Silent but deadly? Physics says seldom, memory says mostly

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Abstract

The belief that a silent passage of flatus smells worse than an audible one appears in many languages but is untested. We follow a passage from sound through dispersion to a bystander's memory with a lip-reed model of the anal valve, dispersion models and observer models from the literature. Most releases, 85%, never set the valve oscillating. We prove that under linear transport a slower release of the same gas cannot give a higher peak, in any room or flow. In computational fluid dynamics of seated and standing people, the warm air rising along the body takes a slow release and lets a fast one pass, so momentum decides which nose a release reaches. With passages as emitted and settings weighted by how often people share them, a bystander finds the silent passage worse in 0.5% of pairs and the audible one in 6.9%; only in a closed lift are the two about equal. A silent passage is noticed only if smelled, and this selection alone can explain the belief: among remembered pairs the silent passage seems worse in 88%. It predicts that releasers hold the belief less firmly than bystanders and that anosmic people never remember a silent passage.

Keywords: convective boundary layer; indoor air; odour dispersion; starting jet; Berkson bias; olfactory perception; flatus

1 Introduction

In the film *3 Idiots* [1], a student, Chatur, nicknamed "Silencer" produces silent but foul flatulence and, in one scene, declares the silent release the deadliest. The belief behind the joke is old. An 1811 slang dictionary defines a related term as an escape "more obvious to the nose than ears" [2], and English has called such releases "silent but deadly" since at least 1970 [3]. A documentary survey of 32 languages (Section S10) finds the distinction between silent and loud releases lexicalised in at least five language families. The claim that the silent release smells worse is stated explicitly in Chinese and English sayings, and it is built into the definitions of smell-specific "silent" words that arose independently at least four times within Indo-European.

We found no test of the claim. The odour of flatus is well characterised: hydrogen sulfide, methanethiol and dimethyl sulfide carry most of it [4, 5], and the volume of a passage does not predict its sulfur content [6]. Its sound has been attributed to vibration of the anal skin, like the buzzing lips of a brass player [7], but no peer-reviewed study has measured it. The only data relating sound to smell are informal and not peer reviewed: in 1 619 recorded passages, louder ones were very slightly smellier by a gas-sensor reading ($R^2 = 0.016$), and none was silent [8]. Their direction agrees with what we find, but they cannot test a claim about silent passages and human noses.

The question is narrow, but answering it needs three results that are not specific to flatus.

- *Where does a release next to a body go?* The warm convective boundary layer around a person rises along the body to the breathing zone [9, 10] and carries pollutants released near the body with it [11]. Source location governs exposure when room air mixes poorly [12]; a source at a seated person's groin gives a breathing-zone intake fraction of 5–10 per mille [13]. CFD can follow particles shed from skin and clothing in this flow [14].

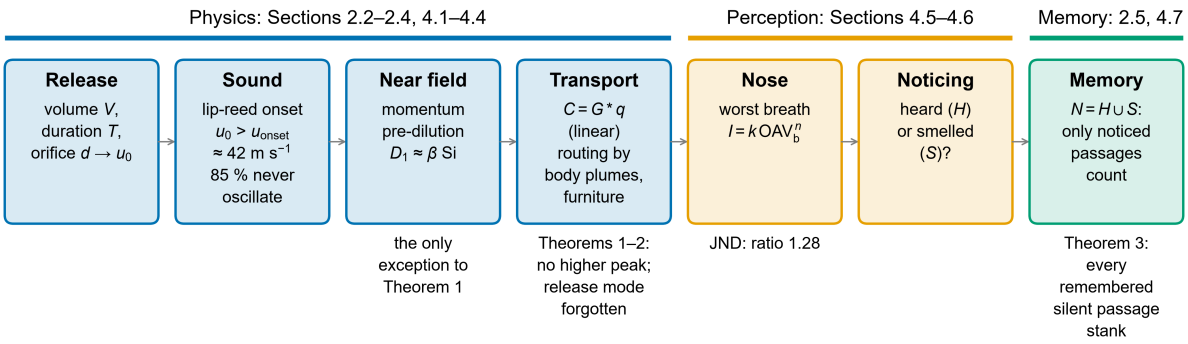


Figure 1: From release to memory: the quantity each stage passes on, and where Theorems 1–3 apply.

These studies concern passive sources and the occupant's own exposure. We show that the momentum of a release decides whether the boundary layer takes it, and so which of several nearby noses it reaches.

- *Can a slower release give a higher peak?* We prove that under linear transport it cannot, in any room, posture or flow. A slower release can win only in the non-linear near field, by a factor bounded by a velocity ratio.

- *How can a sensory belief arise that the physics does not support?* When an event can be noticed through either of two senses, selecting the noticed events makes the two senses appear related (Berkson's bias [15, 16]). We show that this selection alone can explain the belief in a population where it is false, and we derive predictions that can test this explanation.

Both halves of the claim are also ambiguous. A release can be silent because it never sets the anal valve oscillating, or because background noise masks it. "Deadlier" can mean a higher peak at a nose, a larger total dose, or a stronger memory. The comparison can be between the same gas released in two ways (equal mass), between passages as they are actually emitted, or between the passages an observer happens to notice. These bases give different answers, and we keep them apart throughout (Section 2.1).

We follow one passage from its chemistry through sound and dispersion to memory (Figure 1). Chemistry fixes which odorant carries the smell, what sets the buoyancy of a passage, and whether the odorants survive the trip to a nose. A lip-reed model of the valve gives the share of releases that are physically silent. Two theorems bound what linear transport can do to the silent/audible ratio; an analytic model of starting jets and puffs, checked against canonical jets and body plumes, gives the ratio over the range of releases; and computational fluid dynamics (CFD) of two people on a sofa, four in a lift and two standing face to face shows where the body's own airflow takes each release. A third theorem and literature models of observers give how often a remembered silent passage seems the stronger one.

2 Definitions and theory

2.1 What "deadlier" means

A passage is a release of volume V over a duration T through an effective orifice of diameter d, with exit velocity $u_0 = 4V/(\pi d^2 T)$. We take its *deadliness* for a given person to be the perceived

intensity of the worst single inhalation,

$$I = k\,\mathrm{OAV}_\mathrm{b}^{n}, \qquad \mathrm{OAV}_\mathrm{b} = \max_{\text{breaths}} \frac{\int_\mathrm{insp} \dot{V}_\mathrm{insp}(t)\,\mathrm{OAV}(t)\,\mathrm{d}t}{\int_\mathrm{insp} \dot{V}_\mathrm{insp}(t)\,\mathrm{d}t}, \tag{1}$$

where $\mathrm{OAV} = \sum_i c_i/c_{\mathrm{th},i}$ is the summed odour activity value of hydrogen sulfide, methanethiol and dimethyl sulfide at the nose and n is the Stevens exponent. The breath is the natural unit: perceived intensity saturates within one natural sniff [17], still integrates within it [18], and the sniff is a unit of olfactory processing [19]. A passage the person does not smell has deadliness zero, so I applies only above their detection threshold.

