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SUMMARY
We conducted tracer gas experiments in three connected nursery rooms to track simulated exhaled air trajectories and mixing. We emulated exhaled air with a pulse release of ethanol and measured its concentration with 2s time resolution with spatially distributed metal oxide sensors in both the upper and occupied levels of the room. We found that the overhead cooling supply air enhanced vertical air mixing within the rooms. When a room had higher supply airflow than the others, the tracer gas mixed quickly in that room because the supply air dominated the room mixing, thereby isolating it from air mixing with the other rooms. When the forced air system was not operating, the tracer gas resided longer in the upper room before descending. The tracer method also depicts air trajectories from different release locations by detecting the release point and affecting nearby sensors. These experiments support the potential of this method to be used in the field for understanding air trajectories in rooms with upper-room GUV.

KEYWORDS
Airborne Transmission; COVID-19; Childcare; Exposure; Field Study

1 INTRODUCTION
Germicidal ultraviolet (GUV) disinfection is an established engineering control strategy for reducing infectious bioaerosols (ASHRAE, 2023). Upper-room GUV inactivates airborne pathogens as exhaled air transports to the upper room. Although upper-room GUV is shown to be effective, (Noakes et al., 2006), it remains unclear if exhaled air moves directly to the upper room before mixing at the occupied level in real-world settings. There is also not an established method to test its performance in real buildings.

2 METHODS
The field experiment was conducted in three identical nursery rooms (4.5 m × 5.2 m × 3 m rooms) in Austin, Texas, connected by pass-throughs. Three rooms (Rooms 101, 102, 103) are connected in a row between 101 and 102 and between 102 and 103, with 1.9 m wide pass-through openings in the walls between at heights of 0.8 - 2.1 m. The rooms were mostly filled with nursery toys and furniture, with one researcher present for the purpose of releasing tracer gas. GUV was installed on one side of the room at a height of 2.6 m. Each room included one supply and one return register at the ceiling.

To emulate exhalations, we pulse-released the ethanol by injecting and evaporating the ethanol on a hot surface of a heat block. To track the air trajectories, we measured its concentration at 2s resolution with spatially distributed metal oxide sensors in both the upper room and the occupied level. Before starting the test, we cross-calibrated the sensors in an enclosure with a fan inside to create a well-mixed condition and injected ethanol.

The experimental procedure followed these steps. Prior to releasing the ethanol, we waited for complete mixing to establish a reference starting point. Ethanol was then released in short bursts at a potential source location in the room. Tracer concentrations were measured at 2s intervals for approximately 30 to 40 minutes. After each release, we waited for mixing to complete before initiating the next release.

3 RESULTS AND DISCUSSIONS

One of the main findings from the study is that the overhead cooling supply air enhanced air mixing both vertically and within the connected rooms. When the HVAC system was off, the readings from the two sensors in the upper room were significantly higher than the other sensors' responses for two minutes, with a slower and later impact on the sensors at the occupant level. Conversely, when the HVAC system was on, the tracer gas reached the occupant level faster, and both vertical mixing and mixing between connected rooms were quicker. Additionally, higher room air speed induced by the supply airflow rate accelerated both vertical mixing and mixing between connected rooms.

The tracer method enables tracking of different air trajectories and mixing based on overhead cooling supply air and also depicts air trajectories from different release locations. When released in various locations or rooms, we could detect the release point and observe the tracer gas moving upward and affecting sensors nearby. When the tracer gas was released in room 103, it traveled to the occupied level in Room 102 after 1 minute with minimal impact on room 101. Releasing in Room 102 near the pass-through to Room 101 impacted Room 101 and releasing near the pass-through to Room 103 impacted Room 103.

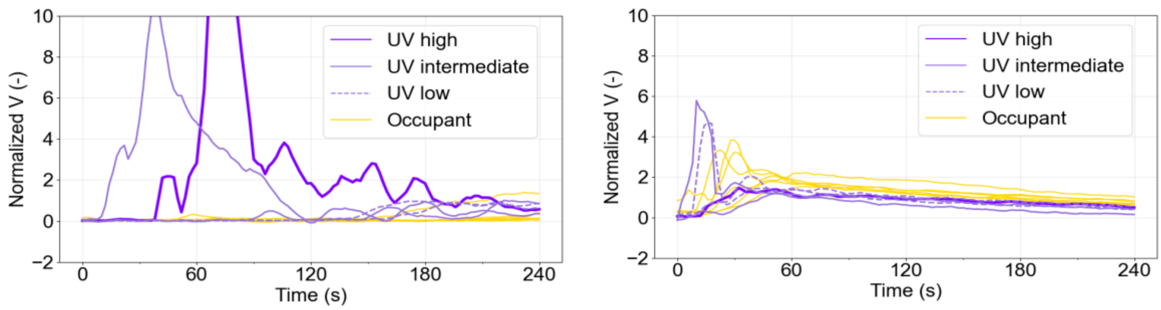

Figure 1. Left: Sensor response after ethanol is released when overhead cooling supply air is off. Right: when overhead cooling supply air is on.

4 CONCLUSIONS

These experiments support the potential of this method to be used in the field for understanding air trajectories and mixing in rooms with upper-room GUV.

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5 REFERENCES

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Noakes et al., 2006. *Indoor and Built Environment*. 15(4): Use of CFD modelling to optimise the design of upper-room UVGI disinfection systems for ventilated rooms.