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Combating COVID on College Campuses: The Impact of Structural Changes on Viral Transmissions

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Introduction:

Jared Knofczynski (JK): Hello, I'm Jared, I'm a rising junior at the University of Oregon and I am joined today by …

Aria Killebrew Bruehl (AKB): Aria, I am a rising sophomore at Reed College in Portland, Oregon,

Ben Warner (BW): I'm Ben, I'm a rising junior at Washington University in St. Louis,

Ryne Shelton (RS): and I'm Ryne, I'm a rising sophomore at Portland Community College.

JK: This summer we participated in the altREU program on "Computational Modeling Serving Your Community" through Teuscher Lab at Portland State University. This program is an alternative, fully online, and project-based Research Experience for Undergraduates.

What are/were you trying to do?

JK: Our team has been looking to model the effectiveness of social distancing measures in reducing the spread of COVID-19 within specific academic environments — particularly college and university-level classrooms.

In doing so, we're hoping to gain insight into the efficacy of specific measures being implemented at our universities and in others around the country. With the prospect of many universities planning on returning to in-person learning in the near future, we are concerned with doing our best to ensure that our communities are both safe, and that the social distancing measures in place are both sufficient and properly enforced.

These measures include, but are not limited to, limiting the number of students enrolled in classes, requiring certain percentages of classes to meet strictly online, requiring masks in common areas, seating students certain distances apart, staggering release schedules/transition periods between classes, and enforcing symptom-checks and self-quarantining at home.

Yet without the massive amounts of quantitative data concerning the efficacy of certain measures that, unfortunately, will undoubtedly arise this fall, we have instead elected to develop an agent-based simulation model that has allowed us to implement and observe the effectiveness of such measures.

AKB: I have a question for you: Why were you, personally, interested in pursuing this project?

JK: For me, this project is really a great way for me to use my skills and the skills that I have been both learning and developing over the last few years to make a change and bring about something that will positively impact the lives of others. I think that COVID-19 is a very serious and important issue and I think that doing everything we can to aid in combating the spread of it, is a really important use of time and energy and resources.

How is it done today, and what are the limits of current practice?

AKB: The simulation we have created models the transmission of COVID-19 in a college or university classroom. With our model a user first selects a classroom layout from a list of maps, the layout is then turned into a digital environment on a local server. The environment is filled with agents representing environmental factors such as desks or doors and agents representing humans. The user can then specify the number of infected, uninfected, and recovered agents as well as the effectiveness of the masks the human agents are wearing. Once the model begins running the agents move to their specified seats then stay in those positions for a designated number of hours. Once the class is over the agents leave the classroom and all surfaces are cleaned. At this time human agents who are considered cautious will check themselves for symptoms and self-quarantine as necessary. This process is considered one class day and is repeated until all agents are either uninfected or recovered.

While the model runs we collect data regarding the number of infected, uninfected, recovered, and quarantined agents, and data regarding the average distance between the agents and data regarding the number of hours and days the simulation has been running. We use this data to then calculate the reproduction rate of COVID-19 while our simulation runs.

Our model is severely limited and simplified. These limitations and simplifications come from two places. First, they come as a result of decisions we made to reduce the number of parameters for creating our agents in order to make our project more manageable. For example, we have only modeled one classroom instead of a larger campus environment and have assumed that agents cannot become infected outside of the classroom. We have also not specified the age or race of our agents even though data has shown that the severity of COVID symptoms and mortality rate varies drastically across age groups and that due to limited access to care and economic inequalities COVID-19 disproportionally affects non-white people in the United States.

Second, limitations and simplifications come from the novelty of COVID. Since COVID-19 is so recent, data concerning viral shedding, asymptomatic transmissions, and the effectiveness of different social distancing measures are constantly being produced. Instead of changing variables in our model as new data has surfaced, we decided to generalize these variables to reflect data trends that have remained constant throughout the pandemic. For example, we have assumed that all humans will recover from COVID after 14 days of self-quarantining since that aligns with CDC guidelines, however, the World Health Organization states that for COVID the quote "duration of RT-PCR positivity generally appears to be 1-2 weeks for asymptomatic persons, and up to 3 weeks or more for patients with mild to moderate disease and In patients with severe COVID-19 disease, it can be much longer" unquote. It should be noted however that the presence of viral RNA does not necessarily mean a person is infectious. We have also assumed that a masked individual is less likely than an unmasked individual to contaminate a surface or infect others. The percent likelihoods we have decided on are not backed by data sets and instead are very rough estimates based on studies that have demonstrated the importance and effectiveness of mask-wearing.

