

NTAD (Nasal Tract Airflow Detector)

Work-based Learning Project (Extended) · BMPF7010

Designing a Low-Cost Nasal Airflow Measurement Device for the Singing Studio

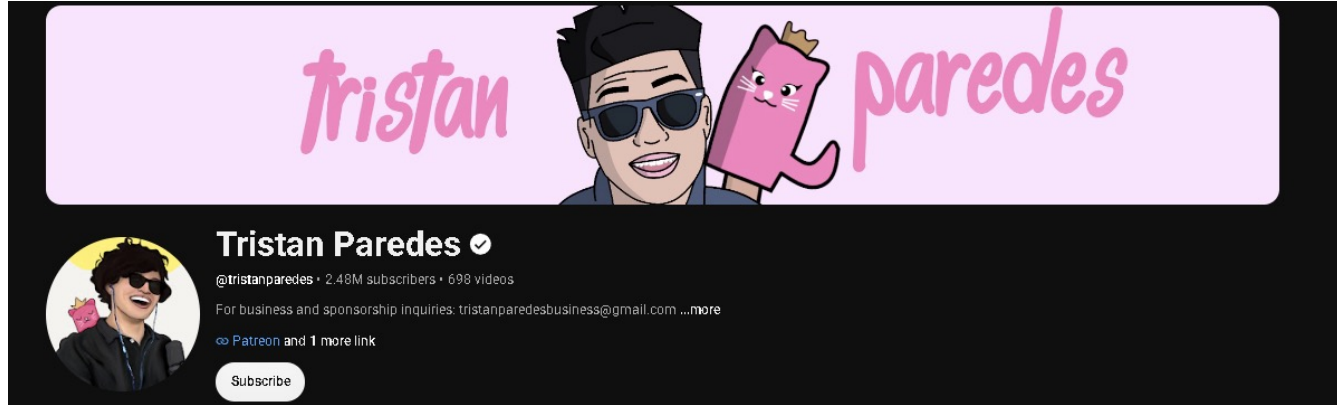
Tristan Paredes

7 October 2026

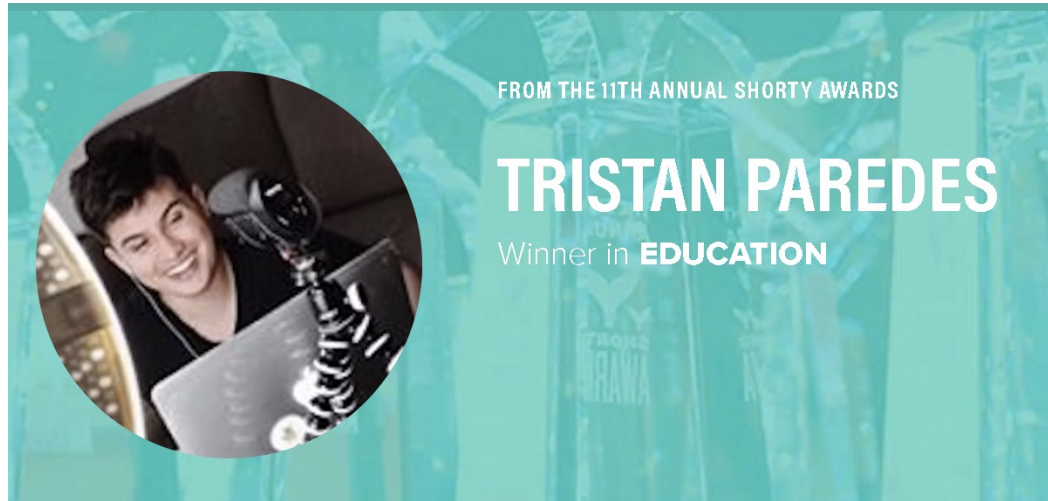


Figure 16. Iteration 2.1

About me



My YouTube channel, October 2026



11th Annual Shorty Awards, winner in Education

Tristan Paredes

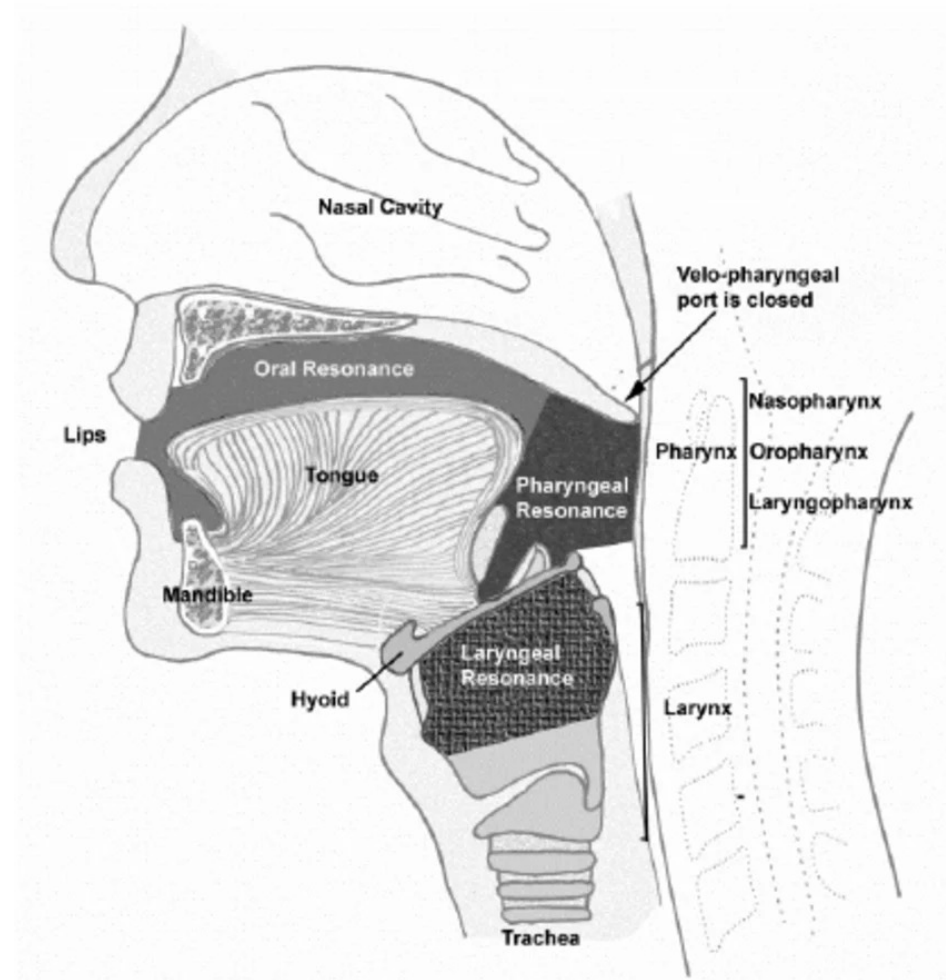
YouTube vocal coach with my own private studio

I teach mostly contemporary commercial music (CCM)

Certified in Complete Vocal Technique (CVT), a science-based voice program in Europe



Introduction



Nair, Nair and Reishofer (2016), Figure 4. Resonance spaces of the vocal tract, velopharyngeal port closed.

- “Nasal resonance”, framed here as nasal emissions or nasal airflow during singing, **is controversial** (Perna, 2020, p. 429)
- Historically seen as poor technique, **linked to a nasal timbre** (Stark, 1999, pp. 52-53, 211)
- **Singers generally do have nasal emissions**, depending on pitch and vowel (Tanner et al., 2005; Jennings and Kuehn, 2008; Perna, 2014)
- Nasal airflow might be beneficial for singers’ **vocal health and resonance** (Vampola, Horáček and Laukkanen, 2021, 2024; Konrot et al., 2025)
- **I study classical tenors here** because that is where the literature is, **even though I am a CCM teacher**

Reviewed singing studies, 2000 to present (report Table 2).

The Problem

- Measurement tools are costly, hard to customize, limit data access and can be invasive, **barriers to studio use** (Dewhurst et al., 2025; Cler et al., 2016; Birch et al., 2002)
- Aerodynamic systems cost about \$10,000 (Cler et al., 2016, p. 1022)
- **Little real-time feedback for singers**, though visual airflow feedback can help singing students (Lã et al., 2017; Lã, Sundberg and Granqvist, 2022)

Within the literature reviewed, this may be the first affordable, noninvasive aerodynamic nasal flow sensing device for singers, built from consumer-grade components, open-source software, and providing real-time feedback.

Aim and Objectives

“The addition of the nasometer in the voice studio could prove to be additionally valuable both in finding an appropriate increase in nasalance for passaggio and in decreasing excessively nasal tone.”

Perna (2014, p. 409)

Aim

To increase access to nasal airflow measurement within voice pedagogy by designing, building, and evaluating a low-cost prototype suitable for future use in the singing studio.

