Supplementary Material: Open Design and Experimental Comparison of Two MRI-Compatible Flow Olfactometer Architectures

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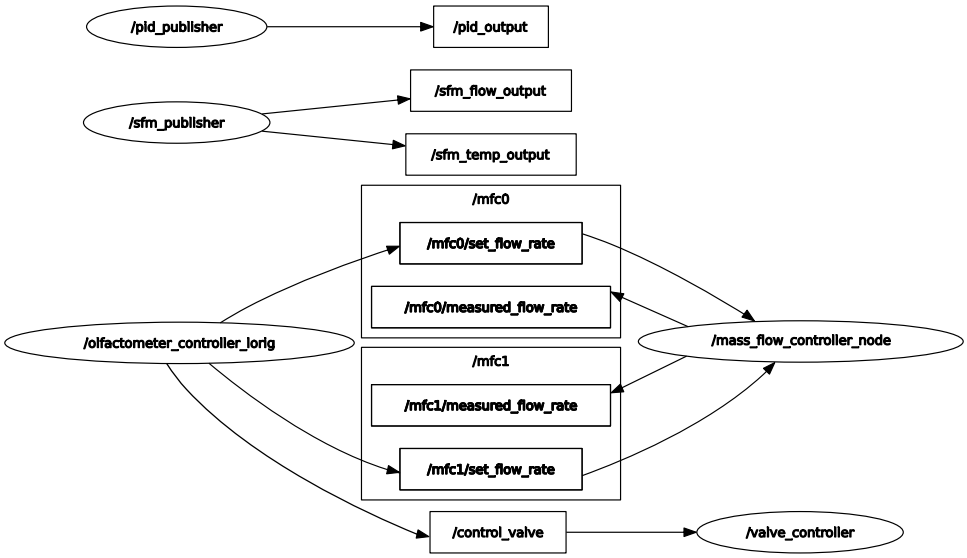
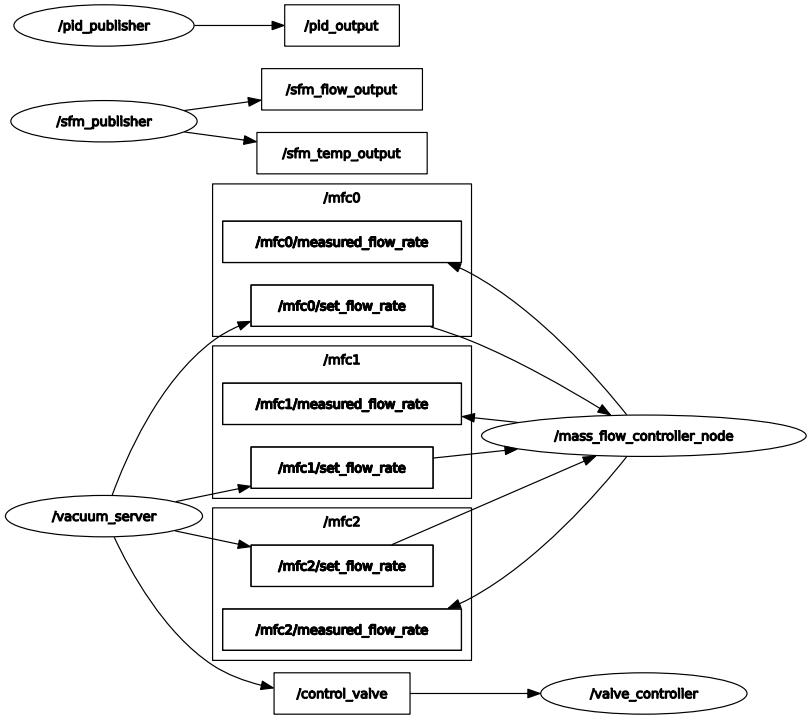
SUPPLEMENT A
EXTENDED MATERIALS AND METHODS