Despite these limitations and simplifications our model clearly demonstrates the importance of mask wearing, social distancing, and staying away from others if one is showing symptoms of COVID.

BW: I have a follow up question: What was the social distancing protocol you were most interested in looking at?

AKB: I was most interested in the effectiveness of wearing masks since it is something so simple and easy to be implemented on people without really disrupting day to day life. But it seems to be something that a lot of people seem to have the strongest issue with in certain areas and are really not doing when it is something so simple to implement and see how big of an impact that super simple action will have on disease spread. That's what interested me the most.

JK: And what was the most difficult social distancing measure to implement in the simulation?

AKB: The most difficult social distancing measure to implement was maintaining a six foot distance between the agents. And we weren't actually able to implement this perfectly. When the simulation begins, all the agents are at the door together and all kind of stacked up on top of eachother and we aren't able to keep six feet between them. And to deal with this we just made it so that at that door position, when all the agents are together, they can't actually infect each other. And it's once they start moving out of it then they can [infect each other] even if they're within six feet of one another.

What is new/different/better in your approach?

BW: There are several novel strengths with our agent-based model. In general, agent-based models are useful for simulating different protocols for reducing transmission without knowing the relative efficacy beforehand. In addition, agent-based models are useful since they offset the health and economic risks carried with relying on empirical data, allowing our stakeholders to save lives more effectively and dedicate more resources where it is needed to combat the spread of COVID .

As discussed earlier, our model works as a grid of cells, with each cell capable of containing human agents and a variety of environmental agents, including walls, air, surfaces, doors, and so on. Human agents and environmental agents interact in tandem with each other to infect one another, producing a result that emulates the results that a real world classroom might generate. While there is some consideration towards the logic and math behind these basic interactions---such as airflow, human agent movement patterns, etc.---our model is advantageous here as these interactions allow for an overall pattern to emerge from these underlying behaviors.

Our model can simulate a variety of protocols, including social distancing measures, masking, limited schedules, quarantining, and so on. Our model also has the capacity for supporting a variety of other measures that might be implemented in future work. In addition, our model is highly parameterizable, allowing us to adjust the number of infected, uninfected, and recovered individuals, the effectiveness of masks, and so on. Moreover, our model can be customized with environments that can be designed out in an image file, allowing us to represent different types of classrooms, hallways, buildings, and so on, with relative ease.

With our parameterized model, we are capable of making conclusions about the relative efficacy of each parameter--allowing us to determine which measures are of the most importance to limiting the spread of COVID. In our model, we determined using linear support vector regression, that the number of agents were most responsible for the peak R_0 ,which is the rate of transmission, with the number of initially infected agents being responsible for 26% of the known effect and the number of uninfected agents being responsible for 24% of the known effect. We also found that the number of hours spent in the classroom was responsible for 23% of the known effect upon the percentage of people infected at the maximum of the infection curve. Future work may find that different parameters are more effective at reducing the spread of COVID within the classroom, as well as make more accurate conclusions towards their efficacy.

AKB: I have a follow up question for you: What is the biggest difference between the model we have today and the model we originally envisioned?

BW: Uh so probably the biggest difference between the model we envisioned back then and, uh, what we have today is the scale. Initially, we envision a larger campus so, maybe, hallways, whole buildings. But in terms of what we were actually able to look at, we only did small scale classrooms.

AKB: And I have another follow up question: What part of our model are you most proud of?

BW: So there's a couple parts of our model I think I'm most proud of, personally. The first one would be the human agents. They're fairly complex but I think they mimic human behavior pretty well for what we were able to achieve with this limited time frame. I'm also proud of the way the airflow interacts. It's fairly simple but I feel it represents natural diffusion of air pretty well. So, those are the two aspects of the model I'm most proud of.

