Dr Björn Birnir

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SARS-CoV-2 coronavirus: How it spreads in confined spaces

Research Objectives

Developing new mathematical tools that open the theory of turbulence up to theoretical investigations, leading to real-world applications.

Detail

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Bio
Björn Birnir has been a Professor of Mathematics at the University of California in Santa Barbara since 1984, and Director for the Center for Complex, Nonlinear Science and Data Science (CNLS) since 1998. He is a Fellow of the American Association for the Advancement of Science and in 2013 became Editor in Chief of the *International Journal of Nonlinear Science and Numerical Simulations*.

Funding
University of California, Santa Barbara

Collaborators
- Colleagues from the University of California at Santa Barbara: Joe Incandela, Vice Chancellor for Research, Dept of Physics
- Scott Grafton MD Campus COVID-Mitigation Program Manager, Dept of Psych & Brain Sciences
- Jordan Sager PE, Energy Manager, Facilities Management, Design Facilities and Safety Services

References

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Personal Response

If a venue is unable to implement all the changes identified, how might the model help people prioritise the benefit of taking different actions, for example improving air conditioning versus reducing number of customers?

" We can use the program to plot the number of people that can safely be inside the restaurant versus the ventilation in the restaurant, measured in air exchanges per hour (ACH), in the restaurant (see Figure 2). ACH measures how often the air in the restaurant is completely replaced by fresh or filtered air in one hour. We need to know the size (volume) of the restaurant and the how large a percentage of the population has been vaccinated. Let us assume that the restaurant has the volume 125 cubic meters (or roughly 4,400 cubic feet). This restaurant, with the height of the ceiling 2.5 meters, could contain 50 guests under normal conditions. "

SARS-CoV-2 Coronavirus

How it spreads in confined spaces

The transmission of SARS-CoV-2 Coronavirus (COVID-19) is an important research subject for public health. It is now known that airflow plays a large role in transmitting Covid-19. Professor Björn Birnir, Director of the Center for Complex, Nonlinear and Data Science at the University of California at Santa Barbara (UCSB), studied how airflow transmits COVID-19 in confined spaces. He created a model that predicts transmission rates in any given public space. The results can be used to alter real-life spaces to reduce COVID-19 infection rates.

At the start of the outbreak of SARS-CoV-2 Coronavirus (COVID-19), it was thought that the virus mainly spread through coughing and speaking, hence global public health advice to stay 2 metres (6 feet) apart. However, it was later discovered that droplets containing COVID-19 could travel via a turbulent cloud up to a distance of 7 to 8m when an individual violently coughs or sneezes. Even more crucially, it has been shown that transmission via small droplets and aerosols (a suspension of particles dispersed in air or gas) plays a larger role in transmitting the virus. COVID-19 contaminated aerosols can spread from an infected person simply breathing and can build up in a confined space with poor ventilation over time. As we begin to return to normal life and indoor public spaces, it is vital to ensure the transmission of COVID-19 is minimised. Professor Björn Birnir of the University of California, Santa Barbera (UCSB) has developed a computer model that unlocks the door to safer public spaces.

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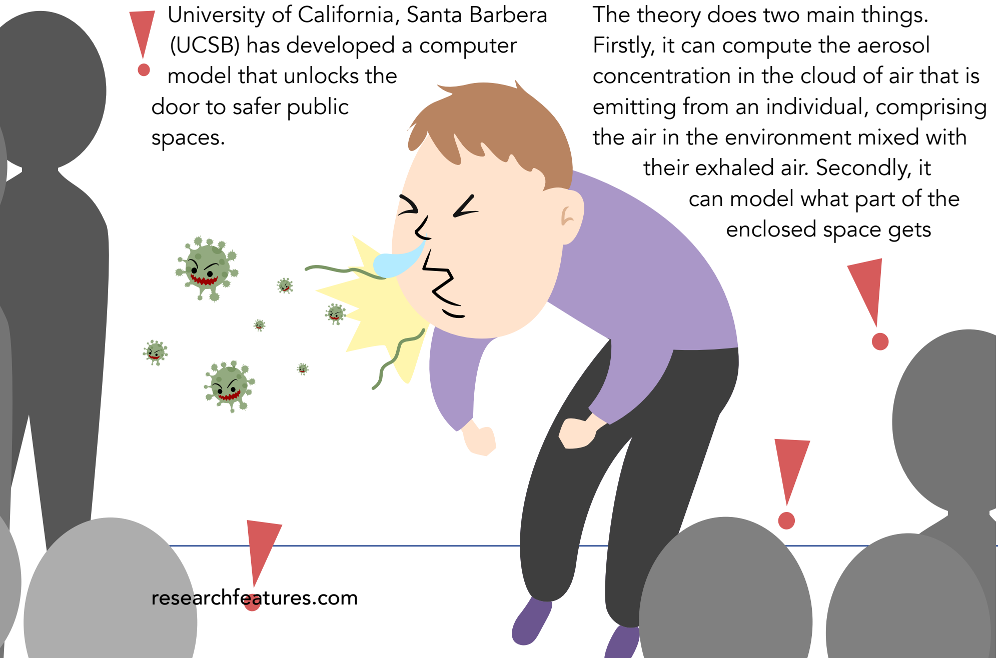