Objectives

- **Measures nasal flow**
- **Non-invasive**
- **Provides real-time feedback**
- **Comfortable**
- **Sensitive**

The Velopharyngeal Port

The velopharyngeal opening (VPO) is an opening created by the pharyngeal walls and the posterior velum (Kummer, 2011, p. 151). **This allows airflow to enter into the nose** (Tanner et al., 2005).

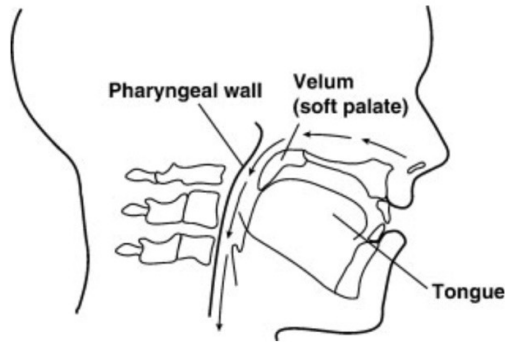


Figure 1 Position of the velum during normal nasal breathing.

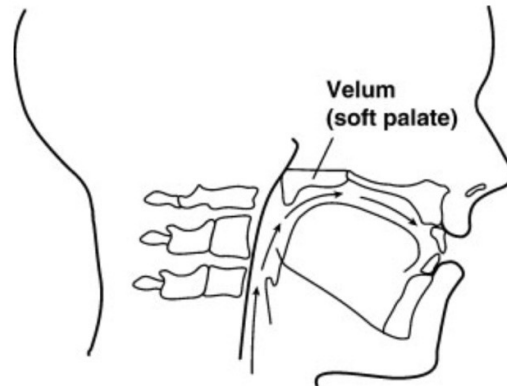


Figure 2 Position of the velum during normal oral speech.

Velum position in nasal breathing (left) and oral speech (right). Kummer (2011, p. 151), report Figure 1a.

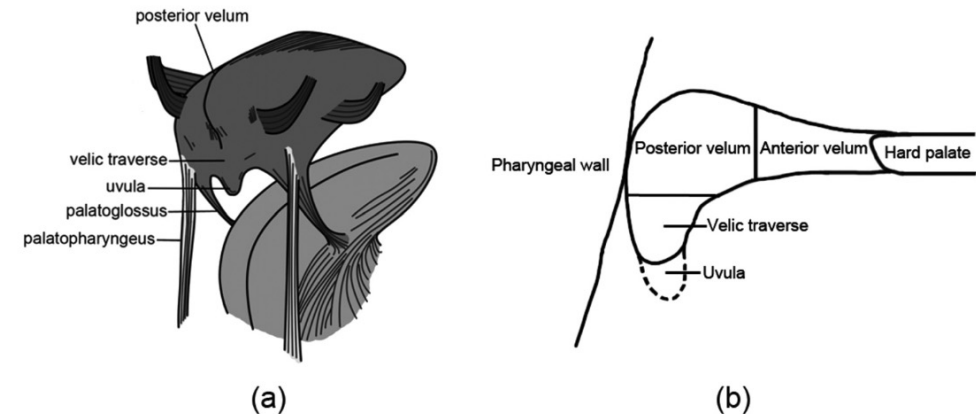


Fig. 1. (a) Velum and tongue, posterior view; (b) regions of the velum, midsagittal view.

The velum and tongue. Gick et al. (2013, p. EL209), report Figure 1b.

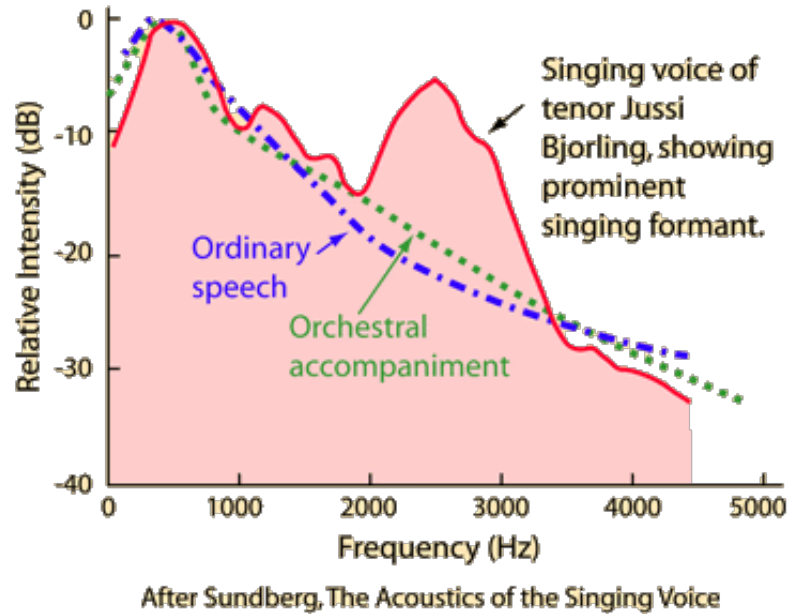
So Why Do Singers Use a VPO?

Formant Tuning: A VPO may create an **acoustically favorable environment** depending on the singer, vowel, pitch, volume, etc. (Vampola, Horáček and Laukkanen, 2021, 2024)

Vocal Economy: May improve vocal economy (Echternach et al., 2021; Vampola, Horáček and Laukkanen, 2021, 2024).

Singer's Formant: A VPO may also strengthen the singer's formant (Vampola, Horáček and Laukkanen, 2024)

VPO Improves Singer's Formant



Singer's formant. Nave (no date), adapted from Sundberg (1977, cited in Nave, no date), report Figure 7b.

