Hybrid measurement of respiratory aerosol reveals a dominant coarse fraction resulting from speech that remains airborne for minutes

Yang Shen, Joseph M. Courtney, Philip Anfinrud and Adriaan Bax

Laboratory of Chemical Physics, NIDDK,

National Institutes of Health, Bethesda, MD, 20892-0520, USA

SI Text

Aerosol detection chambers. Chamber 1 contains two separate speaker ports at the front side of the chamber, S1 and S2. The ceiling of the chamber is removable but sealed to the chamber by high density foam rubber. Each inlet port consists of a 4.5 cm inner diameter (ID) carbon fiber tube with a wall thickness of 1.6 mm, closed by a cone-shaped removable stopper, lightly coated with vacuum grease. The upper port of chamber 1 is centered 56 cm above the bottom of the chamber and the tube is 3.9 cm in length. A muffin fan is mounted inside the chamber, 10 cm below the upper port and 12 cm away from the wall, operating at an adjustable flow rate of 3-20 $L.min^{-1}$ to promote rapid mixing of expired air with the contents of the chamber and to prevent condensation on the walls. The fan, operating at a flow rate of 12 $L.min^{-1}$, was typically shut off 20 seconds after emission of droplets into the chamber, prior to the start of the actual measurements. The interior of the chamber is connected to an external thin polyethylene bag with a maximum capacity of 15 L that serves as an overflow reservoir when expiring air into the chamber. The chamber is covered in thermal insulation but can be heated externally, on the inside of the insulation, with the internal chamber air temperature monitored by two thermocouples mounted near the top and bottom of the chamber.

The bottom speaker port, centered 19 cm above the bottom of chamber 1, is co-axial with the observation port on the rear wall of the chamber, behind which a SONY alpha SII camera equipped with a FE 24-mm, F1.4 GM lens is used for recording video images. A single-pane, anti-reflective coated glass window separates the camera from the interior of the chamber. The bottom inlet port extends 18.5 cm inside the chamber, to 7.5 cm away from, and orthogonal to, the vertically

polarized sheet of laser light that enters and exits the chamber through anti-reflective coated glass windows, mounted at Brewster's angle on the side walls of the chamber (Fig. 2A).

The light source was a blue light (450 nm) PWM/TTL laser engraving module with an adjustable optical power of 0-6 W. Three cylindrical lenses were used to generate a thin (~0.7 mm) sheet of bright laser light that traversed the chamber. In the high-speed, 120 frames.s^{-1} video recording mode, a rectangular section of the light-sheet (51.0 × 90.7 mm) is observed, corresponding to a volume of *ca* 3 cm^{-3}.

Chamber 2 differs from chamber 1 as follows. Chamber 2 lacks thermal insulation and contains only a single speaker port, S, centered 60 cm above the bottom. The same SONY camera and lens used for chamber 1 are mounted at the center of the removable top lid, facing down. The light-sheet is horizontal and enters and exits the chamber *ca* 5 cm above the floor and has a thickness of 13 mm and a width of 30 (36) cm when it enters (exits) the chamber, *i.e.* covering nearly the entire horizontal cross section of the chamber.

Each chamber contains a Honeywell HIH-5030 humidity sensor, positioned near the rear bottom of the chamber. For all measurements, the temperature in the chamber was 21±1 ºC. Between measurements, the air in the chamber was refreshed at a rate of 40 L.min^{-1} for at least 15 minutes, with the internal muffin fan running at its maximum speed, and the laboratory supply air, dried to a RH of *ca* 1%, filtered through a Prep-Air® II coalescing air filter (0.01 μm particle rating; Parker Hannifin Corp.) and a Numatics C14D-01 pneumatic filter-regulator (.3 μm particle rating; www.nriparts.com).

Breath volume measurement. The total volume of exhaled breath, $n \times q$, was derived from the change in relative humidity, ΔRH, in the chamber before and after breathing:

$$\Delta RH = \{p/(p+q)\}^n \, RH_{before} + [1 - \{p/(p+q)\}^n] \, RH_{breath} \} - RH_{before} \qquad [5]$$

where RH_{before} is the relative humidity before breathing, p is he volume of the chamber plus the overflow bag, n is the number of breaths (n=1 for most measurements), and q is the volume of expired air in each respiratory activity. RH_{breath} = 200% is the relative humidity of exhaled breath converted to room temperature (21 ºC), assuming the absolute humidity of exhaled breath is 36.7 mg.L^{-1} (1). Exhaled breath volumes derived this way agree to within 5% with those recorded on a ndd Medical EasyOne™ air spirometer (https://mfimedical.com), acquired after most measurements were completed.

Decompression and linearization of video recordings. The 128 Gb memory card of the SONY alpha SII camera limits the capacity to store RAW image format data and all video images therefore were recorded in SONY's compressed XAVC S HD format. As is the case for all consumer product video recording equipment, the ADC has a very limited dynamic range, corresponding to 11 bits. All videos were therefore recorded in the SONY S-log3 mode to obtain the maximum dynamic range. S-log is a logarithmic gamma curve, designed to record and transmit as much of the information recorded by the camera's sensor as possible in a compact 8-bit format, allowing for adequate reproduction of light across a wide intensity range. The FFmpeg program (https://ffmpeg.org/) was used to restore each frame to a 1920 × 1080 matrix format and only the blue intensity was retained. When videos are recorded using the S-log3 setting, pixel intensities that are stored after a logarithm conversion from the raw sensor readings need to be regraded in the post-production process. The conversion is applied using the SONY-provided equation, which translates the recorded S-log3 intensity, I_{Slog3}, to a reading that is approximately linear in terms of photon counts (2), I_{linear}, according to:

$$I_{linear} = \begin{cases} 8 \times \left(e^{\frac{I_{Slog3}-21.403}{28.392}} - 1\right) & I_{Slog3} > 42 \\ 0.4723 \times \left(I_{Slog3} - 23.75\right) & I_{Slog3} \leq 42 \end{cases}$$

where I_{Slog3} has an integer value in the range from 24 to 255, with the converted I_{linear} values falling in a range from 1 to 30,000.

References

1. J. M. Courtney, A. Bax, Hydrating the Respiratory Tract: An Alternative Explanation Why Masks Lower Severity of COVID-19. *Biophys. J.* **120**, 994-1000 (2021).
2. SONY https://download.pro.sony/FNGP/protein/1237494271390/1237494271406.pdf.