To model how COVID-19-laden aerosols disperse through an environment, it was first necessary to figure out how respiratory droplets and aerosols travel in the air. This is complicated because airflow is naturally very turbulent and hard to simulate, so applying computational fluid dynamics becomes labour-intensive and time-consuming. However, there is another mathematical theory that can be applied to the problem: the so-called Lagrangian theory of passive scalars. This theory explains the distribution of particles that are too small and light to disturb the airflow. It was developed by theoretical physicists 50 years ago and has been used successfully to compute the distributions of many different types of airborne particles, without disturbing the airflow itself. Now, Professor Birnir has used the theory to model COVID-19-laden aerosols.

The theory does two main things. Firstly, it can compute the aerosol concentration in the cloud of air that is emitting from an individual, comprising the air in the environment mixed with their exhaled air. Secondly, it can model what part of the enclosed space gets contaminated, and the concentration of the aerosol in that space.

WHY MODEL AEROSOL TRANSMISSION?

There is mounting evidence that aerosol transmission is a large source of contagion in confined spaces. One of Professor Birnir's studies looking at a COVID-19 outbreak in a restaurant in Guangzhou, China, shows that three families were all infected by one person in the restaurant. One family, including the infected individual, had travelled from Wuhan (the epicentre of the pandemic). The three families were all seated directly in the airstream of the air conditioner, and only individuals sitting in this airstream fell ill. No other customers or restaurant staff fell ill with COVID-19, and so these results are consistent with droplet and aerosol transmission theories.

After modelling the restaurant's conditions, accounting for the size of the restaurant, where the infected person was sitting, the velocity of exhaled breath, air conditioning wind speed, amongst other parameters and physical laws, Birnir carried out a simulation of the dispersion of the droplets and aerosols in the restaurant. The study showed how within the confined space, which had poor ventilation, the concentration of the aerosols increased significantly within one hour, most likely causing the outbreak. This increase in the concentration is greater and faster (quadratic in time), than previously anticipated, when there is little or no ventilation in the confined space.

This computer model is an important new tool for computing the risk of COVID-19 in a public space. The model acts as a catalyst to develop protocols to reduce the probability of infection in the real world.

REAL-WORLD IMPLEMENTATION

Modelling the restaurant in Guangzhou gives important information on how to improve the restaurant in the future. Using the model, it was calculated that five times the recommended air injection would have been needed to make the contaminated area safe. Vents should have been open, and heating could have been lower to prevent the evaporation of small drops into aerosols. Implementing the results of the model to the real world has the potential to reduce COVID-19 infections.

The computer model has been employed at the UCSB Library to create safe working environments for the students. The program calculates the concentration of droplets, the probability of infection, and the probability that one person in the room is infected (see Figure 1). All that needs to be inputted into the program is the volume of the room, the air exchange rate of the room, the number of infectious persons in the room, whether everyone wears a mask, how many people are in the room, and if people are at rest or exercising.

With this information, it was calculated how many students could safely work in the library, and how long they could safely spend there. The model also calculates how long it would take ventilation to clean the room once an infected person has left. The model points to changes that could be made in ventilation and how air conditioning units can be improved, for example, increasing their effectiveness to filter microscopic particles. As well as the library, theatre and dance studios, art studios, brain-imaging clinics, physics machine shops and laboratories at UCSB have all been studied. The model is being implemented in the real world to make indoor spaces safer for everyone.