Every comparison below states its basis:

(A) *equal mass*: the same gas, released quietly or loudly;

(B) *as emitted*: silent and audible passages drawn from their own volume and momentum distributions, in the settings where people meet them;

(C) *as remembered*: only the passages an observer noticed.

Folk experience is basis (C). Physics answers (A) and (B). On bases (B) and (C), a pair of one silent and one audible passage has four outcomes for a given person: neither is smelled, the silent one is worse, the audible one is worse, or they cannot be told apart (concentrations within the just-noticeable ratio, Section 3.5; since I rises monotonically with OAV, this is the same as a tie in intensity). The headline is the share of each outcome; ties are not split.

2.2 Linear transport bounds the silent advantage

Odorants at sub-ppm levels are a passive scalar: the air carries them without being affected by them. Once the release has lost its own momentum and buoyancy, the concentration at a fixed nose is a linear functional of the release history $q(t)$ (volume of flatus per unit time):

$$C(t) = \int G(t-s)\,q(s)\,\mathrm{d}s = (G * q)(t), \qquad \int q\,\mathrm{d}s = V, \tag{2}$$

where the Green's function G encodes everything about the room, the bodies, the furniture and the ventilation. Time invariance of G requires the flow to be statistically stationary over the release, which holds for the quasi-steady convective boundary layers and room flows considered here.

Theorem 1. Let a silent release be a smoothed version of an audible one, $q_\mathrm{s} = q_\mathrm{a} * \kappa$ with $\kappa \geq 0$ and $\int \kappa = 1$. Then, for any G:

(i) the time-integrated dose $\int C\,\mathrm{d}t = V \int G$ is the same for both;

(ii) the peak concentration of the silent release does not exceed that of the audible one.

The proof (Appendix A) needs nothing about G beyond linearity, and it covers the breath-averaged OAV of Eq. (1) and releases stretched by any integer factor. In the linear regime, therefore, a quiet release can never be deadlier than a loud release of the same gas, whatever the posture, room or flow.

2.3 Release mode is forgotten

Theorem 2. In a closed room of fluid volume V_room whose air mixes, so that $G(t) \to 1/V_\mathrm{room}$ as $t \to \infty$, every release of volume V approaches $C = V/V_\mathrm{room}$, whatever its history q, and the ratio of two release modes tends to one (proof in Appendix A). Any difference between release modes is therefore carried by the early, near-field part of G.

2.4 Where the theorems fail: momentum and buoyancy

Equation (2) fails only near the source, where the release still carries its own momentum and buoyancy and so changes the flow that carries it. Two effects survive this.

Near-field pre-dilution. A momentum-dominated release entrains ambient air until its self-induced velocity has decayed to the ambient velocity u_h (the body's convective boundary layer or room air). For a starting jet, a puff or a steady jet alike, the dilution at that hand-off is

$$D_1 \approx \beta \frac{u_0}{u_h} \equiv \beta\,\mathrm{Si}, \qquad \beta = O(1) \tag{3}$$

(Appendix B). We call $\mathrm{Si} = u_0/u_h$ the *Silencer number*. With the nominal $u_h = 0.15\,\mathrm{m\,s^{-1}}$, an audible release ($\mathrm{Si} > 279$, the acoustic onset) arrives pre-diluted; a slow silent one does not ($\mathrm{Si} \approx 5$ for the slow reference release of Figure 3a and 23 for the median silent release of the simulations, Section 3.4). At equal mass, pre-dilution favours the silent release by at most the ratio of the two Silencer numbers.

Routing. Momentum also sets which flow the release joins, and different flows lead to different noses. This effect can favour either release. In the rooms of Section 4.4 it changes the ratio by more than pre-dilution does.

2.5 Selection biases what is remembered

Let H be the event that a passage is heard and S the event that it is smelled. An observer can only compare passages they noticed, $N = H \cup S$.

Theorem 3. Whatever the joint law of H and S,

$$P(S \mid \neg H, N) = 1, \qquad P(S \mid H, N) = P(S \mid H). \tag{4}$$

The proof is two lines (Appendix A). Among remembered passages, then, every silent one stank, while audible ones stank only at the base rate p_S, even when sound and smell are independent. The gap $1 - P(S \mid H)$ is largest when smelly passages are rare. This is Berkson's bias [15, 16]: selecting on an event that either of two causes can produce (here, noticing, produced by hearing or by smelling) makes the two causes appear related among the selected cases. Nothing in it is specific to flatus: any event noticed through either of two senses is remembered with this bias.

An observer whose noticing does not depend on smell has no such bias. The emitter, who feels every release, has N certain for all passages and so compares silent and audible releases at their true frequencies.

3 Methods

Every parameter, with its source, range and whether it is measured, derived or assumed, is listed in Table S4. Code and data are openly archived (Data accessibility).

3.1 Source

Passage volumes span 17–375 mL [6]; the median of the 16 subjects' mean passage volumes, computed from the same data, is 92 mL. In the Monte Carlo analysis, volume V, duration T (0.3–20 s) and effective orifice diameter d (1–8 mm) are drawn log-uniformly. Neither duration nor diameter has been measured for a passage; their upper bounds come from anorectal physiology (Section S2) and the lower bounds are assumed.

Sulfur gas concentrations are taken from 87 passages of 16 volunteers [4]: H_2S 1.06 µmol $\mathrm{L^{-1}}$, methanethiol 0.21 µmol $\mathrm{L^{-1}}$ and dimethyl sulfide 0.08 µmol $\mathrm{L^{-1}}$. They vary between passages by

a log-normal factor with $\sigma_{\ln} = 1.1$, derived from the reported standard errors, drawn independently of volume because sulfur concentration does not correlate with passage volume [6]. Buoyancy, computed from measured compositions, is likewise drawn independently of volume (Spearman -0.15 across the 16 subjects).

3.2 Odorants and sound

Details are in Sections S1 and S2. Each sulfur gas contributes an odour activity value, its mole fraction over its detection threshold; the passage's OAV is their sum (no mixture suppression). We compare two measured compositions [4, 5] under three threshold sets, from a trained panel [20] to population means [21]. Gas-phase losses use IUPAC rate constants [22] and office oxidant levels [23].