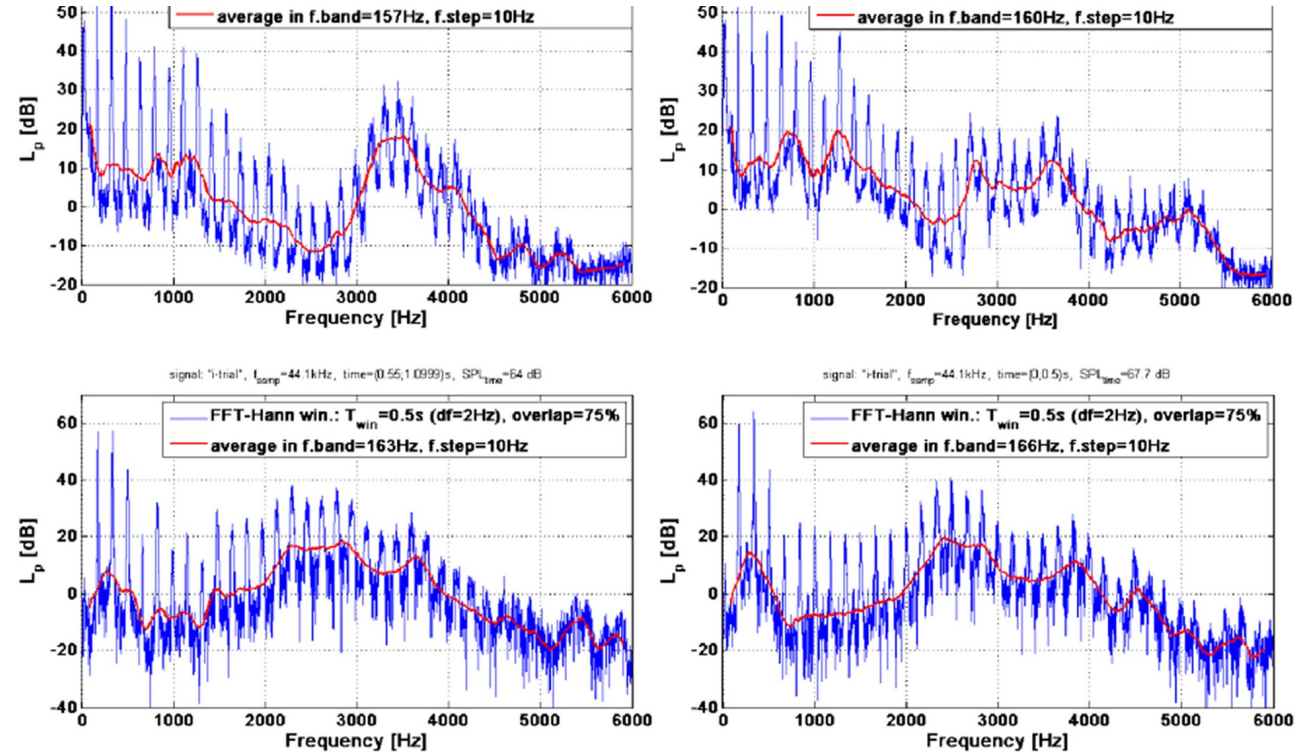
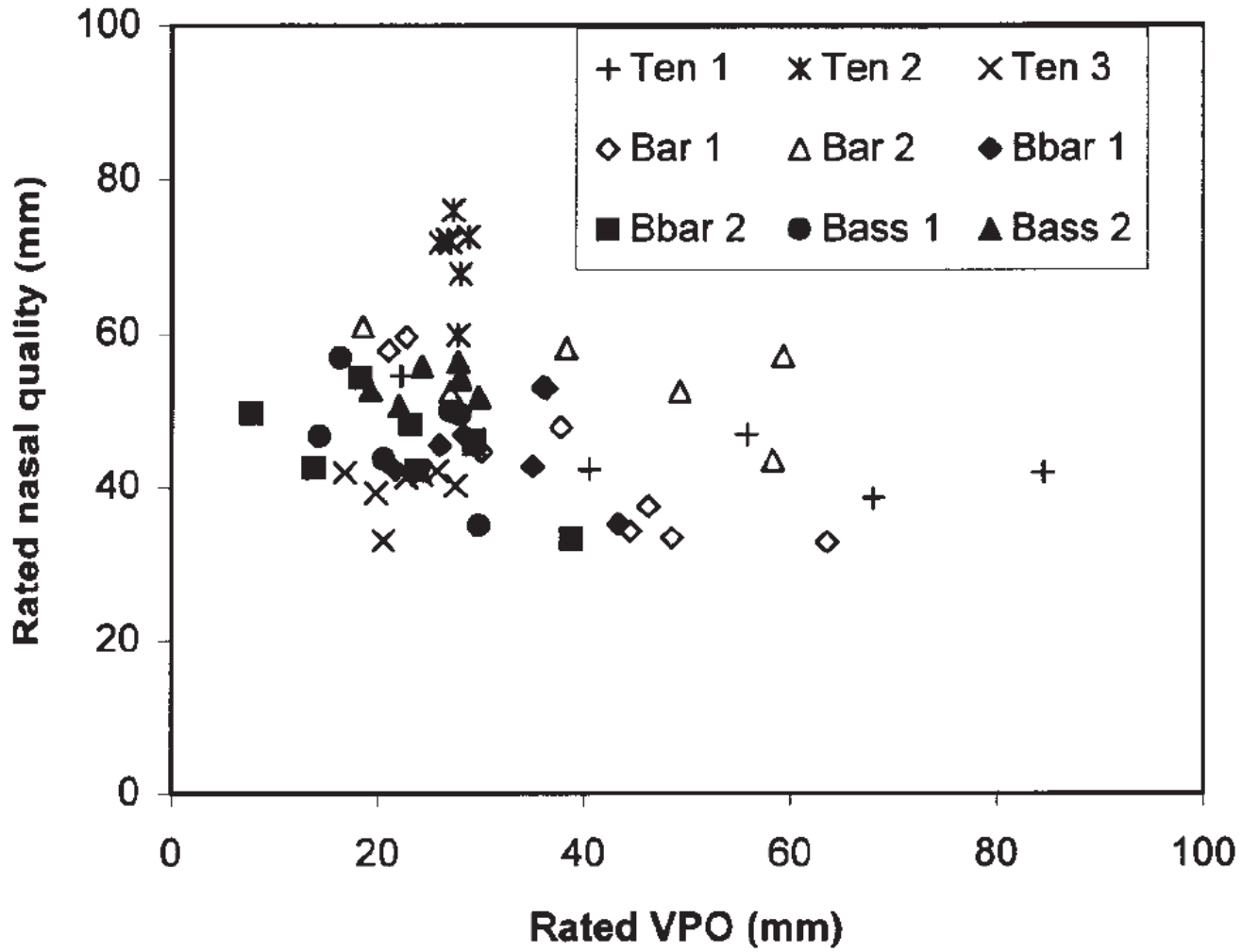


FIG. 13. (Color online) Spectra of the vowels [a:] (upper panel) and [i:] (lower panel) measured *in vivo* in the female subject; nasalized (left) and non-nasalized (right) phonation. The thick red lines show the formants in the spectra after removing the fundamental frequencies ($f_0 = 157$ or 160 Hz for the vowel [a:] and $f_0 = 163$ or 166 Hz for the vowel [i:]) and their higher harmonics [for the method, see Radolf *et al.* (2016) and Horáček *et al.* (2017)].

Vampola *et al.* (2020, p. 3227), Figure 13. Measured spectra of [a:] (top) and [i:] (bottom), nasalized (left) and non-nasalized (right), female subject.

Common Misconception



“Nasal timbre” and an open velopharyngeal port (VPO) **are not necessarily the same thing** (Birch et al., 2002; Perna, 2020)

How Is It Measured?

I needed to know this to create a device

Indirect - acoustic

Microphones record sound (fast pressure changes).

Nasalance (%), level (dB), F0 and F1 (Hz)

Indirect - aerodynamic

Pressure difference or airflow.
NTAD: 100 samples/s.

Pressure (Pa) or flow (mL/s)

Direct - imaging

Nasoendoscopy, X-ray, videofluoroscopy and MRI

Not practical in the voice studio.

Birch et al. (2002); Kummer et al. (2012); Blaylock, Goldstein and Narayanan (2016).

Limitations of VPO Indirect Measurement Devices

Indirect measures cannot establish VPO size or shape with certainty.

Leakage and other artifacts can cause over or underestimation of nasal emissions.

Setups are invasive or difficult to sing with.

Most are not designed for singers; live feedback for singing may be limited.

Commercial aerodynamic systems can cost \$10,000 or more (2016 prices).

Direct Measurement

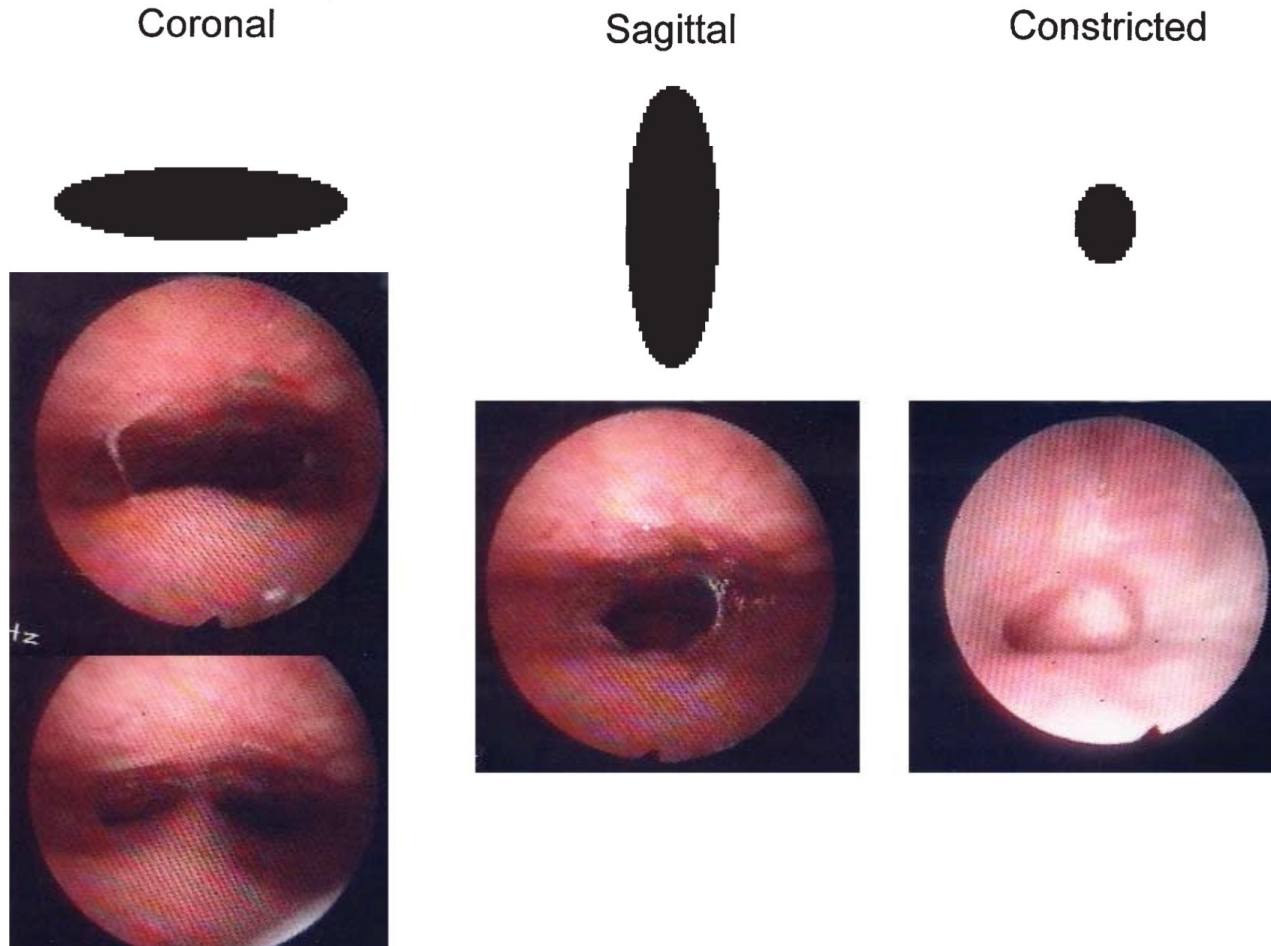


FIGURE 5. Schematical examples from the nasofiberscopy documentation of the three main shapes of VPO observed in the singers.

