Modelling the effect of adherence behaviour on infection spread in crowds

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Abstract People's adherence to health measures significantly impacts the spread of infectious diseases. Using a crowd dynamics model for simulating infection spread, we model varying adherence levels for mask-wearing and physical distancing, looking at adherence of infectious and susceptible agents separately. We find that mask-wearing is highly effective in a direct manner, while adherence to physical distancing can indirectly change the infectious agent's behavior which then has surprising effects on infections spread.

Keywords Infection modeling, Adherence behaviour, Infection prevention measures, Crowd modeling

Simulating how people's adherence influences infection spread

In this work, we want to connect infection modelling with people's behaviour, since the effectiveness of measures strongly depends on people's compliance. To our knowledge, this has not been explored in small-scale contexts. We argue, that combining these fields can improve our understanding of how to manage and predict the spread of infectious diseases based on human behavior.

Our model builds on the transmission framework by Rahn et al. [1, 2], incorporating agents — either infectious or susceptible — navigating from an ingress to a destination. Infectious agents exhale aerosol clouds that impact susceptible agents who may inhale these aerosols. One can then measure the exposure of susceptible agents for different conditions.

In this work, we simulate a scenario to examine the impact of varying adherence levels for two measures: physical distancing and mask-wearing. We aim to determine which adherence levels are needed to effectively control disease spread. Additionally, we explore the impact of an infectious agent's adherence compared to other agents and whether proper mask-wearing can replace the need for physical distancing.

We simulate a bottleneck scenario, shown in Figure 1, representing an entrance, exit, or food court at a sports event, with 100 susceptible agents and one infectious agent. Each agent spends 15 seconds at the target, simulating ticket control, bag checks, or food ordering. Physical distancing is set to 1.5m, and mask filtration efficiency to 90%.

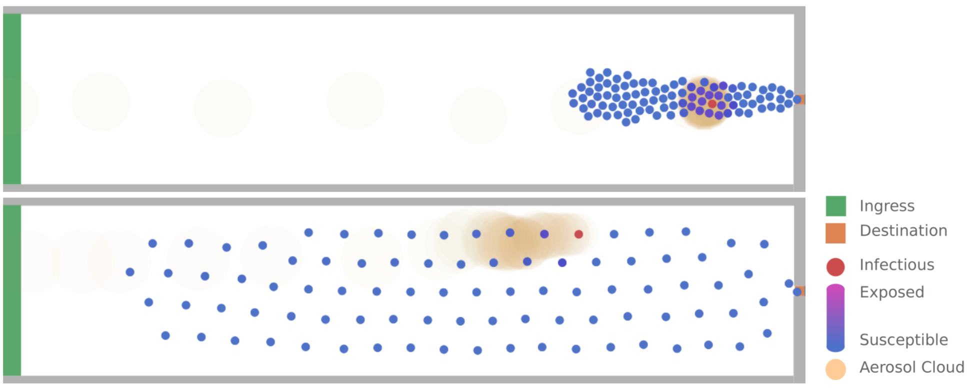

Figure 1: Bottleneck scenario with and without physical distancing.

Figure 2 depicts the average pathogen exposure of all agents in the bottleneck scenario, considering adherence probabilities of 0%, 50%, and 100% for susceptible agents, each condition with and without

*Email of the corresponding author: sophia.wagner@hm.edu adherence by the infectious agent. For mask-wearing, exposure levels appear to decrease linearly as the adherence probability of susceptible agents increases. When all susceptible agents wear masks, exposure is reduced by a factor of 10 compared to scenarios with no mask use. The effect is even more substantial if the infectious agent wears a mask, decreasing exposure by a factor of 10 with only their adherence. Overall, when both susceptible and infectious agents wear masks, exposure can be reduced by a factor of 100.

For physical distancing, when the infectious agent does not adhere, exposure levels decrease as adherence probability increases. Interestingly, when the infectious agent adheres, the opposite occurs. This counterintuitive observation occurs because the adhering infectious agent changes its behavior by moving away from non-adhering susceptible agents to avoid close contact, thus preventing others from walking into its aerosol clouds. Conversely, if other agents also adhere, the infectious agent remains within the group, allowing others to pass through their aerosol trace. Therefore, the greatest effect is observed when the infectious agent behaves differently than the group, either fully adhering while the group does not or vice versa.

In conclusion, the most significant impact occurs when both the infectious agent and all susceptible agents wear masks. On the other hand, adherence to physical distancing can alter behavior based on awareness of infectiousness, and it is 20 times less effective than mask-wearing when everyone complies.

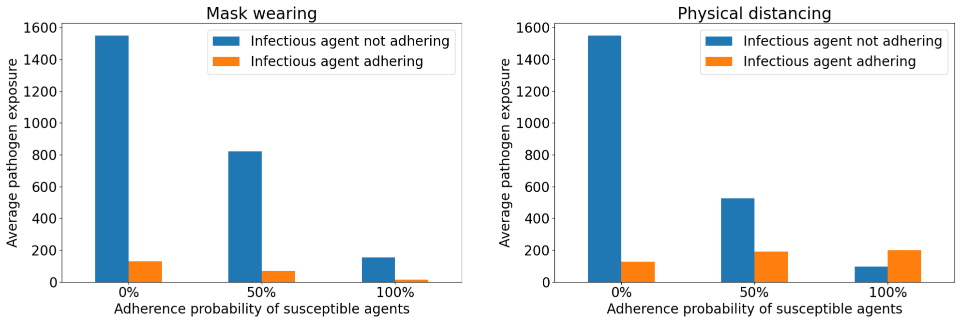

Figure 2: Average pathogen exposure for susceptible agents in the bottleneck for mask wearing (left) and physical distancing (right) for different adherence levels.

In the future, we plan to incorporate survey data on adherence at sports events, influenced by clarity of instructions, personal risk perception, shared social identity, and compliance of other people around. By combining infection modeling with crowd psychology, we aim to understand how these psychological elements influence adherence to Covid-19 guidelines and, consequently, disease spread. These insights are essential for developing effective public health strategies that reflect real-world behaviors.

References

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