(A) Nodes and topics in Lorig configuration



(B) Nodes and topics in Vacuum configuration

Fig. S1: Diagrams showing ROS 2 nodes (ovals) and topics (rectangles) running on the Raspberry Pi for both configurations. The diagrams are made with the rqtgraph package. */pid_publisher* publishes PID data received from Teensy, */sfm_publisher* publishes flow rate and temperature data from the Sensiron flow rate sensor, */mass_flow_controller_node* sets flow rate's for each MFC and receives measured flow rate data back from each MFC, */valve_controller* communicates with the Arduino to control solenoid valves. The difference between the two configurations is the lack of MFC 2 for the Lorig configuration, and the main control node. For the vacuum configuration, this is the */vacuum_server* node, but for the Lorig configuration, the */olfactometer_controller_lorig* node is used. All code can be found in the GitHub repository: https://github.com/DART-Lab-LLUI/olfacto_ros2.git

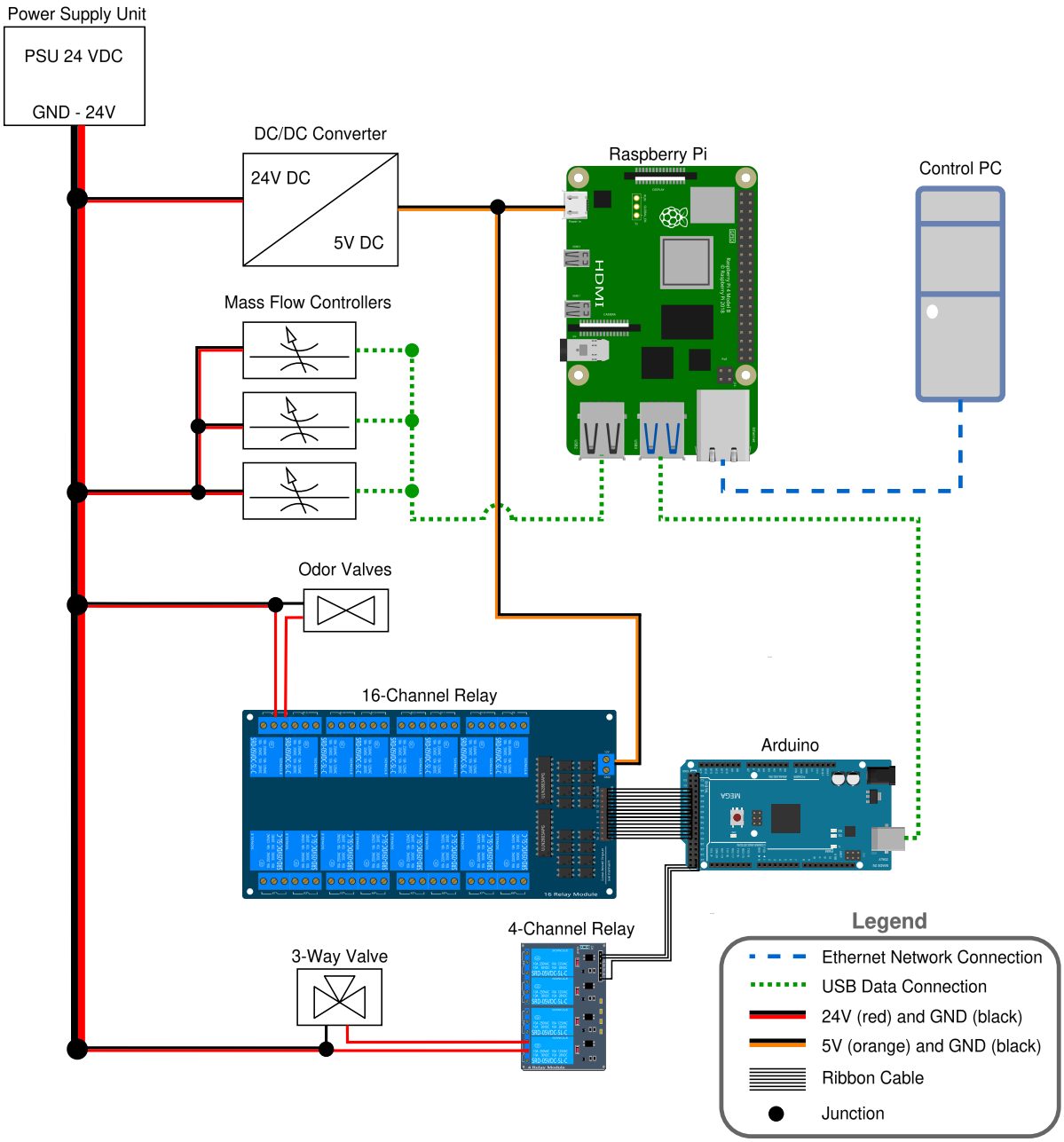


Fig. S2: This diagram shows a basic overview of the power and data connections of the main electrical and pneumatic components in the system. The 24 VDC power supply provides power to the mass flow controllers, the odor valves, the 3-way valve, and the DC/DC converter. The mass flow controllers are daisy-chained together for both power and data, and communicate with the Raspberry Pi via USB connection. The DC/DC converter supplies 5 VDC to the Raspberry Pi and the 16-channel relay module. The Raspberry Pi also connects to the control PC via Ethernet and to the Arduino via USB. The Arduino controls both the 16-channel and 4-channel relay modules using a ribbon cable connection. The 3-way valve is powered directly from the 24 VDC supply and switched via the 4-channel relay, which is itself powered by the Arduino. For simplicity, only one of the 16 odor solenoid valves controlled by the 16-channel relay is shown. The diagram applies to both the Lorig and vacuum-switch configurations; however, in the Lorig configuration, the 3-way valve and third mass flow controller are not used.