Coronal, sagittal and constricted velopharyngeal openings observed in singers. Birch et al. (2002, p. 66), report Figure 7a.

Description

Imaging methods include nasoendoscopy, X-ray, videofluoroscopy and MRI (Kummer et al., 2012; Blaylock, Goldstein and Narayanan, 2016).

A scope passed through the nose views the port directly (Birch et al., 2002).

Limitations

Invasive: Birch et al. (2002) used a local anesthetic.

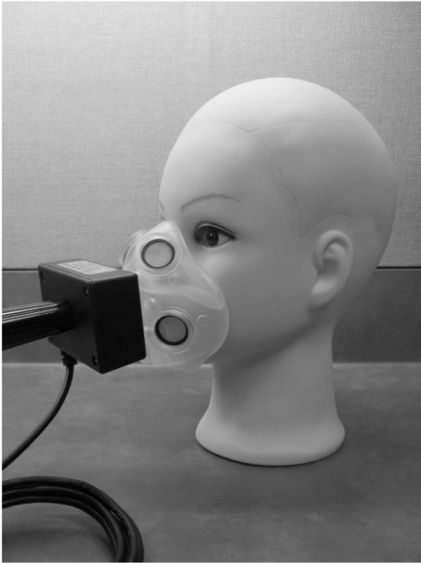
Among the studies reviewed here, only Birch et al. (2002) **directly documented VPO during singing.**

Acoustic Measurement (Microphones)

Microphones record sound (fast pressure changes). Acoustic measurements include level (dB), F0 and F1 (Hz).

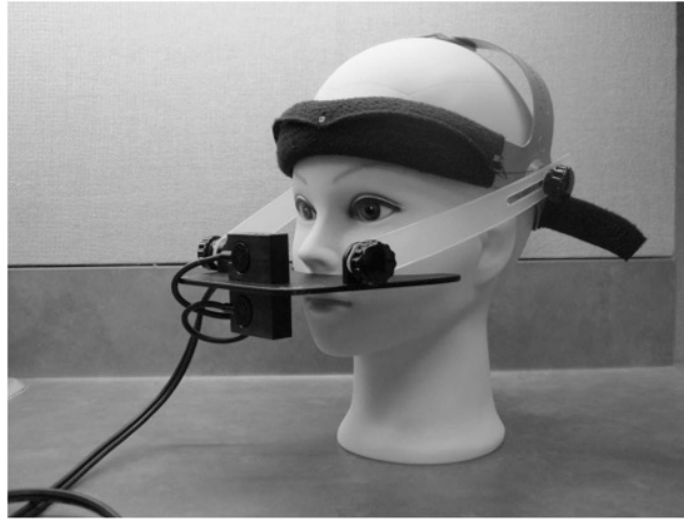
Nasalance: "the ratio of nasal to oral-plus-nasal acoustic energy", expressed as a percentage (Bundy and Zajac, 2006).

Mask



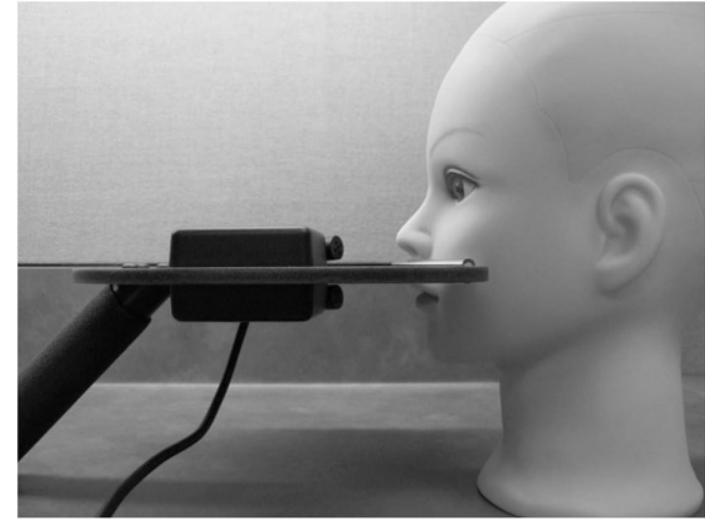
Nasalance System with a face mask. Bressmann (2021), report Figure 4.

Headset



Nasometer headset. Bressmann (2021), report Figure 2.

Open divider plate



Nasalance System with a separator plate. Bressmann (2021), report Figure 3.

Acoustic Measurement Limitations

Sound passing through the palate can register even with the port closed (Bundy and Zajac, 2006).

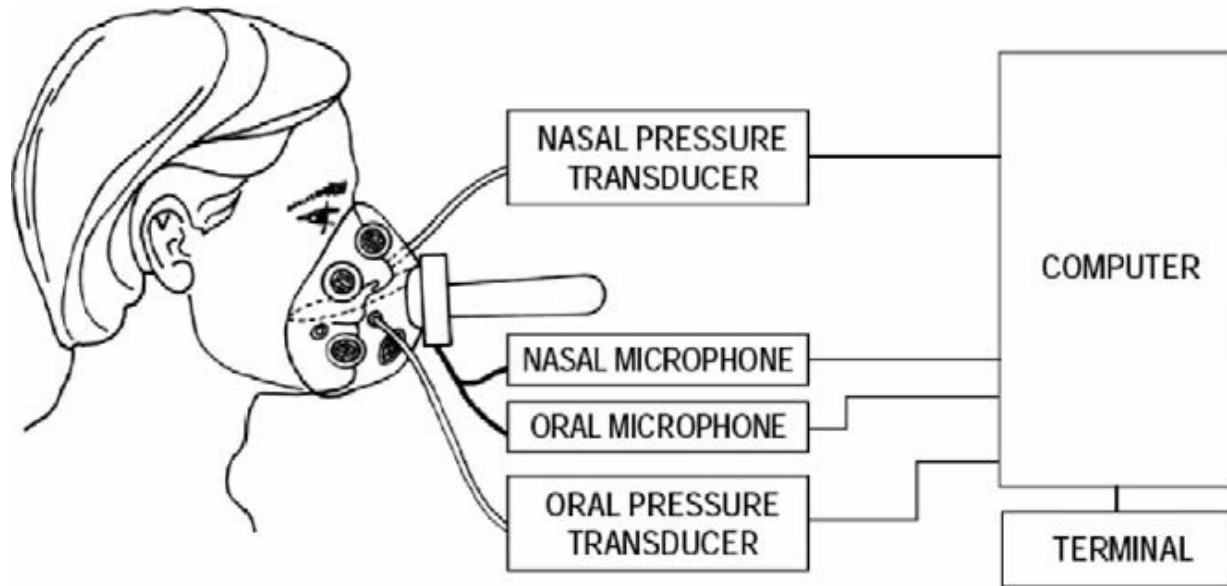
Sound can cross between the nasal and oral microphones (Bundy and Zajac, 2006; Rothenberg, no date).

For band-limited measurements, **results depend on bandwidth**, vowel and pitch (Perna, 2020, p. 431; Rothenberg, no date).

Readings vary across commercial models (Awan and Virani, 2013).

Masks can disturb singing, feedback and jaw movement (Birch et al., 2002).

Aerodynamic Pressure Sensors (Mask)



Divided mask with nasal and oral channels. Bundy and Zajac (2006, p. 694), report Figure 5.

Masks measure nasal and oral airflow (Rothenberg, no date; Gill et al., 2020).

Reported as: flow (mL/s), or flow nasalance (%).

