Modelling behavioural influences on pathogen exposure in crowds

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Abstract Human behaviour strongly influences disease transmission, yet most infection models neglect the effects of social influence. We use a local-scale infection model in which each agent's adherence to mask-wearing is sampled from survey data. The data contains information on how adherence is affected by the behaviour of a role-model group and also the agent's shared social identity (SSI) with that group. Results show that high SSI amplifies the effect of non-adherent role models, increasing exposure, whereas low SSI reduces it.

Keywords Infection modelling, Adherence, Shared social identity, Mask wearing, Crowd simulation

Simulating the effect of shared social identity and adherence of others on infection spread

Human behaviour critically shapes infectious disease transmission, yet many local-scale models still neglect behavioural dynamics. In our previous work [1], we demonstrated that heterogeneous adherence to mask-wearing and physical distancing substantially alters exposure patterns in crowds, highlighting the need to integrate empirical behavioural data into pedestrian simulations. Building on this foundation, we now investigate how factors influencing adherence, in particular shared social identity (SSI) and observed adherence of others, affect pathogen exposure in a crowd setting.

We use an exposure model, developed by Rahn et al. [2] and implemented in the crowd simulation software Vadere [3], in which agents move from an ingress to a destination while an infectious agent emits aerosol clouds that may be inhaled by susceptible agents. Mask-wearing reduces exposure: if a susceptible agent wears a mask, we reduce the number of inhaled pathogens by 90%. If an infectious agent wears a mask, we reduce the number of exhaled pathogens by 90%. The mask efficacy is taken from [**?**]. In the simulations we present here, the infectious agent never wears a mask, because otherwise no susceptible agent would become highly exposed, making adherence of susceptible agents irrelevant. This allows us to quantify each susceptible agent's exposure under varying behavioural conditions and to identify the number of agents at high risk.

To parameterise behavioural responses, we draw on survey data from Templeton et al. [4], collected as part of the UK Government's Events Research Programme. The survey of 2,502 attendees of different sports and music events assessed perceptions of COVID-19 guidance and factors influencing adherence. The data show a clear social influence effect: seeing others adhere increased one's own adherence, while observing non-adherence reduced it. This effect was particularly strong among frequent attendees, who typically exhibit higher shared social identity with fellow attendees, i.e. a sense of belonging to a common group.

While our earlier work [1] focused solely on heterogeneous adherence levels, we now model the drivers of adherence. Specifically, we examine how SSI and the adherence behaviour of a "role-model group" influence mask-wearing decisions and therefore exposure.

We simulate a ticket-checkpoint scenario with 100 susceptible agents and a single infectious agent (Fig. 1). First, a role-model group (20 agents) passes through the checkpoint, either fully adhering or fully not adhering to mask-wearing. Next, an imitating group (80 agents), including one infectious agent, enters. These agents identify to a certain degree with the role-model group, measured throug a parameter

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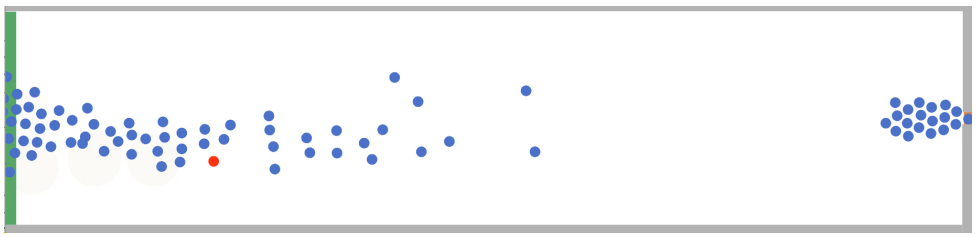

Figure 1: Agents move toward a ticket checkpoint on the right. Susceptible agents are shown in blue, infectious agents in red, who emit aerosol clouds (light orange). A small role-model group is already at the checkpoint, with an imitating group entering afterwards.

called SSI, that is, shared social identity. Given each agent's own SSI and observed behaviour of the other group, we sample the agent's mask-wearing probability from the survey data.

Fig. 2) shows that, for the event in [4], when the role-model group fully adheres, adherence in the imitating group remains high regardless of SSI. As a consequence, the number of highly exposed agents stays very low (around 1). However, when the role-model group does not adhere, SSI becomes the decisive factor. For low SSI, imitating agents still tend to adhere and exposure remains limited (around 4 highly exposed agents). In contrast, for high SSI, the imitating group mimics the non-adherence of the others, and the number of highly exposed agents increases significantly (around 12 on average). This reflects real-world contexts where individuals imitate behaviour of in-group members, such as fans aligning with other people supporting the same team.

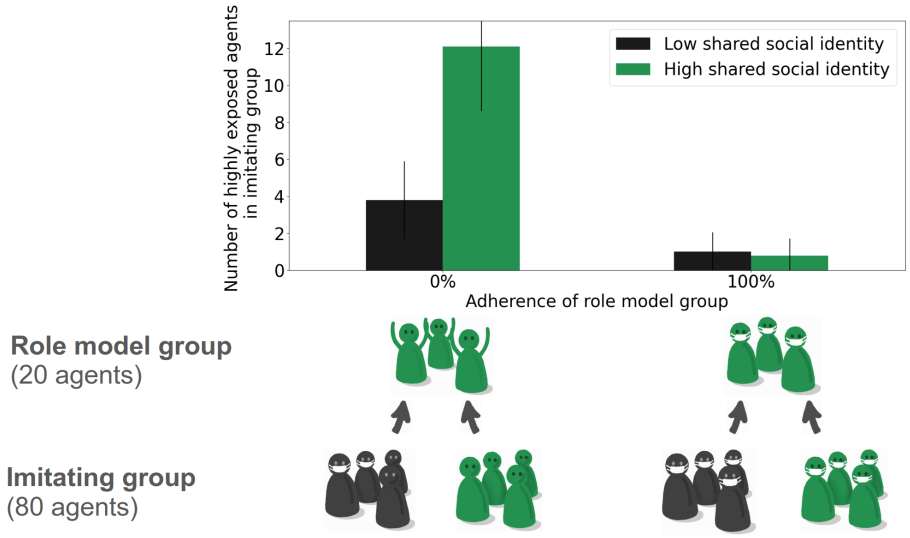

Figure 2: The number of highly exposed agents in the imitating group depends on the adherence of the role-model group and the shared social identity between groups.

Our findings indicate that shared social identity amplifies the effect of obeserving other individual's non-adherece to mask-wearing and, consequently, increases infection risk. This highlights the importance of considering social dynamics when designing interventions to reduce exposure at crowded events.

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