Who cares? If you are/were successful, what difference will it make?

RS: Okay, now I'm going to talk about "Who even cares about this?"

Answering the question of who cares about the implementation of computational models to predict the spread of infectious diseases poses itself as a simple question to answer. Instead let's propose another question. Who would benefit most from the development of models, specifically aimed at simulating the spread of COVID-19 amongst students on school campuses? My initial thought is myself, I would enjoy some quantitative answers to the more pressing question, what is my risk of contracting covid if schools do reopen? Aside from myself, school administration, other students, their families, and the medical professionals responsible for treating those potentially infected would all surely be beneficiaries. We are risk assessing creatures who are experts at determining appropriate risk to reward. But as our lives become more complex and we need new tools that help us identify risks and guide us towards their solutions.

One of the earliest accounts of mathematical modeling of disease spread dates back to roughly 1760. This model was developed by Daniel Bernoulli, a Swiss mathematician, and predicted the increase of life expectancy due to the treatment of smallpox. Today we possess the machine computational power which allows models to perform calculations upwards of a billion times faster than the speed at which Bernoulli would have performed the calculations within his model one by one, by hand. In 2018, by using the immense computational power of modern computers, the Institute of Disease Modeling funded by the Gates Foundation modeled a deadly flu which could kill more than 30million people within 6 months. Later that following year a similar situation happened to unfold upon the world stage. Insights like these allow those at risk to prepare appropriately and may have provided an early warning to the world for what was about to come towards the end of 2019. Warnings like these are priceless.

Because of the high accessibility of Python, the programming language that we used, our work can be easily carried on by others in the future. Even though we were not able to represent all the aspects of transmission that we hoped to model, the possibilities of future updates to our model program allows for them to be added at a later date. This is what makes modeling of this type preferable to other forms that are for the most part, one and done trials. We have been successful in creating the groundwork necessary for either our team members or others to easily run with in the future.

Our team has done a tremendous job getting work done. Our greatest success was our consistent work week in and week out that has allowed us to complete tasks on time and produce well polished deliverables regardless of our conflicting schedules and limited time. Aria's communication and ability to obtain support for our team has given our team direction, especially at first, when we were quite lost about where to start. Ben has been a workhorse that ironed out multiple bugs in our code and kept the culture amongst our group goal oriented.

Leadership, when it comes to our group, has been held steadily by Jared who orchestrated tasks and was never short of positive ideas to keep our group on track. It was an honor to be a part of this team and watch the talent amongst this group show itself. We aimed to work together for the purpose of completing this commitment and for these reasons we must report nothing less than a tremendous success.

Any follow up questions?

AKB: I would like to say thank you for all the great questions that you [Ryne] asked us. They really helped guide our model and come up with new things to add and ways to make our model even better and more realistic.

And then, in terms of follow up questions: How will this model change the way to interact with others once you return to in person learning?

RS: Yeah I guess the first thing I got from all this was just to realize how fragile my life is and, uh, all the lives around me, and that I need to be grateful for the people that I have. ‘Cuz, you know, crazy things like this can happen and I can potentially lose a lot of very important people in my life. So just being grateful day in and day out despite the horrible news that I hear every day about thousands of people dying I think is going to be the most important thing that keeps me sane so...

AKB: This could also probably be answered by other people…

JK: Yeah, definitely. I know that for me this mode will definitely… while it hasn’t necessarily changed the content of what I’ll be doing, of the measures I’ll be adhering to and steps I will be taking to ensure safety of both myself and others, it has definitely served to remind me of the importance of all these measures and adhering to not just one of them but all of them in conjunction for the most effective reduction in transmission rates.

AKB: Great, now we would like to introduce our faculty mentor during this project, Lisa Merriott, and ask her a few questions about our model and COVID-19.

Interview with Faculty Mentor Lisa Marriott

AKB: Could you start by maybe introducing yourself, saying who you are, what type of work you do, et cetera?

Lisa Marriott (LM): My name is Lisa Marriott I am an associate professor of public health in the OHSU PSU School of Public Health. I have a lot of different projects, mostly workforce development but we have a state-wide project looking at COVID in Oregon.