Limitations

Masks must be tightly sealed and can disturb singing, feedback, and jaw movement (Birch et al., 2002)

Masks can leak at the rim and miss nasal flow (Birch et al., 2002, p. 64; May and Scherer, 2018)

Phantom nasal flow of up to 30 mL/s (Fisher and Swank, 1997, cited in Bundy and Zajac, 2006)

Aerodynamic (Pressure-Flow)

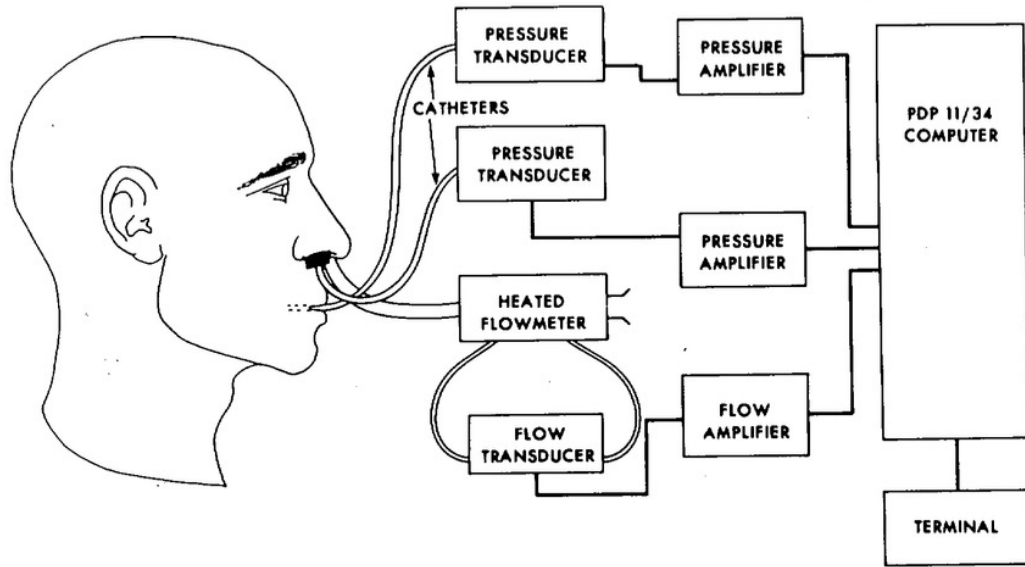


FIGURE 1. Diagrammatic representation of the pressure-flow technique for quantifying temporal patterns

The pressure-flow technique. Warren et al. (1985, p. 12), report Figure 6.

Records nasal and oral pressure and nasal flow, then **estimates the port's opening area** with an orifice equation (Warren and DuBois, 1964).

Reported as: pressure in pascals (Pa), and flow in mL/s, and VPO area mm²

Limitations

The equation was built on sharp-edged openings; rounded openings were **overestimated by up to 100%** (Pelorson, 2001)

Cost: PERCI-SAR system components total **\$16,895** at 2016 prices (MicroTronics Corp., 2016)

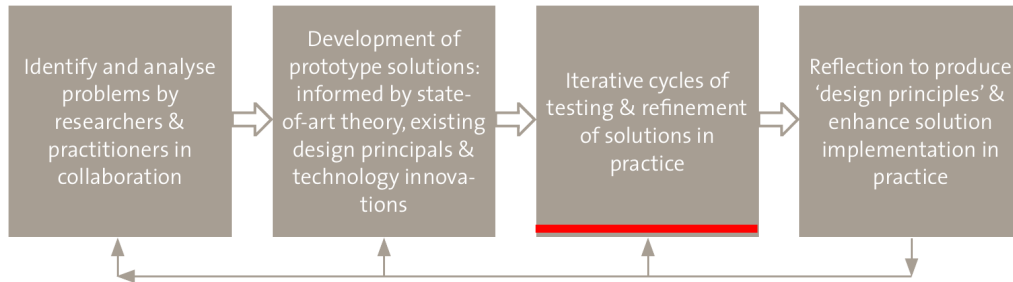
Studying the Velopharyngeal Port

Report Table 2

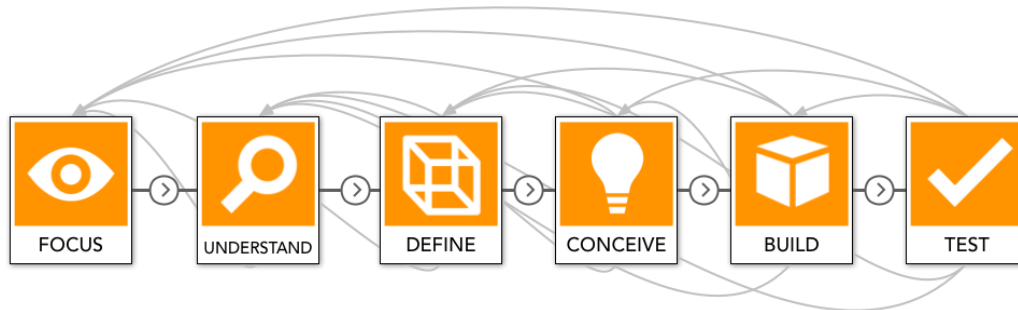
Study	Instrument model	Interface	Measurement
Acoustic (Microphone-Based)			
Fowler and Morris (2007)	Glottal Enterprises OroNasal System	Divided vented mask	F0 nasalance
Perna (2008)	Glottal Enterprises Nasality Tutor	Divider plate	Acoustic nasalance
Jennings and Kuehn (2008)	Nasometer II 6400 (KayPENTAX)	Divider plate (headset)	Acoustic nasalance
Santoni et al. (2020a)	Nasometer 6450 (KayPENTAX)	Divider plate (headset)	Acoustic nasalance
Santoni et al. (2020b)	Nasometer 6450 (KayPENTAX)	Divider plate (headset)	Acoustic nasalance
Jayakumar et al. (2024)	Nasometer II 6400 (KayPENTAX)	Divider plate (headset)	Acoustic nasalance
Aerodynamic (Airflow)			
Birch et al. (2002)	Glottal Enterprises MS 100-R2	Divided mask	Nasal and oral airflow
Gill et al. (2020)	Glottal Enterprises flow mask; MS-110 interface	Divided mask	Nasal and oral airflow
Echternach et al. (2021)	Glottal Enterprises MS-110 PT-2E transducer	Divided mask	Flow nasalance
Jayakumar et al. (2024)	Glottal Enterprises Aeroview	Rothenberg mask	Nasal airflow
Orifice Area Estimation (Pressure-Flow)			
Tanner et al. (2005)	MicroTronics PERCI-SARS 3.22 heated pneumotachometer (Hans Rudolph)	Nasal tube; foam-tipped catheter in opposite nostril; oral catheter	Nasal airflow; oral and nasal pressure; estimated VPO area
Martell, Lastowiecka and Bae (2025)	MicroTronics PERCI-SAR HR7319-FP heated pneumotachograph	Nasal tube; foam-tipped catheter in opposite nostril; oral catheter	Nasal airflow; oral and nasal pressure; estimated VPO area
Aerodynamic (Nasal Pressure)			
This project NTAD	Sensirion SDP810-125Pa	Cannula	Nasal pressure

Design-Based Research

Design-based research builds something to solve a real problem and studies the building process in order to learn from it (Plomp, 2009).



Reeves' four phases of design-based research. Reeves (2006, cited in Plomp, 2009, p. 14), report Figure 8a.



The six-phase design process. Easterday, Rees Lewis and Gerber (2014), report Figure 9.

Pragmatism: Dewey's instrumentalist paradigm judges ideas by their **practical effectiveness** (Dewey, 1938; Bannen, 2018).

Two models

Reeves' four phases for **the project as a whole** (Figure 8a)

Easterday's six phases for **each design iteration** (Figure 9)

Reeves (2006, cited in Plomp, 2009, p. 14)

Instrumentalist paradigm. Less concerned with precise measurements as VPO cannot currently be known by indirect measurement alone (Pelorson, 2001; Bunton, 2015). More focused toward pragmatic implementation.

Insider Research, Reflexivity and Ethics

Ethics

Approval before development

Self-testing only: no students or other participants

A new cannula and tubing for each session

I stopped when tired or uncomfortable

Insider researcher

I was the designer, participant and evaluator

Bias

I designed the tasks

I adjusted my vocal technique to the live trace

Choosing takes adds selection bias

Self-experimentation

Researchers experimenting on themselves (Weisse, 2012)

Fitting the cannula, 28 September 2026

Evaluation Criteria

Criterion	Requirement	Rationale and sources
Assessed on the final build only (Iteration 2.1)		
1 Cost and accessibility	Be affordable and accessible.	Commercial aerodynamic systems are costly (Cler et al., 2016; MicroTronics Corp., 2016).
Assessed through the tasks: qualitative		
2 Practical usability, comfort, and ethics	Be comfortable and non-invasive.	Nasal emission measuring devices can be invasive and interfere with singing (Birch et al., 2002; Tanner et al., 2005; Echternach et al., 2021; Martell, Lastowiecka and Bae, 2025).
Assessed through the tasks: quantitative		
3 Sensitivity	Distinguish low-pressure signals from baseline variability.	Nasal flow during singing can be low and overlap with closure artifacts (Gill et al., 2020; Hoit et al., 1994; Zajac, 2000).
4 Responsiveness	Follow brief changes during singing.	Brief changes in nasal emission and vocal onset require a responsive signal to provide real-time feedback (Caren, Michon and Wright, 2020; Martell, Lastowiecka and Bae, 2025).
5 Graded rather than binary output	Distinguish the intended None, Slight and Much conditions.	The benefits of a VPO may depend on its degree of opening (Bunton and Story, 2012; Bunton, 2015; Gill et al., 2020).
6 Reliability	Give reasonably consistent readings under comparable conditions across takes and sessions.	Device performance should not degrade over long tasks or between sessions.