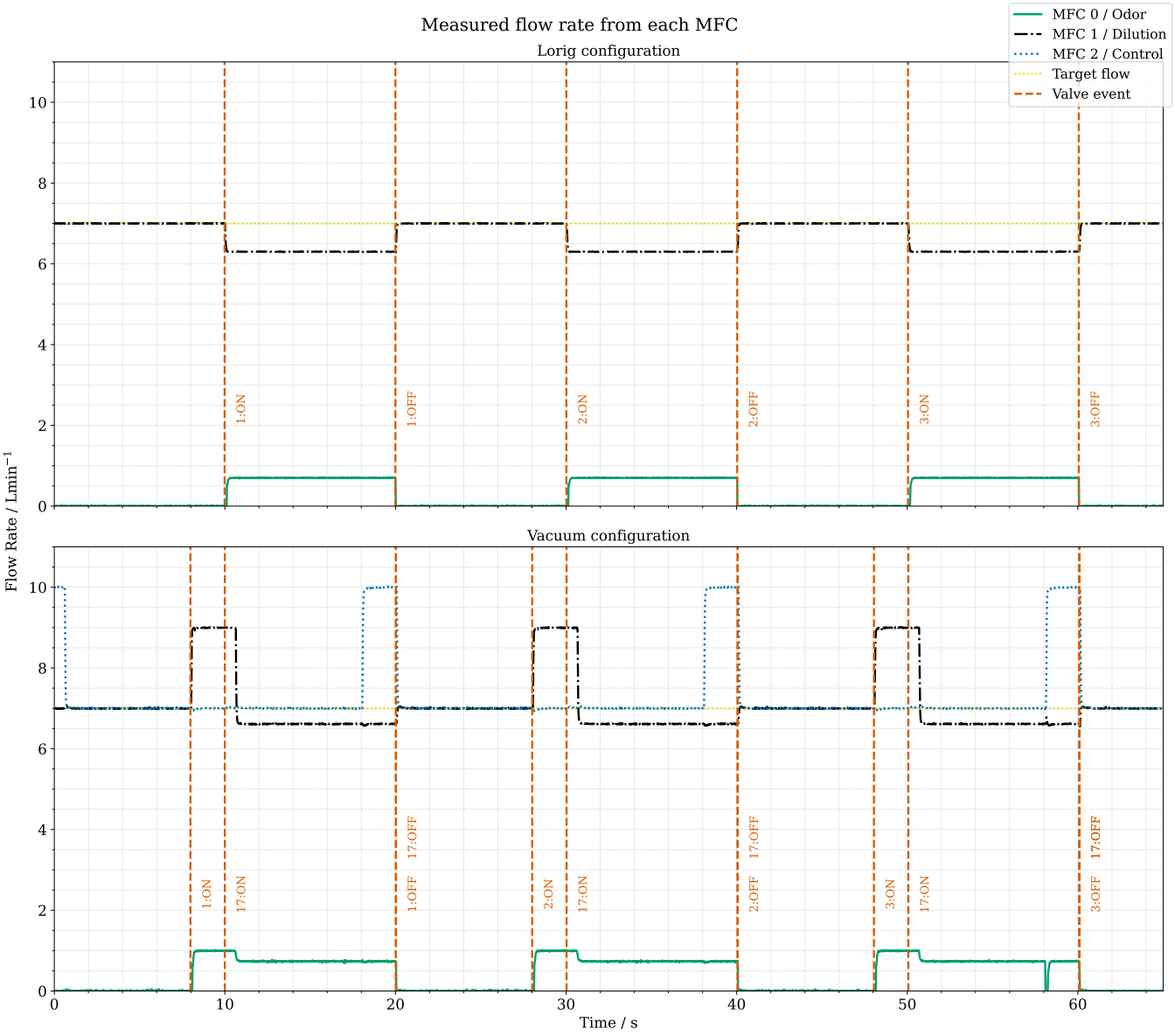


Fig. S3: This plot shows the measured flow rates from each mass flow controller (MFC) during one of the tactile stimulation measurements, with a target flow rate of 7 L min^{-1} and a 10 % dilution ratio. The vertical dashed lines indicate valve events: the number refers to the actuated valve (1, 2, or 3 for the odor valves, and 17 for the 3-way vacuum valve), while ON or OFF indicates whether the valve is opened or closed, respectively. The difference in control sequence between the two configurations is clearly visible. In the Lorig configuration, the control sequence is straightforward: during stimulus periods, the MFCs are set to achieve the desired dilution ratio by providing 0.7 L min^{-1} from MFC 0 (odor line) and 6.3 L min^{-1} from MFC 1 (dilution line). In contrast, the vacuum configuration employs a more complex sequence to achieve smoother transitions during switching. During the 2-second preload phase, the total flow rate is temporarily increased to 10 L min^{-1} while maintaining the 10 % dilution ratio (1 L min^{-1} from MFC 0 and 9 L min^{-1} from MFC 1). This elevated flow continues for 0.6 s after the 3-way valve is actuated. Following this, the flow rates are adjusted to maintain the dilution ratio, with the total flow boosted by 5 % (0.735 L min^{-1} from MFC 0 and 6.615 L min^{-1} from MFC 1). When switching back to no stimulus, the control line is briefly boosted to 10 L min^{-1}; however, because of the smaller total volume in the vacuum line, extending this boost after the valve switch was found to be unnecessary.