The anal canal is modelled as a lip reed, a soft-tissue valve that self-oscillates in the flow through it, as the lips do on a brass instrument [7]. It oscillates when the driving pressure $\frac{1}{2}\rho(u_0/C_\mathrm{d})^2$ exceeds a threshold of 0.6–2.5 kPa, bracketed by brass playing [24] and by oesophageal and tracheo-oesophageal speech, the closest measured soft-tissue sphincter source [25–27]. This gives an onset exit velocity of about $42\,\mathrm{m\,s^{-1}}$ (21–71). An oscillating valve radiates as a harmonic monopole with a fundamental of 160 Hz (60–300 Hz). A release counts as *audible* when a harmonic exceeds both the hearing threshold [28] and the masked threshold of the background, from a 35 dB(A) living room to a 77 dB(A) subway car.

3.3 Analytic dispersion model

Dispersion is modelled in two phases. In the near field the release behaves as a starting jet and then a puff, or as a buoyant thermal, until its self-induced velocity has fallen to the ambient velocity u_h (Appendix B). The cloud is then advected to the nose and spreads as a Gaussian puff, $\sigma^2 = \sigma_0^2 + 2Kt$, with indoor eddy diffusivity $K = 10^{-4}$–$1.3 \times 10^{-2}\,\mathrm{m^2\,s^{-1}}$ (measured in residences down to 10^{-3} [29]; the lowest decade is assumed for still air). Two receptors are modelled: the releaser's own nose, reached by the convective boundary layer, the layer of warm air rising along the body [9], at a speed taken from the CFD trajectories below; and a neighbour 0.8–1.4 m away, reached by room air. Concentrations are averaged over one inspiration.

We draw 20 000 pairs of silent and audible releases, each classified by the acoustic onset and evaluated with environmental parameters drawn from their ranges. Three simplifications favour the silent release: turbulent-jet constants are used even for laminar silent releases, the nose sits on the cloud centreline, and the centreline concentration is used.

3.4 Computational fluid dynamics

We use OpenFOAM 13 with transient Reynolds-averaged Navier–Stokes equations (RANS), the k–ω SST turbulence model, the Boussinesq approximation for buoyancy and the energy equation in internal-energy form.

Scenes (Section S4). Manikins built from geometric primitives, with skin at 33 °C, stand or sit in rooms at 23 °C:

- a sofa: two seated people 0.6 m apart in a $3.2 \times 3.2 \times 2.6$ m living room, with the releaser upright, reclined by 4.5 ° or leaning forward by 10 °;
- a lift: four standing people in a closed $1.4 \times 1.1 \times 2.1$ m car, fan off, with the releaser in the front row and a person behind;
- a standing pair: two people face to face, noses 1.0 m apart, in the same living room, in still air and with office ceiling ventilation at 2.9 air changes per hour (EN 16798-1 Category II [30]).

The upright sofa and both standing rooms are also run with long trousers on everyone: a porous shell over pelvis and thighs, 2 cm from the skin, with the air permeability of denim and open at the waist and hems.

Releases. Each room first runs 90 s without a release, until the body plumes have developed. Four representative passages are then released behind the releaser's buttocks, 30 s apart, each carried by its own passive scalar so that their doses can be read separately: the median and 90th percentile of the exit momentum flux $M_0 = \dot{Q}_0 u_0$ (volume flow rate $\dot{Q}_0 = V/T$) within each class of the source model (silent: 122 mL over 4.8 s at $u_0 = 3.5\,\mathrm{m\,s^{-1}}$, and 66 mL at $22\,\mathrm{m\,s^{-1}}$; audible: 86 mL at $94\,\mathrm{m\,s^{-1}}$, and 279 mL at $162\,\mathrm{m\,s^{-1}}$). Each enters as an inlet that carries the release's momentum and odorant flux (audible releases are pre-diluted with room air to fit the 1-cm inlet at the same M_0; Section S4), with its buoyancy as an equivalent temperature excess, and is followed for 150 s. Exposure after 150 s is taken from the well-mixed room level (Theorem 2). In two 10-minute runs of the sofa (one silent and one audible 92-mL release), this level is 0.67–1.00 times the worst breath found over the full 600 s. The odorant is sampled 2.5 cm in front of each nose over sinusoidal breathing cycles.

Peak factor. RANS gives the ensemble-mean concentration, while a nose meets filaments. Large-eddy simulations (WALE subgrid model) of the upright sofa, bare and in trousers, release the four representative passages once each and the two medians a second time, and give the ratio of the large-eddy to the RANS worst breath for each release and nose.

Validation (Section S3). A free round jet reproduces the canonical decay constants to within 10–16% (grid uncertainty 3.7%); the known over-spreading of k–ω SST over-dilutes audible releases by about 15% and so favours the silent release. The convective boundary layer of a seated manikin is 40–56% faster than thermal-manikin data [9] and follows their trend with room temperature. For a source at a seated manikin's groin [13], the scene settings give a breathing-zone intake fraction of 8.1, 9.1 and 11.0 per mille over 10, 22 and 100 min, against 5.5, 7.7 and 9.8 measured. Their unheated case is not compared: without body heat the flow near the source is set by supply, lighting and aerosol temperatures that are not reported, and every scene here has heated occupants. Refining the sofa mesh by 1.5 in every direction (0.72 to 2.2 million cells) changes the median silent dose by a factor 0.55 at the neighbour and 3.0 at the releaser's own nose. A boundary layer that is too fast raises its momentum flux m_p, lowers $\Pi = M_0/m_\mathrm{p}$ (Section 4.4) and so lets it capture slow releases too readily: the simulations may understate silent doses at the neighbour on the sofa, and overstate them for the person behind the releaser in the lift, whom the captured release reaches (Section 5.5).

3.5 Perception and observers

The nose samples only during inhalation: sinusoidal flow at a conventional 12 breaths per minute (10.1 ± 3.0 measured at rest), inspiratory fraction 0.42 [31]. Perceived intensity follows Stevens' power law, $I \propto \mathrm{OAV}^n$, with $n = 0.28$ measured for the H_2S of flatus (canine flatus, rated by an odour judge) [32]. Two passages are distinguishable when their concentrations differ by more than the olfactory Weber fraction of 0.28 [33] (coincidentally equal to n), i.e. a just-noticeable ratio of 1.28.

The OAVs of the dispersion model use trained-panel thresholds [20]. For untrained observers:

- population thresholds for H_2S and methanethiol are 10–23 times higher [21, 34];
- detection is a per-passage probability $\Phi(\log_2 \mathrm{OAV}/\sigma)$ with $\sigma = 2$ binary steps [21], since one person's threshold varies over time about as much as thresholds vary across people [35];
- a bystander who is not expecting an odour needs 26 times the threshold for a 50% response, with $\sigma = 3.5$ binary steps (Amoore's analysis [21] of the tests of ref. 36).