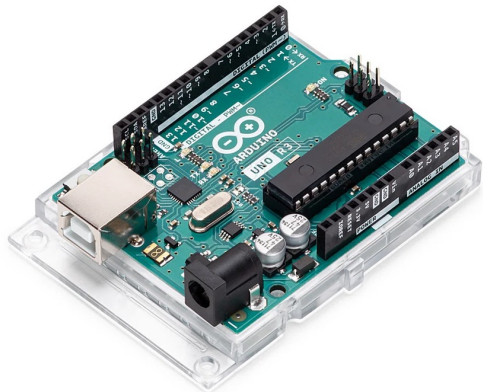
Evaluation Criteria (continued)

Criterion	Requirement	Rationale and sources
Established during sensor and platform selection		
7 Evidence-based	Ground the measurement method and its interpretation in the literature.	Nasal pressure has been used to detect nasal emission during phonation (Thom et al., 2006; Bunton and Hoit, 2018), and nasal airflow measurements are used extensively in singing literature (Birch et al., 2002; Gill et al., 2020; Echternach et al., 2021).
8 Open hardware and software	Use open hardware and software to support experimentation and troubleshooting.	Low-cost, adaptable platform to support troubleshooting and further development (Caren, Michon and Wright, 2020; Dewhurst et al., 2025; Wang et al., 2026).
9 Potential for future development	Allow customization and report physical units to support later calibration.	Device should be produced in such a way that future iterations are possible.

Device Design



Sensirion SDP810-125Pa (Sensirion AG, no date).



Arduino Uno R3 (Arduino, no date).

Arduino Uno R3

Affordable hardware + open-source, free software (D'Ausilio, 2012; Pearce, 2012)

SDP810-125Pa

\$30.86 before tariffs; ± 125 Pa range for the small nasal flows that matter in singing (Gill et al., 2020; Sensirion AG, 2019)

High repeatability and no offset drift, per the manufacturer (Sensirion AG, 2019)

Used in medical devices and research: recommended for CPAP machines (Sensirion AG, 2024) and used in a portable breathing monitor tested against reference equipment (Vieira Junior et al., 2025), for example.

Low voltage: 5 V from the computer's USB port, far below the 50 V guarding threshold (Occupational Safety and Health Administration, no date)

Prototype Development Process

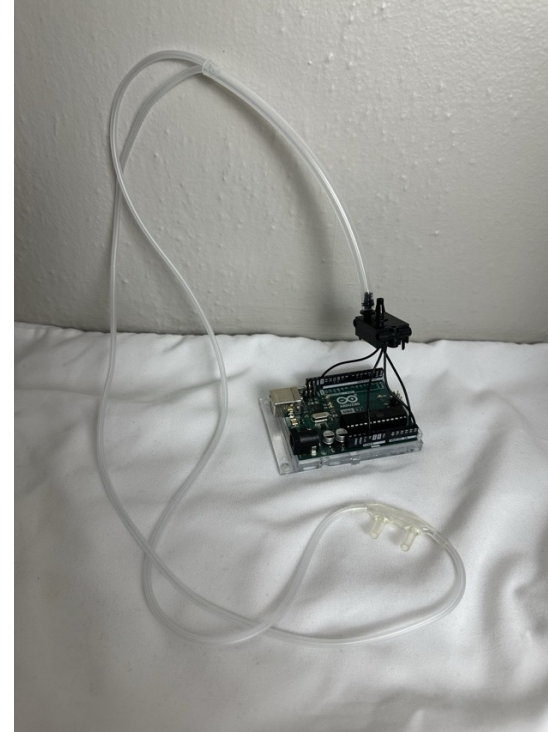
One port at the nostrils,
one open to room air.

**Relative pressure
difference in pascals**

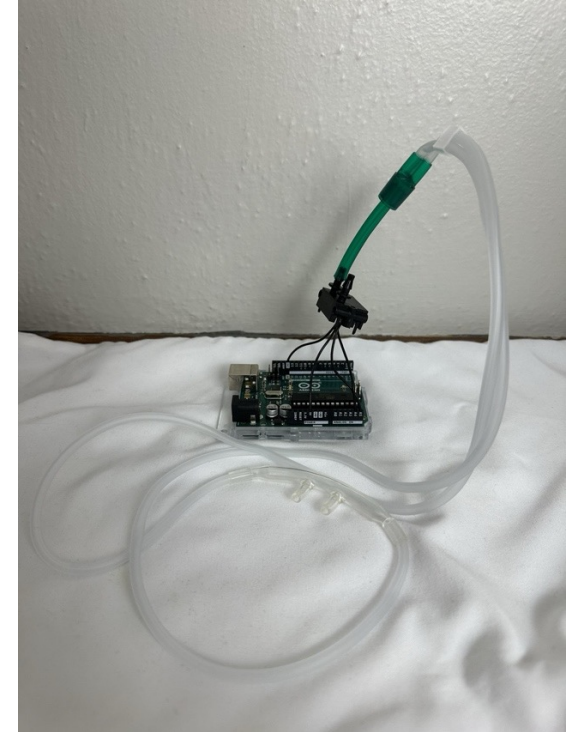
(Bunton, Hoit and
Gallagher, 2011; Sensirion
AG, 2019)



7 July. Iteration 0.



Iteration 0.2.



Iteration 2.1, tested build.

Iteration 2.1 Build Cost

Part	Supplier	Price (USD)	US tariff at purchase (USD)
Sensirion SDP810-125Pa differential pressure sensor	DigiKey	\$30.86	\$4.79
Arduino Uno R3 (A000066)	Amazon	\$27.60	Included in listed price
Molex 4-position 2.00 mm connector housing (502351-0400)	DigiKey	\$0.45	\$0.13
ResOne high-flow adult nasal cannula, 2 ft, pack of five	Amazon	\$9.99	Included in listed price
USB 2.0 A-to-B cable	Already owned	Not included (about \$5 new)	
Total		\$68.90	\$4.92

Table 5. Iteration 2.1 build cost (USD).

Results

DISCLAIMER: The objective of these findings is not to derive scientific conclusions.

A feasibility test to compare against the relevant literature and see if it works well enough for studio application.

An initial prototype test stage of a low-cost, relative pressure-sensing device for singers. These tasks are not intended to test, validate, or invalidate pedagogical theories.

Device performance

1. **Artifact:** sharp /p/ onsets to check for signal artifacts.
2. **Degree:** None, Slight and Much, compared with Gill.
3. **Ramp:** gradual increase in intended nasal flow.
4. **Low-Flow:** closed-port and low-flow notes.
5. **Straight-tone:** Slight with and without vibrato.

Exploring studio applications

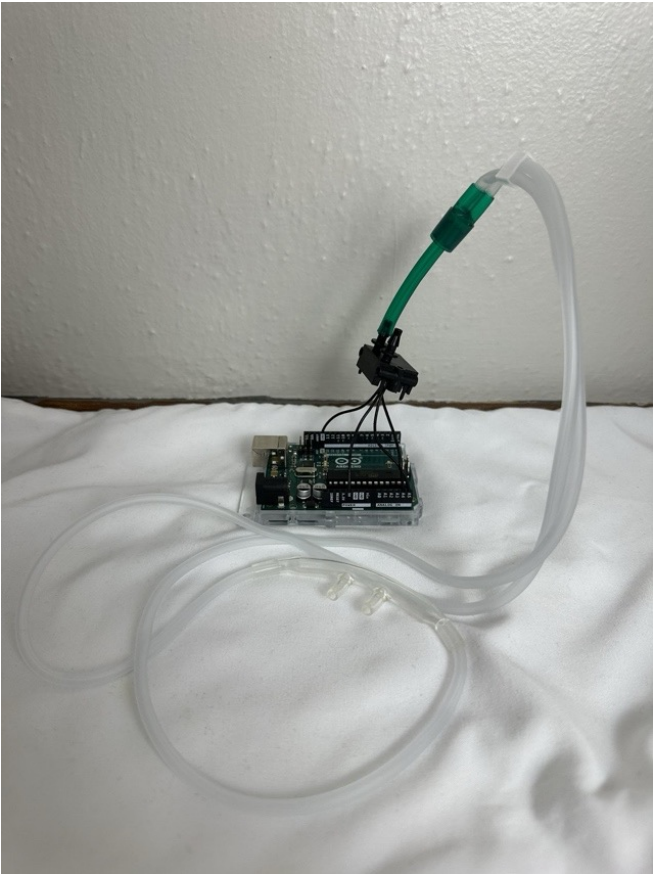
6. **Singer's Formant:** notes with and without nasal flow.
7. **Pinch and Release:** sustain /i/, pinch, then release.

Additional checks: resting noise, baseline drift, closed-port readings and tap response.