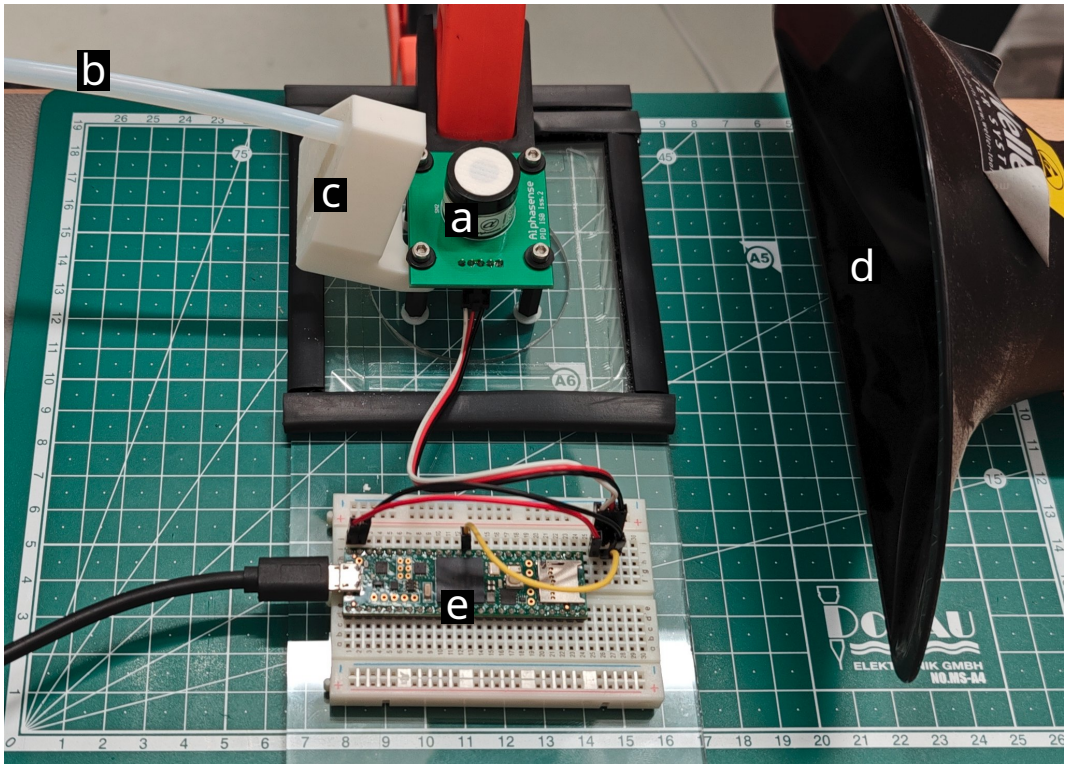


Fig. S4: PID test setup. (a) PID sensor, (b) stimulus tube, (c) 3D-printed tube mount, (d) vacuum, (e) Teensy 4.2.

Fig. S5: Position of the vacuum-switch in the MRI room. Shown here is the position at the bore entrance. The picture does not show the table inside the MRI bore, which is the case for the test.

SUPPLEMENT B
EXTENDED RESULTS

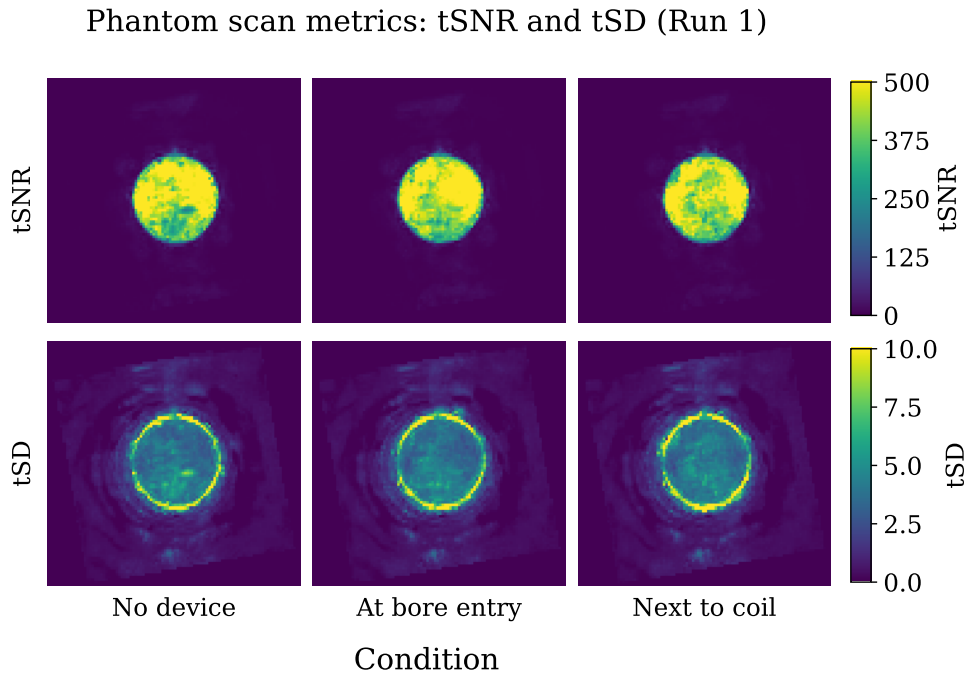


Fig. S6: Representative voxel maps for the first run of each condition. Top row: temporal signal-to-noise ratio (tSNR); bottom row: temporal standard deviation (tSD). Columns correspond to device position: *No device*, *At bore entry*, and *Next to coil*. The slice shown is the mid-phantom plane ($z = 0$). Across all three positions, the tSNR maps exhibit the same mild non-uniformity with a small reduction near the center-bottom of the phantom, while the tSD maps show elevated noise at the rim and lower values centrally. No additional artifacts or structured signal loss are visible when the vacuum-switch is inside the bore or at the bore entry.