With the population thresholds, the attentive bystander's 50% point lies at a trained-panel OAV of 20, and the distracted bystander's at $20 \times 26 = 520$. Distraction reduces noticing [37] but did not significantly reduce the peak rated intensity [38], so intensity is computed from the attentive OAV. Two variants follow: clothing removes 22% of the sulfide gas [39], and a sound can make a distracted bystander attentive for that passage.

3.6 Uncertainty analysis

Input uncertainty is propagated through the analytic model; one multi-release CFD run costs one to several days on four to eighteen cores, too many for a sampling design. First-order Sobol indices (the share of the variance of $\log_{10} R$ explained by one input alone) are estimated by binning the Monte Carlo sample, with bootstrap 90% intervals. Because the silent and audible releases of a pair are drawn by rejection, the inputs are dependent and the indices are descriptive. The regime map shows $\log_{10} R$ at equal mass against the audible release's Silencer number and the travel time.

Passages as emitted in the simulated scenes. The 20 000 passages of the source model each have a volume V, an exit momentum flux M_0 and a class. At each nose a passage gets the dose per unit volume of the representative releases of its class, interpolated in $\log M_0$ and held constant outside their range, times V: the odorant is a passive scalar, so the dose is linear in volume, and the flow path is assumed to depend on the momentum but not on the volume. Its hearing at each nose comes from the acoustic model. Pairs of one silent and one audible passage then fall into four outcomes: neither smelled; silent worse (only the silent one smelled, or both and the silent one above the just-noticeable ratio); audible worse (the reverse); and a tie. A bystander remembers a silent passage only if smelled (Theorem 3), so the remembered shares are the same outcomes among pairs whose silent passage was smelled. Scenes are weighted by the time an adult spends close to another person in each setting (sofa 0.73, lift 0.005, standing 0.26; Section S6), with home- and office-centred days as bounds. In the clothed variants each passage is in trousers with probability 0.7 or 0.85, independently.

4 Results

4.1 The odorants and the gas that carries them

Over two measured compositions and three threshold sets, methanethiol carries 43–94% of the summed OAV and never less than H_2S (Section S1). This differs from the conclusion drawn in ref. 4, where H_2S is the main sulfur gas and the one whose concentration the judges' malodour ratings followed. Weighted by odour thresholds, the same measured concentrations give methanethiol at least an equal share: it is one fifth as concentrated, but its threshold is 5–6 times lower. Composition does not enter the silent/audible comparison, because transport is linear and acts on all three gases alike. Stevens' law with these OAVs predicts the judges' ratings of zinc-acetate-treated flatus (0.31–0.59 predicted, 0.28 and 0.59 rated) without fitting.

Composition, not temperature, sets most of the buoyancy: after cooling to room temperature 25–38% of passages are heavier than air. Gas-phase oxidation removes at most 0.4% of any odorant within 120 s (Table S1).

4.2 Most releases are physically silent

In the lip-reed model, 85% of the releases sampled never set the valve oscillating (Figure 2); the other 15% are audible in any quiet room. No release in the sampled range oscillates without being heard in a quiet room: the smallest oscillating release, about $33\,\mathrm{mL\,s^{-1}}$ through a 1 mm orifice, gives a 47 dB fundamental at sofa distance (0.6 m), against an 18 dB hearing threshold at

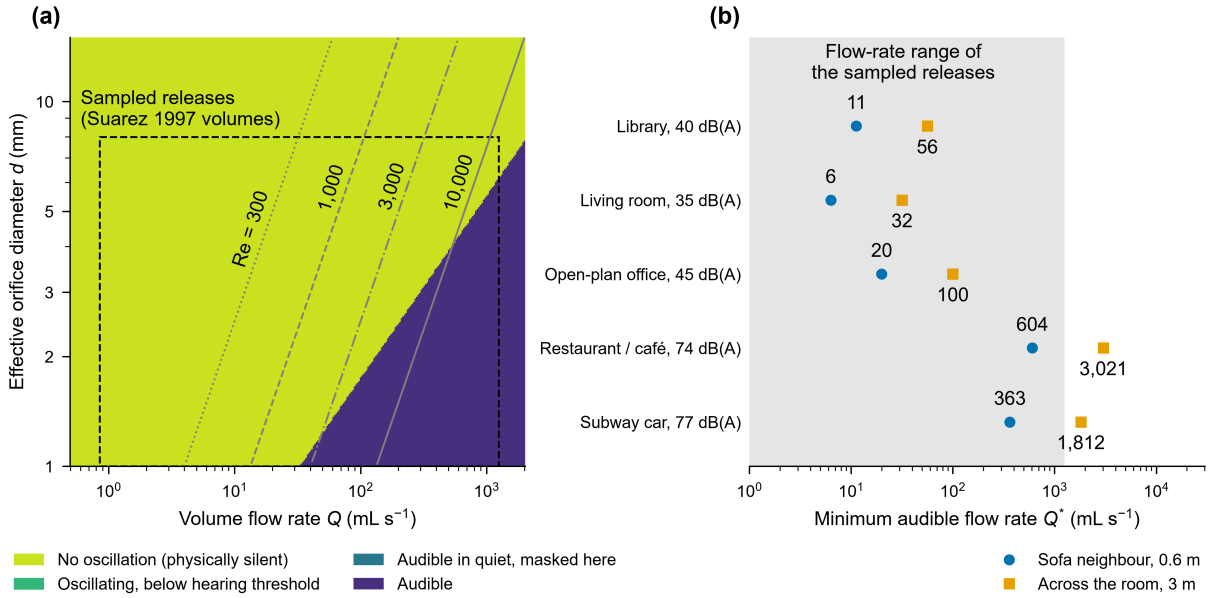


Figure 2: Acoustics. (a) Whether a release is heard, by volume flow rate and effective orifice diameter, for a neighbour at 0.6 m in a 35 dB(A) living room: the valve does not oscillate (physically silent); it oscillates but is masked here (audible in a quiet room); or it is audible. Dashed box: the sampled range of releases. Grey lines: jet Reynolds number. (b) Minimum audible flow rate of an oscillating release for five backgrounds, at 0.6 m and 3 m. The grey band is the flow-rate range of the sampled releases. Nominal onset pressure 1.2 kPa, fundamental 160 Hz, eight harmonics.

Table 1: Silent-to-audible concentration ratio in the analytic model (20 000 pairs).

receptor	basis	median R	5–95%	$P(R > 1)$
own nose	equal mass	1.94	0.94–16.4	0.93
own nose	as emitted	1.23	0.20–6.1	0.59
neighbour	equal mass	1.45	0.97–10.3	0.93
neighbour	as emitted	0.96	0.15–4.8	0.48
neighbour, trousers	as emitted	0.62	0.11–3.3	0.31

160 Hz. A release that is not heard is therefore either physically silent or masked by background noise.

Masking needs loud backgrounds: in a restaurant or a subway car only near-maximal passages are heard (0–13% of releases, depending on pitch). Audible releases are fast, with a median exit velocity of 90 m s^{-1}.