Device Performance

Specification	NTAD (Iteration 2.1)
Sensor range	±125 Pa
Sampling rate	100 Hz (10 ms)
Resting noise	0.00 Pa mean, 0.01 Pa SD
Baseline drift	0.02 Pa over 3 h 17 min
Artifact (/p/ onset)	−0.49 to +0.12 Pa
Closed-port sustained notes	−0.19 to +0.11 Pa
Rise time after a tap	Within one 10 ms sample for firm taps (limit of 100 Hz sampling)
Estimated display delay	0-35 ms
Estimated audio alignment	within about 0.05 s
Parts cost	\$68.90 (plus \$4.92 tariffs)

Report Tables 5 and 6. Prototype results from one measured session.



26

Degree Task

Median pressure

None -0.02 Pa Slight 0.81 Pa Much 4.29 Pa



Degree task recording.

Limitations

It took me an hour or two to get this result because I couldn't get the volume even.

Not vocalizations intended to be used for singing

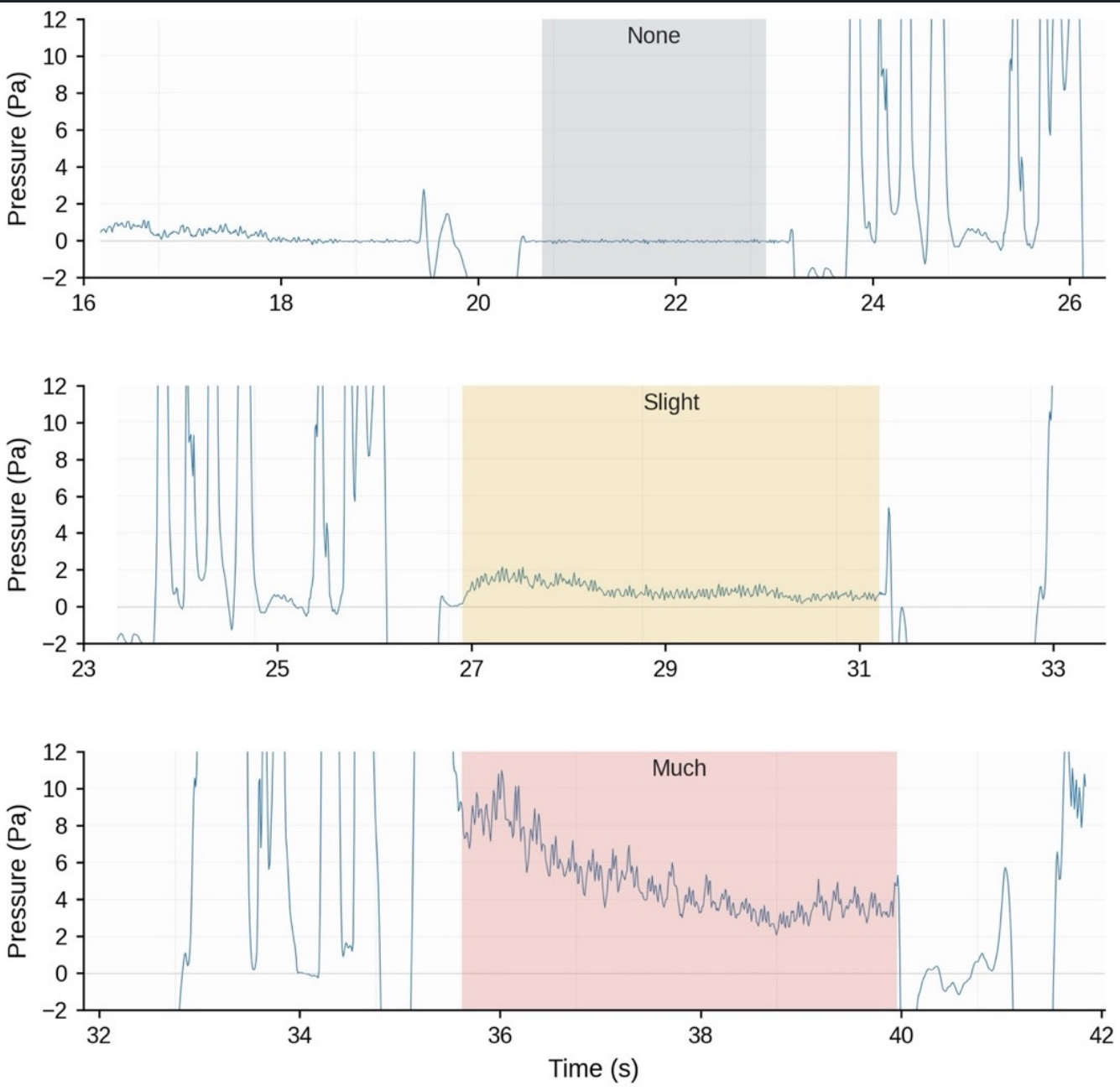
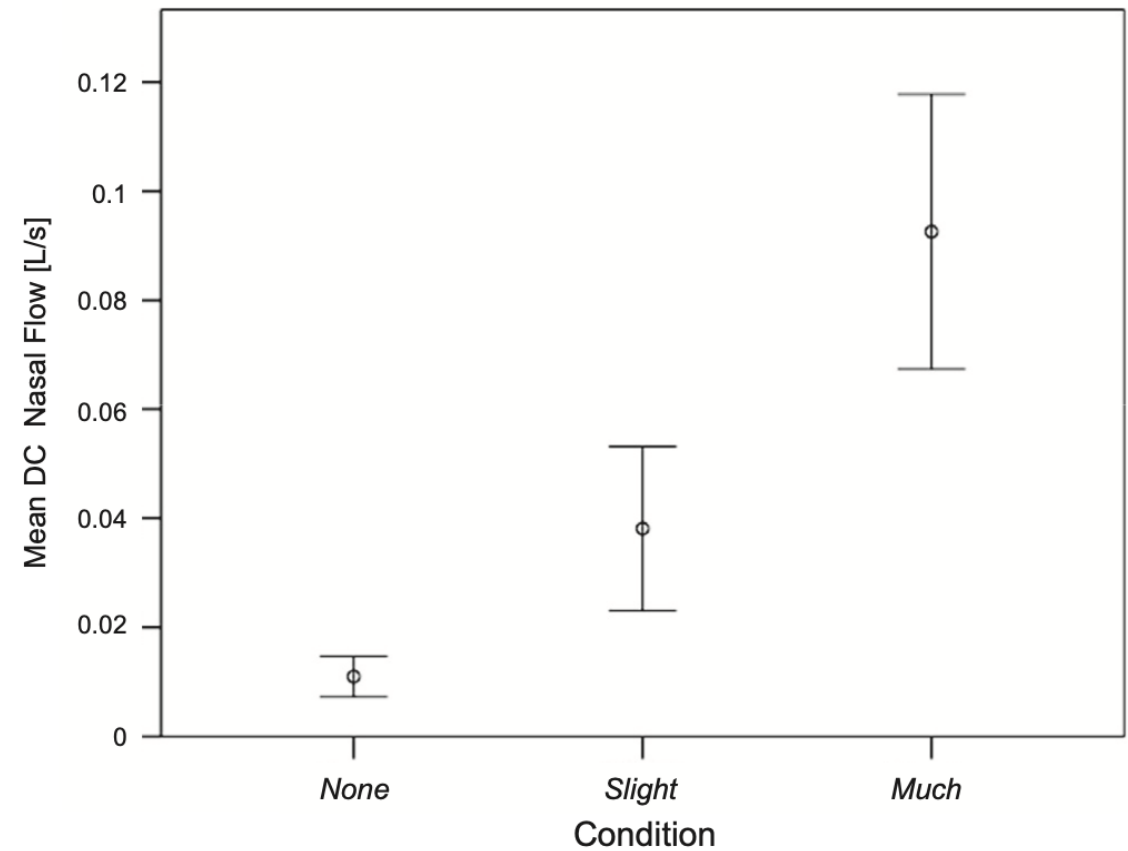
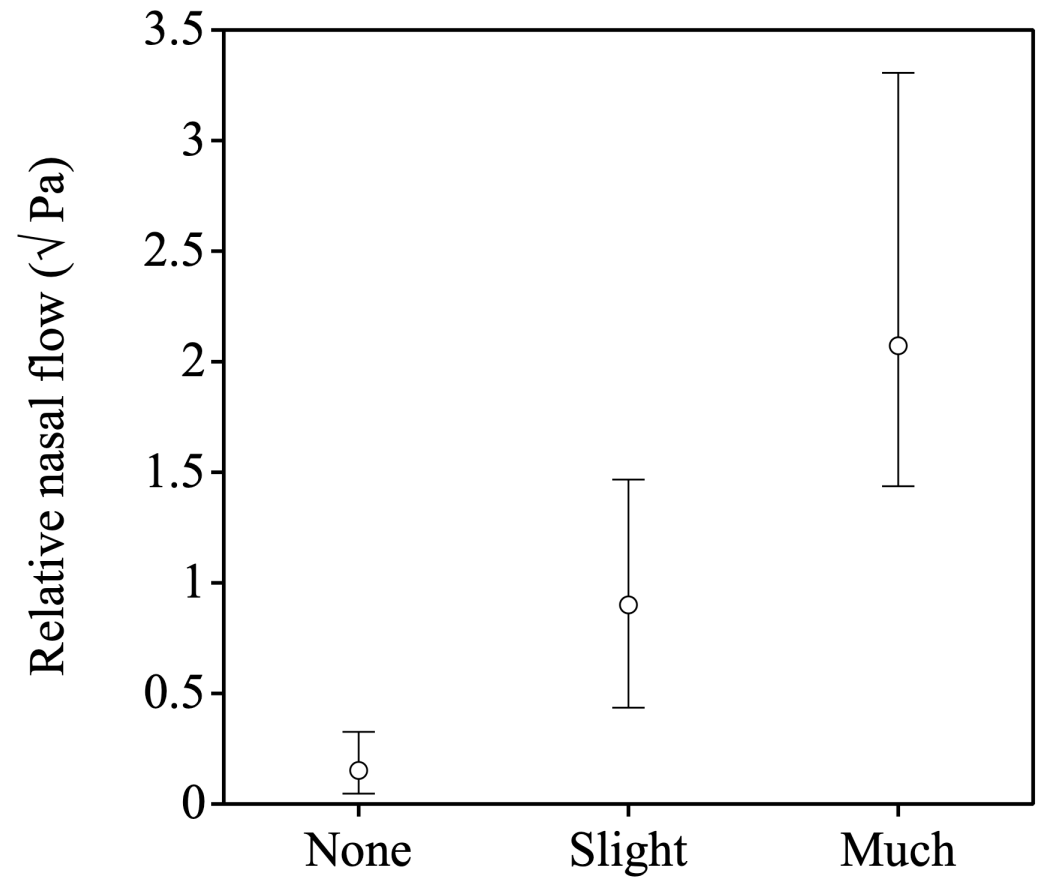