AKB: Wonderful, thank you! So the first question is: What do you think is the best way to educate the public about the importance of social distancing for reducing the reproduction rate of COVID in all environments, schools, grocery stores, airports, et cetera?

LM: So there's a couple of lines of evidence that you can use. In our previous studies we've looked at, most people uh... for reasons of doing something sometimes they will talk about either the personal benefits or the style benefits. So, if you can really emphasize those two pieces those are two ways you can do it. However, when you look at vaccine hesitancy, sometimes the reasons for not doing it or what are the consequences if you don't do it are some of the most effective. So, I would then emphasize those things combined with those personal/societal benefits.

AKB: So it kind of seems like you were saying a little bit of reverse psychology maybe? With showing what will happen if you don't do this.

LM: Yeah, that's most successful for some of the vaccines. For getting individuals to see a different side of vaccine acceptance.

AKB: Yeah, interesting. Do you think there will be an increase in the number of COVID-19 cases in Portland or, in any other large cities, after students enrolled in colleges and universities in that area return to campus and in-person instruction?

LM: Definitely, no question.

AKB: And do you think that part of that increase will have to do with the way that colleges and universities are structured: with dorm living and having big cafeterias and public gyms, and facilities like that?

LM: Yes, that would be exactly right. Any time when we're all together and social distancing is a problem, masks can be a problem, we're going to have some of these issues, and now they're starting to suggest using goggles as well.

AKB: So, assuming that we return to in-person learning in the fall, what precautions will you be taking to limit the spread of COVID-19? And, what will you do that might differ from other faculty or members of your institution?

LM: So, for me, I'm not returning to in-person. I am very very lucky to be able to do everything remotely, so, all of my class will be remote, and that will be very likely, I'm expecting that to be for the next year. As such I feel very very lucky. Some of my colleagues don't have that same luxury, especially if they are doing these classes that require this in-person component. So there's that level of stress related to that.

There's a huge impact on kids. And so right now, for example, they're doing online instruction. But for children of these individuals who are to schools and coming back that is an additional level of stress and exposure that families are going to have. And it's going to be highly socioeconomic dependent, so that bothers me. So there are going to be inequities that are going to be… that I'm expecting to be seeing as some of these… as we start going back to school. So those who are able to either home school or do online there may be less infection than those who are all fully there. That bothers me as a scientist and as a human, that there are going to be some of these gross inequities that are going to be happening.

AKB: For people who don't have the opportunity to have class online, for both the students and the faculty, because they are doing chemistry labs or bio labs, who kind of have to go in and be in person, what precautions do you think that they should take to maximize their safety?

LM: So definitely masks, definitely social distancing, frequent washing of hands. And as they are now starting to... some of these eye guards are the new thing. So there's an easy tip for those sheet protectors. You can use sheet protectors, you shove a headband in it and you can actually create a full on mask shield that'll protect your eyes without needing anything fancy.

AKB: Similar to that topic, what are some of the largest unknowns about how this return to in-person instruction might play out?

LM: I think that, who is able to be reinfected, how long is someone contagious, and how is viral shedding related to someone still being infectious. We're learning more about that but those are huge unknowns. And the other thing that I am concerned about is there are these long lasting impacts of COVID that we're just starting to discover that are months and months and months. So as we're talking about someone having gotten over COVID, they're not finished with it. They're still having these long term impacts on their chronic fatigue and many of their other bodily functions. So there's a study that just came out that was looking at three-quarters of individuals still having hardships related to COVID. So we don't even know some of these effects that we're going to be seeing down the road. So just being really mindful of what we're learning at the time.

AKB: Wow, thank you. I think our last question, other than anything additional that you want to add is: What is one piece of information about COVID spread that you think everyone should know? If you could put it in everybodies brain's, what's the one thing you think is the most important?

LM: Uh, that it's not a respiratory illness alone and that there are very long term effects that are still being discovered currently. So, do not, it is not the flu. Do not take it as such. Take precautions because there are some serious health effects for who knows how long, potentially years to come.

AKB: Great, thank you. Is there anything else you wanna to add?