4.3 The ratio in the analytic model

The analytic model sends every cloud to the nose, so it bounds what dilution alone can do. Table 1 gives the breath-averaged ratio $R = C_{\text{silent}}/C_{\text{audible}}$ for 20 000 random pairs.

Equal mass. At equal mass the audible release arrives pre-diluted by its own momentum (Eq. (3)), and the silent one is stronger at the neighbour in 93% of pairs. This is the near-field exception of Section 2.4, not a violation of Theorem 1, which holds only once the release has lost its own momentum. At the just-noticeable ratio of 1.28, the silent release is perceptibly stronger in 59% of pairs and indistinguishable in 39%.

As emitted. Audible passages are larger, and at the neighbour a silent passage is stronger in

48% of pairs: perceptibly stronger in 39%, perceptibly weaker in 42%. Trousers remove the jet momentum of both releases and lower $P(R > 1)$ to 0.31.

Which inputs matter (Figure 3b). The two passage volumes explain about 0.6 of the variance of $\log_{10} R$ as emitted; the valve parameters set whether a passage is heard, but hardly how strongly it smells.

Regime map (Figure 3a). The silent release is perceptibly stronger only at short travel times and high Silencer numbers of the audible release. At equal mass even a barely audible release is perceptibly weaker than a silent one, at the releaser's own nose (6.7 s; $R = 1.61$ at the acoustic onset) and at the neighbour (12.5 s; $R = 1.33$).

4.4 Real rooms: where the release goes

In the simulated rooms the warm air rising along the body takes a slow release with it, while a fast jet leaves it, and the two then reach different noses.

Sofa. The silent release rises along the releaser's back, over the head and to the ceiling, while the audible jet spreads along the seat to the neighbour (Figure 4a,b). At the neighbour, the worst breath over 150 s (volumes as emitted) is 0.07 and 0.09 for the two silent releases and 0.16 and 16.9 for the audible ones; reclining or leaning forward moves the silent values to 0.12–0.95, still below the trained-panel threshold. The dose rises with the ratio of the release's momentum flux to that of the boundary layer it enters, $\Pi = M_0/m_\mathrm{p}$, where m_p is the upward momentum flux of the boundary layer 15 cm above the release point: a release must break out of the boundary layer to reach a neighbour (Figure 5a).

Standing pair. Face to face and bare, the neighbour stays below OAV 0.2 for every release, in still air and with ventilation, whatever Π: the body plumes carry both clouds upwards between the two people. Momentum is therefore not the only variable; the arrangement of the bodies is the second.

Lift. In a closed car with a person behind the releaser, the silent release rises in the 0.2 m gap into that person's breathing zone (Figure 4c): worst breath 260 for the median silent release, against 36 for the strongest audible one. Every nose in the car passes OAV 1.

Releaser. At the releaser's own nose the relation is not monotonic (Figure 5b): the highest doses at equal mass, up to OAV 70, come from releases with $\Pi \approx 10$–100, which leave the seat region but stay close to the body.

4.5 How often a silent passage is worse

Table 2 gives the four outcomes for passages as emitted, weighted by how often people are in each setting. For a bystander, nothing is smelled in 93% of pairs (attentive) or 98% (distracted). When something is, the audible passage is worse about 13 times as often as the silent one: 6.9% against 0.5% for an attentive bystander. The releaser smells more and still finds the audible passage worse four times as often. The lift is the exception: with a person behind the releaser, the silent passage is worse in 22% of pairs and the audible one in 20%. It weighs little because people spend minutes a day in shared lifts, against hours on a sofa.

Robustness (Section S7). The order of the two physical shares holds under every variation we tried. Home- and office-centred days give 0.5 and 1.1% silent worse against 8.4 and 3.9% audible worse. The psychometric tail (slope, logistic or floored shape, or a deterministic threshold) moves the ratio between 4 and 25. In trousers the audible passage is worse more often (9.3 and 10.2% when 70 and 85% of passages are clothed; silent worse 0.1%). The large-eddy peak factors near threshold are 2.2 (1.0–6.6) for silent and 1.3 (0.27–64) for audible releases; applied by class they give 1.2 against 8.2%. A silent-only factor of about 14 would be needed to reverse the order; only the adverse pairing of the highest silent with the lowest audible factor does so (3.6 against 2.3%). Scaling every silent dose by the mesh-refinement factors (0.55 or 3.0) gives