SUPPLEMENT C
LORIG REVISION PROPOSAL

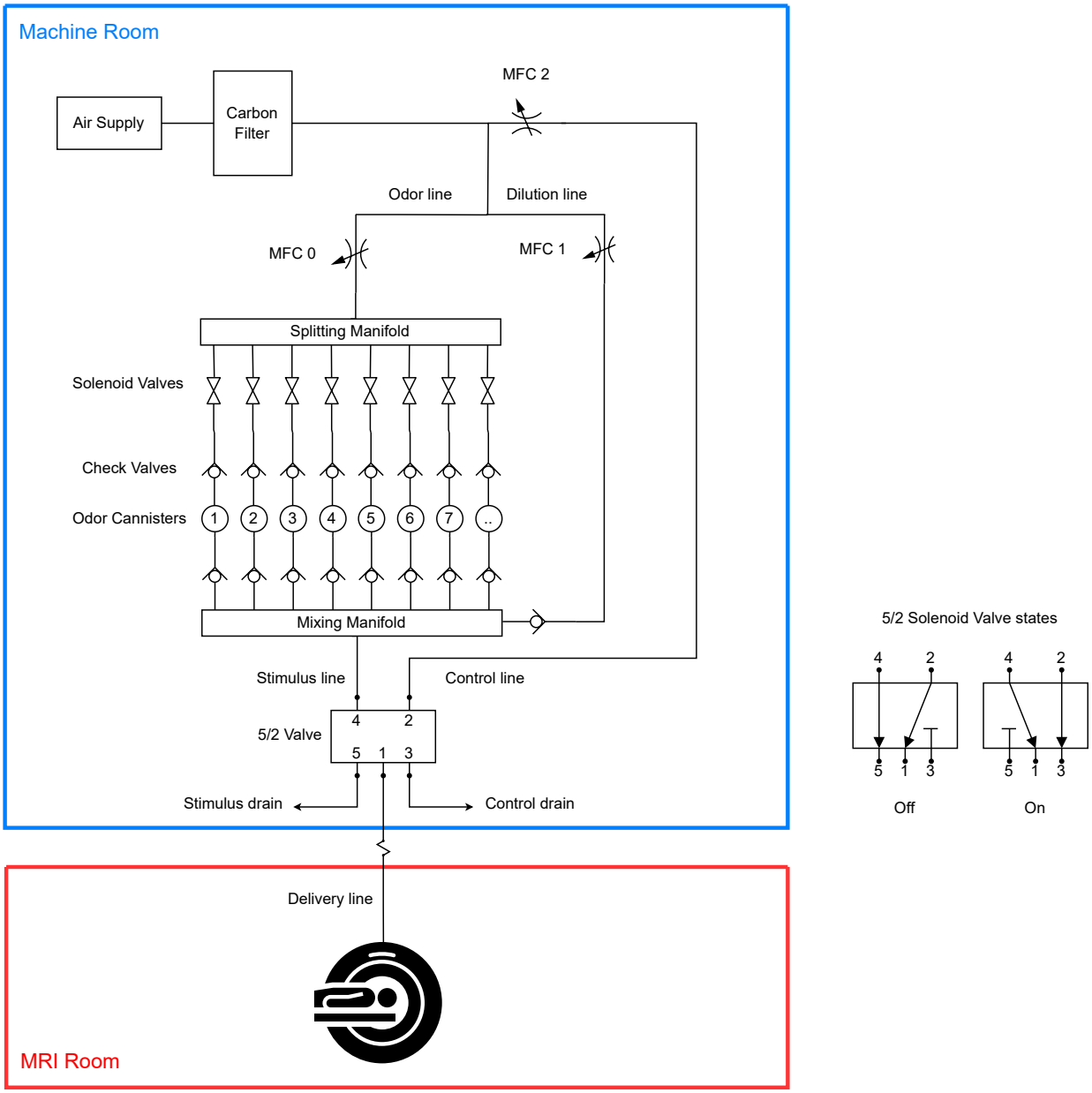


Fig. S7: A possible method to reduce the cross-contamination in the Lorig design is proposed by adding a third control line, similar to the vacuum-switch configuration. This line connects to a 5/2 solenoid valve positioned after the mixing manifold. The stimulus line is connected to the other input of the valve. When the valve is off, the control line (2) will be connected to the delivery line (1) and the stimulus line (4) is connected to the stimulus drain (5). When the valve is switched on, the stimulus line (4) will be connected to the delivery line (1) and the control line (2) to the control drain (3). With this system it is possible to flush the mixing manifold with clean air from the dilution line, without delivering this flushed air to the subject. The flushed air will instead be drained through the stimulus drain, while clean air from the control line is delivered to the subject. This setup could provide an alternative to the tested Lorig setup with reduced cross-contamination.