LOOKING TO THE FUTURE

There is no reason that this model cannot be implemented further to all indoor spaces. It offers a lifeline to places that have to be open in our modern world as we aim to return to normality. Libraries, restaurants, cafes, offices, theatres, and buses would all benefit. The application of the model could be vital to get our workplaces, transport, and leisure activities back, before the rollout of the vaccine is sufficient to supress infections. The library at the UCSB stands as a beacon of hope for the rest of the world; a working indoor public space, based on the model, providing the opportunity to students to pursue their education, whilst dramatically reducing SARS-CoV-2 coronavirus contagion rates.

You can visit the library's website here: https://www.library.ucsb.edu/

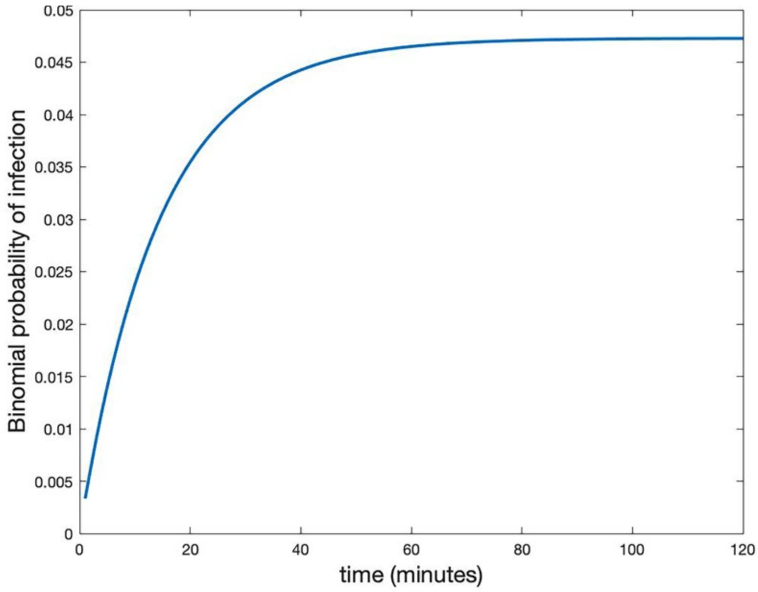

Figure 1 shows the probability of COVID-19 infection in an indoor space over a period of time.

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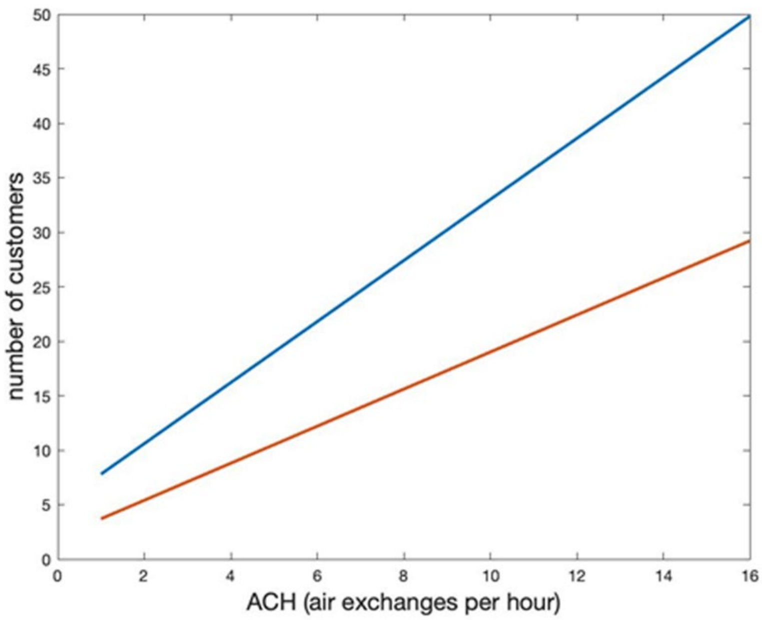

Figure 2 shows the number of customers that can safely be in a restaurant, that can have 50 customers under normal conditions. The number of customers is on the vertical axis and the ventilation, measured in ACH, on the horizontal axis. The blue line shows the number of customers when 70% of the population has been vaccinated, the red line when 50% of the population has been vaccinated. Safe means that the probability of infecting 2 customers in two hours is 10% or less.


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