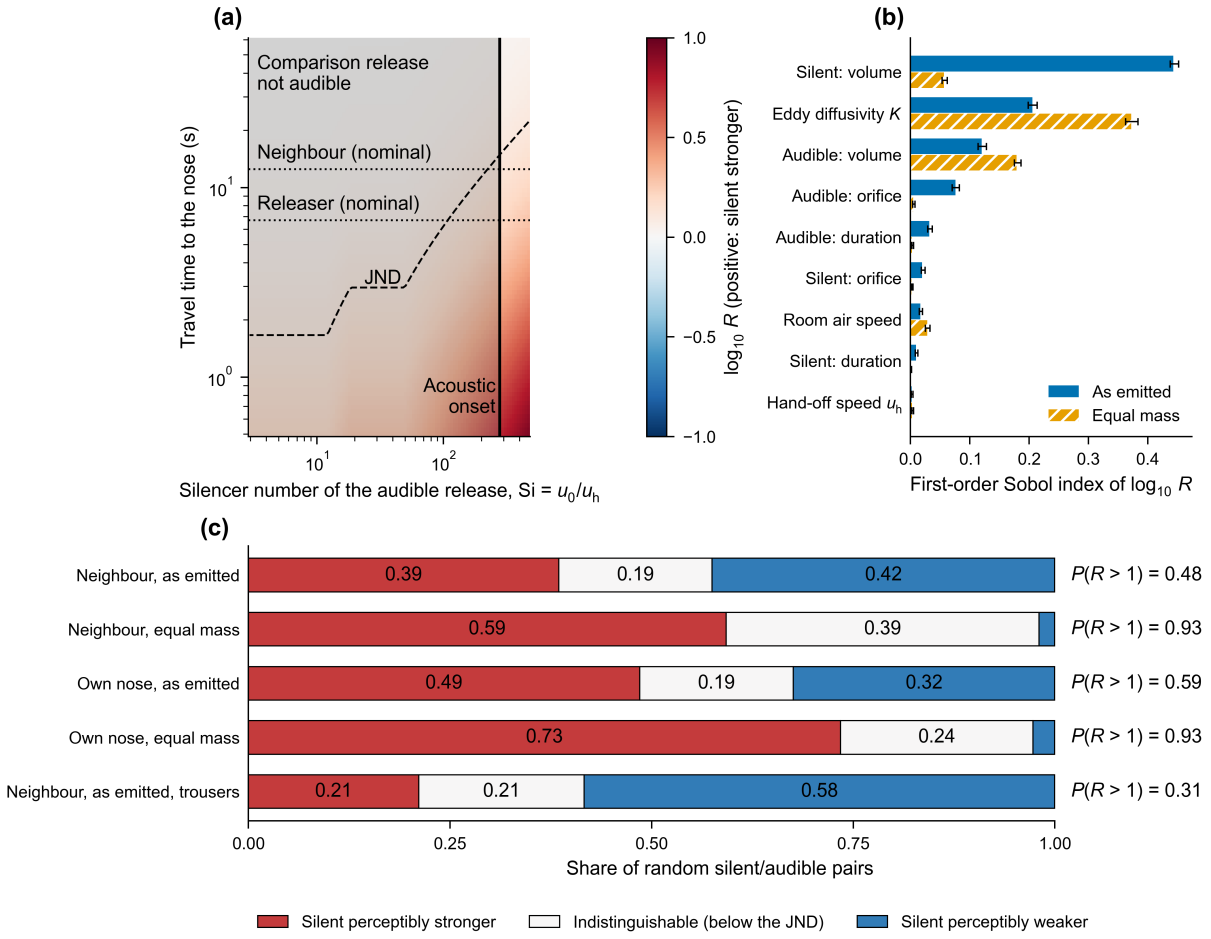


Figure 3: The ratio in the analytic model. (a) $\log_{10} R$ at equal mass and room-air mixing ($K = 10^{-3}\,\mathrm{m^2\,s^{-1}}$), over the Silencer number of the audible release and the travel time to the nose; the silent release is a reference 40 mL over 2 s through a 6-mm orifice, a slow, laminar release near the lower end of the sampled range (Si ≈ 5, Re ≈ 250). The vertical line is the acoustic onset (Si $= 279$); to its left the comparison release is not audible (grey). The dashed contour is the just-noticeable ratio 1.28. Dotted lines mark the nominal travel times to the releaser's (6.7 s) and the neighbour's (12.5 s) nose. (b) First-order Sobol indices of $\log_{10} R$ at the neighbour, as emitted and at equal mass, with bootstrap 90% intervals. (c) Shares of random silent/audible pairs in which the silent release is perceptibly stronger, indistinguishable, or perceptibly weaker, with $P(R > 1)$.

Table 2: Four outcomes for one silent and one audible passage as emitted (bare, weighted by time spent in each setting; %). Remembered: the same outcomes among pairs whose silent passage was smelled (Theorem 3). Bystander shares are given to two decimals.

nose	observer	none	silent worse	audible worse	tie
bystander	attentive	92.62	0.51	6.86	0.01
	remembered	–	88.41	9.55	2.04
bystander	distracted	98.40	0.15	1.45	0.00
	remembered	–	97.44	2.14	0.42
releaser	attentive	77.4	4.6	17.9	0.1
releaser	distracted	95.1	1.1	3.8	0.0
lift bystanders	attentive	55.7	22.3	20.4	1.5

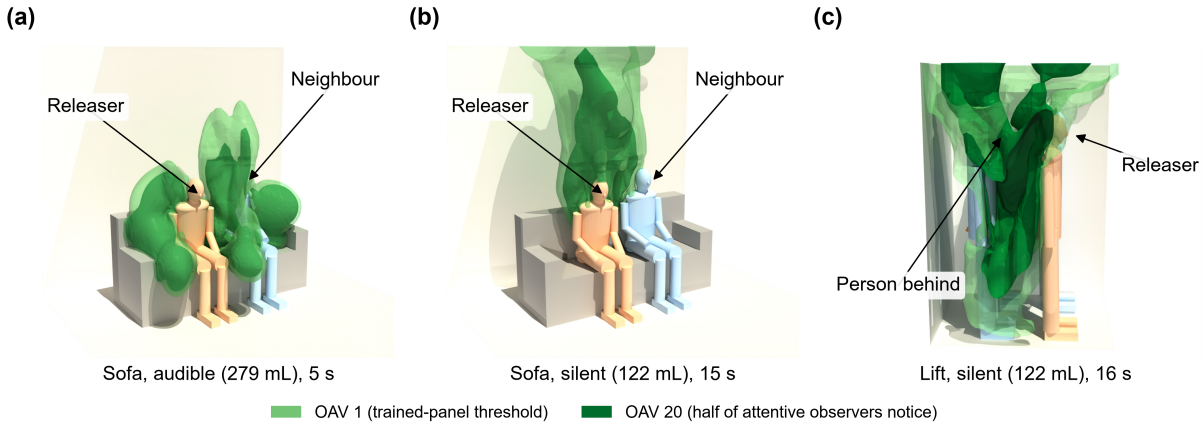


Figure 4: Where the cloud goes (RANS mean flow, volumes as emitted; light and dark green: OAV 1 and 20). (a) Sofa, releaser leaning forward, the strongest audible release 5 s after it starts: the jet spreads along the seat and reaches the neighbour's face. (b) The same sofa, the median silent release 15 s after it starts: it rises behind the heads to the ceiling. (c) Lift, the median silent release 16 s after it starts: it rises from the releaser's back into the breathing zone of the person behind.