LM: No. I'm not a super fan of COVID anymore. *laughs* It makes me sad. It's a crazy virus. Completely baffling how some are completely asymptomatic and some are at such critical issues related to it. So I can't wait to learn more.

So overwhelming. It really is. There's a lot and I undervalue all the places where it's hitting. So I see it in my environmental health class about how, you know, water systems and food access and air quality. Like all of these are being impacted COVID. In addition to respiratory, neurological, cardiovascular, it's just, it's affecting everything.

AKB: Yeah, it's a lot. Great, awesome! Well, thank you so much.

LM: Congratulations, you did it! It's amazing!

AKB: Awesome, thank you!

RS: Thank you!

LM: Bye!

Stakeholder interview

JK: We also reached out to Laura Lhorani, a faculty member at Portland Community College for her input and insight into our project.

RS: Laura would you like to formally introduce yourself?

Laura Lhorani (LL): Hi! I'm Laura Lhorani, I'm the Interim Division Dean for math, science, and career technical education at PCC, South East.

RS: Thank you Laura. Well, as you know, us at the altREU are doing COVID modeling, computational modeling of COVID on college campuses, and, uh, we would like to ask you a few questions.

What long term changes do you think colleges and universities will have to adapt to maintain the health and well being of their students, faculty, and staff even after COVID becomes contained?

LL: Well one thing I can see happening is, not only inspection of our HVAC unit, but also an upgrade, because I think like most institutions, you know… There wasn't particular care put into how the HVAC units were designed. I mean, we've never been in a pandemic, this is our first pandemic. So I think we need to take a look at how air is circulated, is it circulated form, um, classroom to classroom, because if it is then even your modeling system wouldn't work, right? Because there is air coming in from other classrooms. So I think that's going to be key.

The other thing that is going to be key, I think we've proven that we can do is the use of working remotely. And particularly for individuals who have some sort of, who are compromised in some sort of way. Like maybe they have diabetes or they're older or they live with somebody who has a compromised immune system. So those individuals, whether they are faculty or staff will probably be allowed to work remotely, teach remotely. Umm, for those who come to campus I expect more barriers to be put in place. Not only social distancing, but social distancing plus glass barriers. So for example if you walk into our division office you would probably have, you would probably be greeted by a receptionist who is behind a plexiglass barrier. So those kinds of things. And I can see that happening even if we solve COVID we'd probably hang onto those barriers because who knows. And I I I think that we'll be doing, and we've already started to plan for, the use of hybrid classes. So, for example, in my division we have a uh Health 112 class which is CPR and first aid. And so the class itself will be online and the students will only be coming to classes for their skills test and what we're doing with those students is we're putting them in a larger room and we're decreasing the number of students in that room, and they will have a mannequin and and AED that will help them do their skills test for the American Red Cross. They won't share equipment and the afternoon session, the morning session and the afternoon session will be divided up by an hour where there is going to be intensive disinfecting and cleaning before the next cohort comes in to do their skills test.

So those kinds of things. I don't anticipate that all classes will be allowed to come back. I think it will be mostly focused on career technical education. Particularly career technical education focused on, um, you know, first responders. And right now that's all the health stuff. So Cascade and Rock Creek, those cohorts are back for the summer. But uh, our health, our first aid class we're just planning for fall right now. So...

RS: Okay, so, uh, what are some of the largest unknowns that colleges must deal with in regards to returning to the classroom safely?

LL: Just the fact that if you are indeed putting people first and you want to show that you care about people, there's no way to guarantee that somebody won't get COVID. As soon as you bring people together you know, the transmission rate there's… It can result in people getting sick and depending on the individual and their state of health and their age and all of those combinations it can be deadly. So I think that the scariest thing about planning a return to campus is that I can't, I can't guarantee that our students or our faculty or our staff are going to come out of it unscaved. So I think that's the scariest thing.

RS: Absolutely, yeah that's understandable. Before this recording I showed you our model a bit. What do you think our model simulates well? Is there anything you think is lacking within the scope of what we are seeking to accomplish?

LL: Well, I think that, one, one thing, that maybe it didn't consider was the HVAC. You know, an air conditioning, you know, Where's, where's that air coming from where's that air going? Um, so I think if we're looking at the individual room its a perfect model, right? But in the real world these rooms are connected with a HVAC system so I think that that's one thing. But you know, you can't think of everything when you're designing these models so I think it was, I think it was great.