SUPPLEMENT D
BILL OF MATERIALS

Category	Part #	Part Name	Description	Supplier	Qty	Unit Cost (CHF)	Total Cost (CHF)
Electronics	1	Raspberry Pi	Raspberry pi 4 model B	Conrad	1	53.95	53.95
	2	Arduino	Arduino Mega2560	Conrad	1	35.95	35.95
	3	PSU	Mean Well 24 V DC 13.4A 321.6W	Conrad	1	51.95	51.95
	4	16-Channel Relay	TRU COMPONENTS TC-9445344	Conrad	1	21.95	21.95
	5	DC/DC Converter	24 V DC 5 V DC 3A 15W	DigiKey	1	7.48	7.48
	6	Power Distribution Block	2903717	DigiKey	1	64.24	64.24
	7	USB A to RS485	FIT0874	DigiKey	3	4.90	14.70
	8	M8 end cable	RKMV 4-225/5 M	Distrelec	3	10.08	30.24
	9	Splicing Connector	222-413	Distrelec	12	0.60	7.20
	10	4-Channel Relay	Purecrea 4-channel relay module	Amazon	1	5.06	5.06
	11	Ethernet to USB A	USB C to Ethernet Adapter with USB 3.0 to RJ45	Amazon	1	7.77	7.77
Valves and Flow control	12	Mass Flow Controller 20LPM	Sensirion SFC6000D-20SLM	DigiKey	2	308.75	617.50
	13	Mass Flow Controller 50LPM	Sensirion SFC6000D-50SLM	DigiKey	1	308.75	308.75
	14	Vacuum Piston Pump	VP750-30L, 120l/min	VacuumChambers	1	407.01	407.01
	15	3/2 Solenoid Valve	MHP2-M1H-3/2G-M5	Festo	16	63.16	1010.56
	16	Valve Cable	KMYZ-4-24-2,5-B	Festo	16	7.31	116.96
	17	Manifold Block	MHP2-PR10-3	Festo	1	94.25	94.25
	18	Manifold Block	MHP2-PR8-3	Festo	1	80.46	80.46
	19	Cover Plate	MHAP2-BP-3	Festo	2	4.76	9.52
	20	3/2 Solenoid Valve	MHE3-M1H-3/2G-1/8-K	Festo	1	62.74	62.74
	21	Filter regulator	MS4-LFR-1/4-D7-CRM-AS	Festo	1	67.99	67.99
	22	Activated carbon filter	MS4-LFX-1/4-R	Festo	1	66.05	66.05
	23	Ball valve	QH-1/4	Festo	2	20.00	40.00
Tubing and Fittings	24	Tee Union PTFE	UNION TEE 6 MMOD X 6 MMOD X 6 MMOD	TU-LOK	3	12.00	36.00
	25	Male Connector PTFE	MALE CONNECTOR 6 MMOD X 1/8" BSPM	TU-LOK	18	8.00	144.00
	26	Plugs PTFE	PLUG 1/8" BSPM	TU-LOK	18	8.00	144.00
	27	Check Valve PTFE	CHECK VALVE 6 MMOD X 6 MMOD	TU-LOK	21	32.00	672.00
	28	Manifold Block PTFE	MANIFOLD - 16 OUTLETS, 1 INLET & 1 DRAIN - ALL 1/8" BSPF	TU-LOK	1	350.00	350.00
	29	Tubing PTFE	PTFE-tube, 6x4mm, natural	Landefeld	25	10.44	261.00
	30	Gasket PTFE	Gasket PTFE for G1/8	Landefeld	30	0.30	9.00