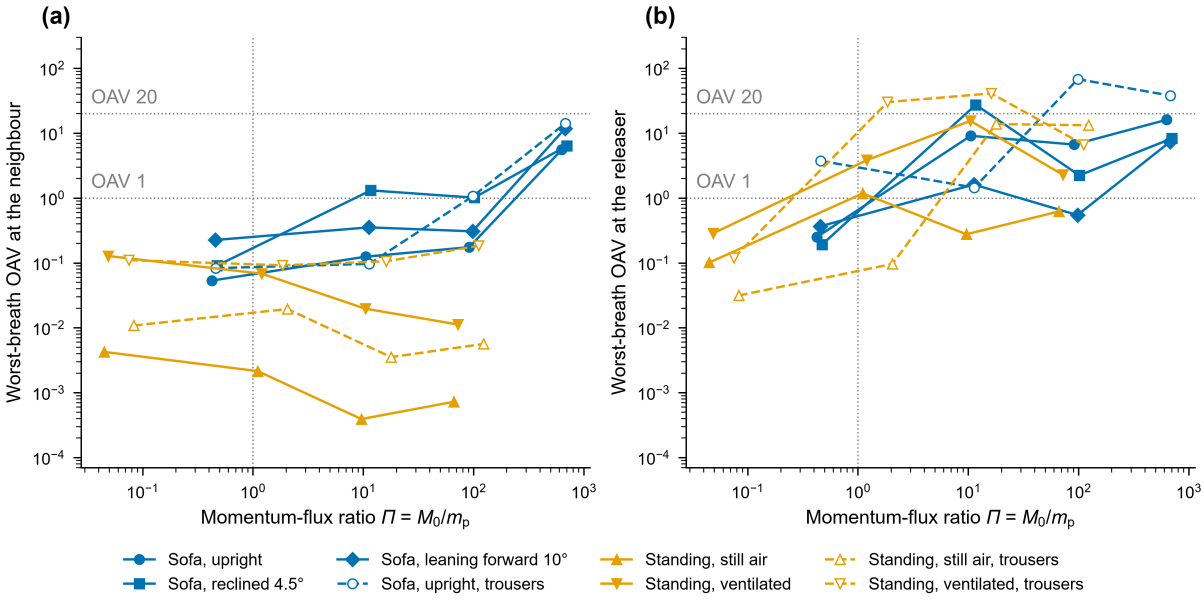


Figure 5: Routing map. Worst-breath OAV over 150 s for the same 92 mL at (a) the neighbour and (b) the releaser, against the ratio of the release's momentum flux to the upward momentum flux of the boundary layer 15 cm above the release point. Each line joins the four representative releases of one scene (left to right: the two silent and the two audible levels); filled symbols bare, open symbols trousers.

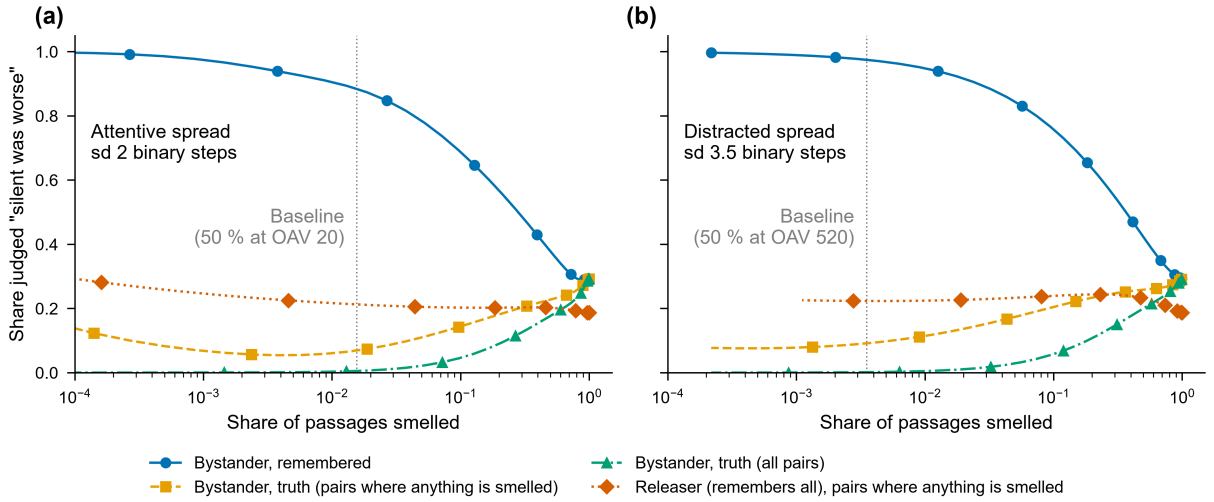


Figure 6: Memory against detection. Share of comparisons in which "the silent passage was worse", against the share of passages smelled at a bystander's nose, as the observer's 50% detection point is varied: bystander memory, bystander truth among pairs where anything is smelled and over all pairs, and the releaser. (a) Attentive spread of the psychometric function (2 binary steps), (b) distracted (3.5). The dotted line marks the literature observer.

0.3 or 1.6 against 6.8–6.9%. The source assumptions move the share of silent passages between 76 and 94% without changing the order.

4.6 Perception

Breath sampling. For a neighbour who is not warned, the worst breath still captures 81–99% of the peak. A listener warned by the sound needs about 25 s of breath-hold for an even chance of missing the cloud (Figure S3).

Expectation. Labels change rated intensity little for most odours, by a few per cent [40, 41], but a warning that an odour is harmful raised it by 18–61% over a 20-min exposure [42]. Every such study announced the label, so the sign of the effect for an unwarned listener has not been established. We do not include expectation in the model.

4.7 Memory

A bystander remembers a silent passage only if it was smelled. Among remembered pairs, the silent passage seems worse in 88% (attentive) and 97% (distracted) of comparisons (Table 2), while over all pairs it is worse in 0.5 and 0.15%. Among pairs where anything is smelled the truth is 6.9 and about 9% (0.51 of 7.38% and 0.15 of 1.60%). The remembered share is not fixed by definition: it falls as more passages are smelled and meets the truth, 29%, when every passage is smelled (Figure 6). The releaser, who notices every release, shows no selection: memory equals the physical shares, 19–24% among pairs where anything is smelled, at any detection rate.

5 Discussion

5.1 Why the belief exists

The physics we model does not make silent passages generally worse. At equal mass the silent advantage at a neighbour is a median factor of 1.45 in the analytic model, often below the just-noticeable ratio, and that model sends every cloud to the nose. In the simulated rooms, with passages as emitted and settings weighted by how often people share them, a bystander finds

the silent passage worse in 0.5% of pairs and the audible one in 6.9%; even among pairs where something is smelled, the silent one is worse in only 7%.

The belief is nevertheless documented across languages. Theorem 3 can explain it without any physical difference: a passage enters memory if it is heard or smelled, so every remembered silent passage was smelled, whereas audible passages are remembered whether or not they smelled. On the same simulated passages this selection turns a truth of 0.5% into a remembered 88% (Table 2), and the gap closes only as detection approaches certainty (Figure 6). This shows that selection is sufficient for the belief, not that it is its cause; the predictions below can decide. Documented memory biases act in the same direction: distinctive pairings are over-remembered [43], and judgements built from biased samples are rarely corrected [44]. A prior verbal association alone can make people report co-occurrences that are not in what they saw [45], so the phrase itself may pass the belief on; documentary evidence cannot separate the two routes (Figure S4).

5.2 Predictions

If selection is the cause, the belief should follow who notices what, and a survey can test this.

