyses of variance results predicting log file behaviors during DSC2

DSC2	Checking Infection	Umbrella Use	Preventive Measure	Logins
Dislike (n=123)	0.14_a	0.07_a	1.30_a	10.54_a
Neutral (n=96)	0.17_a	0.06_a	1.21_a	4.16_b
Like (n=65)	0.19_a	0.02_a	1.68_a	18.69_{ab}
F-value	.529	.646	.173	5.421**
Partial η2	.004	.005	.001	.037

Column means with different subscripts indicate significant difference $p < .05$. Pillai's Trace = .056, F (8, 560) = 2.017, $p = .042$, partial η2 = .028

Interesting new trends arose regarding information seeking behaviors (only available in self-reported responses). In DSC1, there was no correlation between liking DSC and any information seeking behavior. However, in DSC2, liking the virus was newly correlated with several information-seeking behaviors, including looking up information about DSC on Whyville ($r = .120$, $p < .05$), looking up information online about real life epidemics ($r = .172$, $p < .01$) and real life infections or diseases ($r = .280$, $p < 001$), attending a special "Greek Theater" information session ($r = .188$, $p < .001$), and going to the Whyville CDC ($r = .149$, $p < .01$). These responses parallel the increased number of comments about the positive educational value of the DSC in the second version. Players who liked the virus thought it was educational and sought out more information both within and outside of Whyville about DSC and diseases in general. So emotions did affect disease-related behavior in Whyville, but in different ways depending on the iteration of the virus. We consider reasons for these shifts below.

6 DISCUSSION

In the design of the *Dragon Swooping Cough* we sought to engage a youth population in a playful virtual world in "serious" engagement with a virtual epidemic. School-age youth play a critical role in the transmission of diseases for many pathogens [8]. Interventions therefore not only protect children from risk, but also protect the broader society. Many proposed interventions focus directly on changing the health behavior of students, but studies have clearly shown a direct correlation between understanding the utility of the behavior and continued/effective adherence [34]. Thus there is motivation for educating youth about why certain behaviors are helpful in preventing disease at an individual and a community level.

Through our design, we solicited active emotional and behavioral engagement in the virtual epidemic by creating a virus that targeted the things players cared about the most on Whyville: looks, conversation, and money. For the first time (to our knowledge), we provided and studied several preventive measures that allowed Whyvillians to take action against the epidemic and allowed them to investigate their own infectious status before symptoms showed. We developed a second version of the disease in hopes of deepening engagement, refining

informational displays about the virus, and providing opportunity for more explicit community-level participation through a fundraising drive that contributed to the larger good through vaccinations. At first glance, the *Dragon Swooping Cough* epidemic was successful in engaging Whyvillians in the full range of activities we provided to combat the disease. Overall our research demonstrated that the virtual epidemic successfully drew emotional responses and that these emotional responses were linked with actions taken in regard to the disease. Use of preventive measures and checks for infection went up during infection and down in between infectious periods. Considering that Whyville is an informal virtual play space, we consider these shifts in emotions and behaviors to demonstrate considerable engagement with the virtual epidemic.

Intriguingly, different emotional responses played a role in those activities; those who disliked the virus were more likely to engage in preventive behaviors (at least in the first iteration) while those who liked the virus were less likely to engage in those activities. We interpret these different responses as *disease-related* or *game-related*. On the one hand, having a disease is generally annoying, and the DSC was especially distressing to those who disliked how it affected their avatars' appearances, socializing, and virtual wealth. These players treated the DSC much as they would a real disease, as annoying at best. On the other hand, the virtual disease had game-like qualities in its imaginary status related to dragons, the playful swooping movement of infected characters, the spitting fire animation (in DSC2) and the mischievous idea that one could pass it on to others. Many of those who enjoyed DSC liked the symptoms—they were a type of game reward—and the idea of spreading the disease, which might be rewarded with a reaction from other players. These players treated the disease more as a game, as something that was designed, playful, and spread-able (i.e., one could infect others).

One of our new considerations in design was creating a second outbreak of the disease. Notably, in the second outbreak several things changed. Emotions shifted to be less neutral as players became more aware of the disease. Accompanying this was an increase of expressions about the educational and communal values of the virus. Further, in the second round, information seeking was newly tied with positive emotions about the DSC experience. It is impossible with the data available to tease apart whether these changes were because there was a second round of the DSC or because the second version was of a slightly different quality. However, the design team made several choices in the second round that may have influenced the increase in positive feelings: 1) they strategically changed the look and organization of the information available, 2) information about the second DSC was publicized early in the community, allowing players time to anticipate and prepare, and 3) players were invited to take an active stance on fundraising for a vaccine, which may have promoted a deeper sense of agency.

Beyond emotion, usage of preventive measures (aside from the expensive biohazard umbrellas) dropped during DSC2 in comparison to DSC1. There are at least three potential explanations for this. First, the newly available vaccine may have led players to feel more protected, with less need for other preventive measures. Second, players may have used certain DSC-specific measures such as mask and lotion more than the earlier available wash and cover (useful for WhyPox), leading to an overall drop in usage but a shift to more robust preventive actions. Since mask and lotion can be used less frequently and still be effective, this may account for a drop overall in preventive measures [see 19]. A third, more epidemiological explanation is that there was "responsibility fatigue" in which people view certain risks as inevitable and their own efficacy at controlling risk as negligible relative to the total risk. Such cases commonly show decreased adherence to preventive behaviors over time, especially if players were hearing stories about catching the DSC despite using preventive measures or vaccines (which many did complain about). That idea may have compounded because of shared stories across two outbreaks.

Despite our being in the fortunate position to work together with Numedeon, Inc., the company that hosts Whyville and provided the tremendous amount of data for this research, some questions could not be answered because they require different forms of data than was collected for this study. For instance, in Whyville it is quite difficult and costly to measure how long players spent on informational pages or in infection-laden chat rooms, but this could provide deeper insight into learning. Despite relatively good returns on survey solicitations, our study still suffers from the challenge of recruiting a wide range and large proportion of participants in casual online spaces. Such instruments generally gather (as was the case for us) highly involved users, and while their responses are helpful, they do not convey the full range of players on a site. Further, we cannot discern from the online data whether players internalized any ideas about infection and prevention of epidemics in ways that might affect their real life actions.

In his book, *The Proteus Paradox*, Nick Yee [35] claims that though "Virtual worlds hold infinite possibilities" thus far we have explored "only a sliver of those potentials" (p. 213). We hope that in this paper we have begun to expand that sliver of potential at least a small bit. Overall, virtual epidemics create a perfect storm in which both individual and social behaviors impact ongoing disease dynamics in complicated ways that cannot be safely explored via real-world experiential learning. Our hope and expectation is that by designing and understanding virtual epidemics, in which youth can experiment with their behaviors, observe outcomes, and refine their understanding of causal mechanisms of disease and therefore disease prevention, we are enabling better adoption of real-world behaviors that increase health and public safety.

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