	31	Distributor Block ALU	Distributor bar 2x G 1/4"-12xG 1/8", Anodized aluminium	Landefeld	1	30.55	30.55
	32	Flow restrictor 6mm	AS1002F-06-J - AS Series Tube Speed Controller	Distrelec	2	10.08	20.16
	33	PU Tubing 50m	PUN-H-6X1-NT	Festo	2	54.00	108.00
	34	Push-in fitting G1/8 SS	NPQR-DK-G18-Q6	Festo	10	14.80	148.00
	35	Push-in fitting G1/4 SS	NPQR-DK-G14-Q6	Festo	6	18.38	110.28
	36	Distributor block ALU	FR-4-1/4	Festo	1	14.38	14.38
	37	Blanking plug G1/4	B-1/4-F1A	Festo	10	1.45	14.50
	38	Blanking plug G1/8	B-1/8-F1A	Festo	10	1.20	12.00
	39	Push-in fitting L M5	QSML-M5-6	Festo	10	3.66	36.60
	40	Push-in fitting M5	QSM-M5-6-I	Festo	10	2.71	27.10
	41	Push-in fitting M7	QSM-M7-6-I	Festo	40	2.45	98.00
	42	Push-in T-connector	QSMT-6	Festo	10	4.49	44.90
	43	Push-in fitting G1/4	QS-G1/4-6	Festo	10	2.53	25.30
	44	Double nipple 2xG1/4	NPFC-D-2G14-M	Festo	10	8.60	86.00
Bottles and consumables	45	Gas washing bottle	100ml - Plastic PP	LaborXing	16	27.00	432.00
	46	Oxygen mask	Sauerstoffmaske EcoLite	LungenLiga	3	2.20	6.60
	47	Bottle O-ring	O-ring 25mmX31mmX3mm	Amazon	2	5.01	10.02
	48	Bottle Closing Ring	Dichtungsring - 39mm	Amazon	4	7.77	31.08
	49	Bottle Connection Washer	Rubber washer 6mmX12mmX4.5mm	Amazon	2	5.96	11.92
	50	Check Valve O-ring	O-ring 6mmX10mmX2mm	Amazon	1	6.65	6.65
Enclosure and Mounting	51	Enclosure Box ALU	Alutec Classic 48	Galaxus	2	95.95	191.90
	52	Computer Fan	80mm 24V	Amazon	2	6.49	12.98
	53	Dust Filter Fan	Dust filter computer fan 80mm	Amazon	1	7.62	7.62
	54	Rubber Strip	Edge Protection Sheet 1.6 mm x 6 m	Amazon	1	15.35	15.35
	55	Bolts and Nuts	Black 260pcs M3	Amazon	1	7.67	7.67
	56	Bolts and Nuts	440 Piece M3 Screws Nuts	Amazon	1	7.65	7.65
	57	Acrylic sheets	Acrylic Glass Sheet Transparent 3 mm, DIN A2 (420 x 594 mm)	Amazon	2	16.17	32.34
Sensors	58	PID Sensor	PIDX-A-04K0-4,000 ppm PID sensor	Alphasense	1	352.20	352.20
	59	Sensor Mounting Board	PID PCB mounting board	Alphasense	1	36.90	36.90
	60	Flow Sensor	Sensirion SFM4300-20-P	DigiKey	1	103.99	103.99
Total							**6840.92**