- *Releasers.* A releaser feels every release, so their noticing does not depend on smell and Theorem 3 does not apply to their own passages. Releasers should hold the belief less firmly than bystanders. Their own passages also disgust them less: the item "silent but smells strongly" is rated 2.51 for one's own flatus and 3.71 for a stranger's on a 1–5 scale [46]. This lowers the unpleasantness of their passages, not the contrast between silent and audible ones; only an expectation about their own odour [47] could carry the belief over to them.

- *People without a sense of smell.* As bystanders they can notice a passage only by hearing it, so they never remember a silent passage. If they hold the belief, it came from the phrase, not from experience.

- *Background noise.* Masking makes quieter audible passages seem silent, so they enter memory only when smelled, while the passages still heard are the largest; the two effects oppose, so noise is not a clean test.

5.3 Where the odour comes from

The sulfur odorants are trace products held at a balance of production and fast mucosal consumption, whereas the bulk gases set passage volume; we infer that this is why sulfur concentration does not follow volume [6] (Section S9). Diet could shift the balance so that large passages carry less sulfur, in the direction of the belief; no study has measured both across diets.

5.4 When a silent release is worse

At equal mass, at the releaser's own nose, in still air and within a few seconds, a silent release is perceptibly stronger than a loud one (Figure 3a). In a closed lift with someone standing behind the releaser, the slow release rises straight into that person's breathing zone, and silent and audible passages are worse about equally often (22 and 20% of pairs). In these settings the saying holds; they are rare in a day.

5.5 Scope

The four rooms are representative rather than exhaustive, and the time spent in each is partly assumed; the bounds used for the weights do not change the order of the outcomes. The share of passages a bystander smells has never been measured, so the remembered share is reported

against it (Figure 6). The flow path of a passage is taken to depend on its momentum and not on its volume. The simulated boundary layer is too fast, the intake fraction 1.5 times the measured one and the releaser's dose mesh-dependent (factor 3.0; Section 3.4), and the order of releases in a run changes the dose by a factor 0.4 at the neighbour and 0.8 at the releaser (Section S3); none comes near the silent-only factor of about 14 that would reverse the order (Section 4.5).

6 Conclusion

- *Routing.* The body's convective boundary layer takes a slow release and lets a fast one pass, so the momentum of a release next to a body decides which nose it reaches. On a sofa the silent release rises behind the releaser to the ceiling; between two standing people both releases rise between them; in a closed lift the silent release goes straight to the person standing behind the releaser.

- *Physics says seldom.* Under linear transport a slower release of the same gas never gives a higher peak, in any room or flow. In the simulated rooms, with passages as emitted and settings weighted by how often people share them, a bystander finds the silent passage worse in 0.5% of pairs and the audible one in 6.9%, and this order survives every variation of weights, perception, peak factor, mesh and clothing we tried but one adverse pairing of peak factors.

- *Memory says mostly.* A silent passage is noticed only if it is smelled, and this selection alone can explain the belief: among remembered pairs the silent passage seems worse in 88% (attentive) to 97% (distracted) of comparisons. The explanation predicts that releasers hold the belief less firmly than bystanders and that people without a sense of smell never remember a silent passage.

Ethics

This work involved no human or animal participants. The cross-cultural survey uses published sources only.

Data accessibility

Code, parameters with their sources (`params/params.yaml`), processed data such as the archived nose-probe series, and the scripts behind every figure and table are openly available at `https://github.com/ccy5123/sbd`; the repository's `README.md` lists the source files of each result. An archived release with a DOI (Zenodo) will accompany the revised manuscript. Supplementary text, figures and tables are provided in the electronic supplementary material.

Declaration of AI use

I have used AI-assisted technologies (Claude Code, Anthropic) in creating this article for code and literature search; I checked all content and take responsibility for it.

Authors' contributions

C.Y.J.: conceptualization, data curation, formal analysis, investigation, methodology, software, validation, visualization, writing—original draft, writing—review and editing.

Competing interests

I declare I have no competing interests.

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A Proofs of Theorems 1–3

Theorem 1. (i) follows from integrating Eq. (2) over t. For (ii), $C_\mathrm{s} = G * q_\mathrm{a} * \kappa = C_\mathrm{a} * \kappa$, and Young's inequality gives $\|C_\mathrm{s}\|_\infty \le \|C_\mathrm{a}\|_\infty \, \|\kappa\|_1 = \|C_\mathrm{a}\|_\infty$. □

A top-hat release lasting nT is a top-hat lasting T convolved with $\kappa = n^{-1} \sum_{j=0}^{n-1} \delta(t - jT)$, so stretching a release by an integer factor is covered. The breath-averaged OAV of Eq. (1) is itself a convolution of C with a non-negative kernel, so the same argument bounds it.

Theorem 2. Let the release last T_r, so that q vanishes outside $[0, T_\mathrm{r}]$. Then $C(t) = \int_0^{T_\mathrm{r}} G(t - s)\, q(s)\, \mathrm{d}s$, and as $t \to \infty$, $G(t - s) \to 1/V_\mathrm{room}$ uniformly for $s \in [0, T_\mathrm{r}]$, so $C(t) \to V_\mathrm{room}^{-1} \int q \, \mathrm{d}s = V/V_\mathrm{room}$ for any q. □

Theorem 3. On $\neg H$, noticing requires smelling, so $\neg H \cap N = \neg H \cap S$ and $P(S \mid \neg H, N) = 1$. On H, N is certain, so conditioning on N adds nothing. □

B Near field of the analytic model

The release behaves as a starting jet. Its tip follows $x = \Gamma(\dot{Q}_0 u_0)^{1/4} t^{1/2}$, where $\dot{Q}_0 = V/T$ is the volume flow rate and $\dot{Q}_0 u_0 = M_0$ the kinematic momentum flux, and once the source stops it follows the puff law $x^4 = C_p^4 V u_0 t$, with $\Gamma = 2.8$ and $C_p = 2.6$ from the corrected analysis [48] of the measurements of ref. 49. The centreline dilution is $x/(K_c d^*)$ with $K_c = 5.11$ [50], where $d^* = d\,(\rho_0/\rho_\mathrm{a})^{1/2}$ is the momentum diameter of a release of density ρ_0 into air of density ρ_a. In parallel, a buoyant thermal grows with entrainment coefficient $\alpha = 0.25$ [51], and the larger of the two dilutions is kept. The near field ends when the self-induced velocity has fallen to the ambient velocity u_h (0.05–0.25 $\mathrm{m\,s^{-1}}$).

For a steady jet, a starting jet and a puff alike, the momentum carried by the cloud is conserved while it entrains, so the entrained mass grows as the inverse of the remaining velocity. At the hand-off velocity u_h the dilution is therefore proportional to u_0/u_h, which is Eq. (3); the prefactor β collects the jet or puff constants above and is of order one.

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