You know, distancing. I thought that it was really interesting that you could look at how students are placed, how many students are placed. Because it's not going to be business as usual right, when we come back? So we're not going to be in classrooms where there's 30 or 40 people or more. If that's the case, especially at the university level, those classes, the lecture part will be online, and same with us, uh, at PCC.

I think it's important to always base models on epidemiological data like PCC is doing our planning in conjunction with the Oregon health Authorities. Um, so, you know, hopefully you've also done that with your modeling too. So, yeah, there's just no way to eliminate risks enitirely is there? So you have to think of both risks and benefits. And I could see from your model that you're considering students who have had COVID, agents who have had COVID and recovered, agents who are infected with COVID, those who aren't. Um so I think that's a good thing to consider.

Although I don't know. I've heard of COVID mutating, right? So even if you've had COVID are you really still recovered? Um. would you be at risk of getting a different mutation? So, so it it it's novel right, we don't know.

RS: Yeah, and I think that's the problem we face with a lot of things. Not only is it very difficult to model airflow, those are very complex algorithms at are used in the model themselves. But even try to address unknowns in our model. I think we do a lot of good by stating the limitations of our model.

LL: Yeah, I think so too, yeah.

RS: So, um uh, so it's more of just a guide maybe to, uh, make better decisions? But yeah, there's a bunch of unknowns with this, so I think we just did our best.

And our final question: assuming we return to in-person learning in the fall, what precautions will you be taking to limit the spread of COVID-19? What will you do that might differ from other faculty or members of your institution?

LL: So, at PCC, very few programs are coming back in the fall, and again, those programs will have a hybrid model where the learning will be taking place remotely or online. Only the things that are necessary to be done in-person will happen on campus. Campus won't be open; instructors will have to open the building for students to be let in, buildings won't be unlocked, so that will decrease the number of students in one space, because, you know, they can't get in unless a faculty member lets them in. And then in the building, students will be restricted to going to the room where their class is, so we're really trying to decrease the amount of surfaces that are touched and breathed on. That's one thing we're doing, and the other is again, limiting the number of students in the cohort that are coming to campus. If a class was originally around 20 people, it's being cut in half to maybe twelve, *and* we're putting them in bigger classrooms. A health class that might have been held in a 30 person classroom will instead be held in a 40 or 50 person classroom so that they can have more spacing. And finally, in the particular health class I talked about, HE112, each student will have their own equipment and that equipment will be wiped down and disinfected between the morning session and the afternoon session. What we didn't think of, though, and what hasn't been part of the ask, was, how long should the classroom stand empty before the next cohort comes in? And I mean really, if we're thinking this can be spread through the air and the air needs to be cleaned, we didn't make that kind of consideration, and honestly we should have a different classroom for the morning cohort and the afternoon cohort, because an hour break isn't going to air out the classroom, so. But for the most part, PCC is remaining remote for fall term, and as for winter, well, we'll know pretty soon.

RS: Yeah. Well, I'd like to thank you for taking the time to answer our questions, you've provided a lot of insight into what's going on behind the scenes. I know I appreciate it as a student, and I'd just like to thank you again for taking the time to meet with us.

LL: Yeah, thanks for considering me, I appreciate it! Alright, thank you!

Outro:

AKB: We would like to give special thanks to Christof Teuscher for developing this program and giving us this opportunity to learn new skills and create a project that will positively impact our community. We would also like to thank MacKenzie Gray, Program Coordinator, for the consistent support she has given us during these past 8 weeks. We would like to thank Lisa Mariott, our faculty mentor, for her help connecting us to data and articles regarding COVID and infectious disease spread. Finally, we would like to thank Wayne Wakeland, Alexander York, and Merlin Carson for their support with our agent-based modeling approach.

JK: Thank you once again for listening, we hope you learned something. We've definitely learned a lot during these past 8 weeks. If you have any questions, comments, ideas about ways to expand our model in the future, we'd love to hear it. Please feel free to reach out and let us know what you think. Thank you very much!