Figure 18. None, Slight and Much.

Degree Task: Results

Uncalibrated relative pressure; not a direct comparison with Gill's airflow measurements.



Gill et al. (2020), mean and standard deviation.

Figure 18b. Degree task relative flow, median and range.

Singer's Formant Task

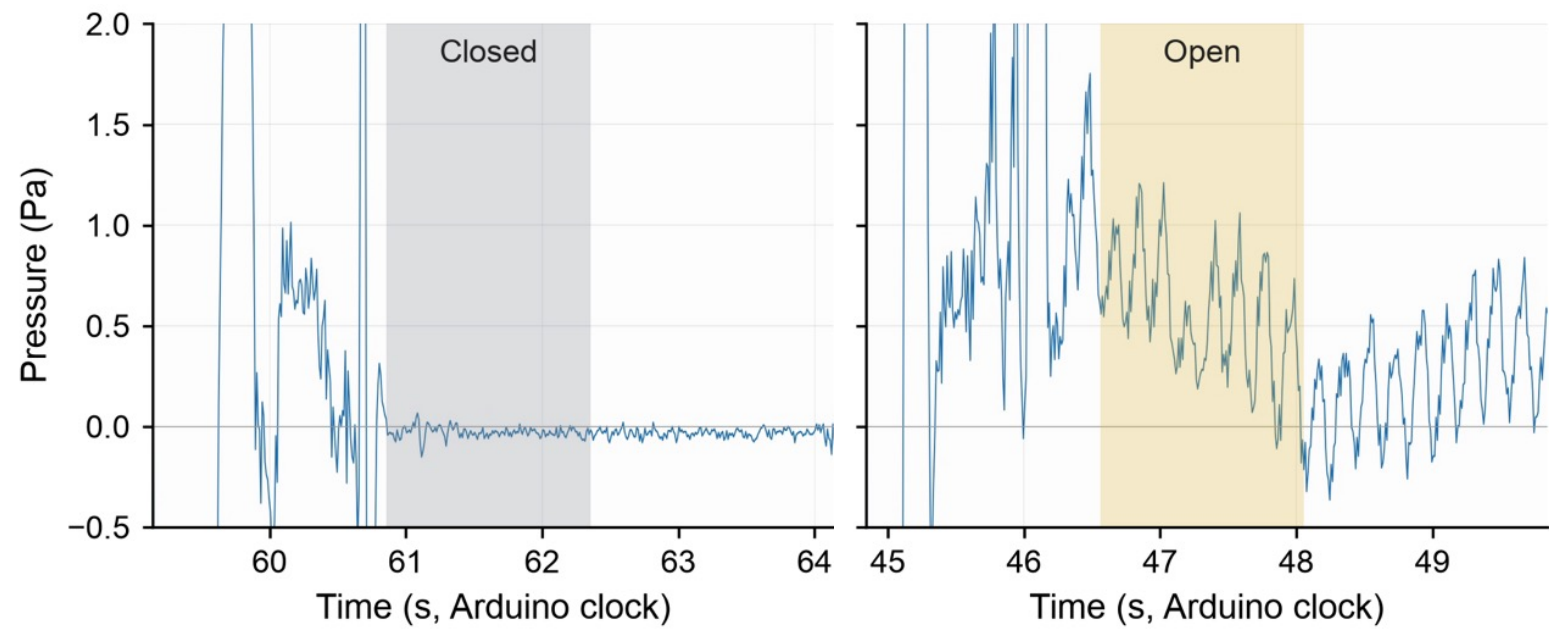


Figure 22. Closed pressure.

Figure 22. Open pressure.

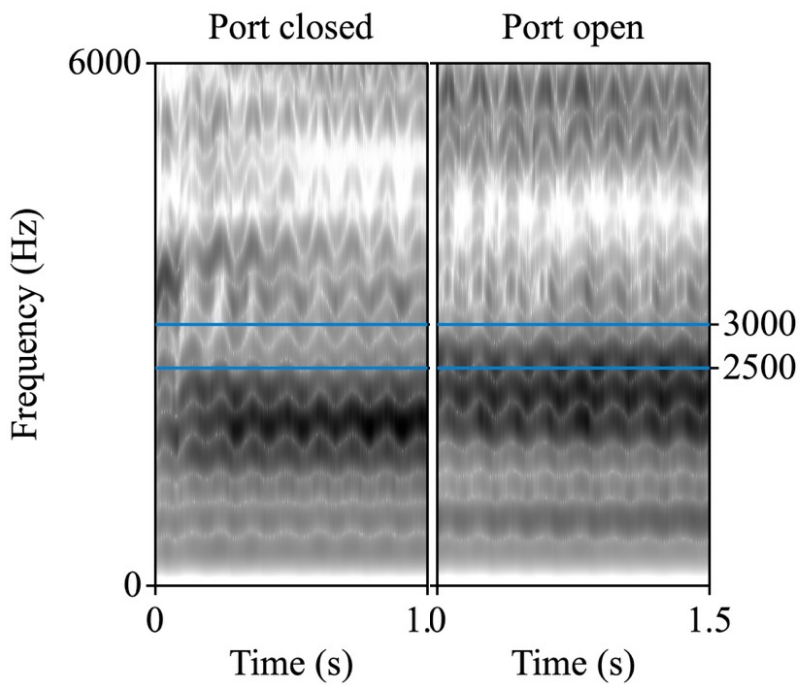
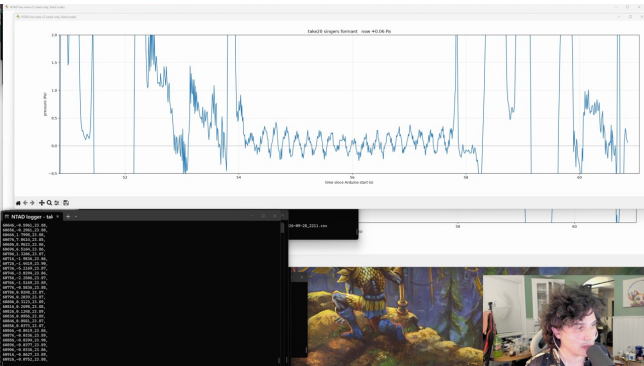
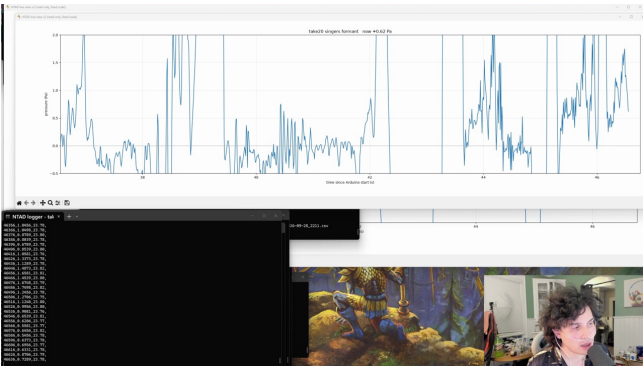


Figure 23a. Closed Spectrograph.

Figure 23a. Open Spectrograph.



Closed-port recording.

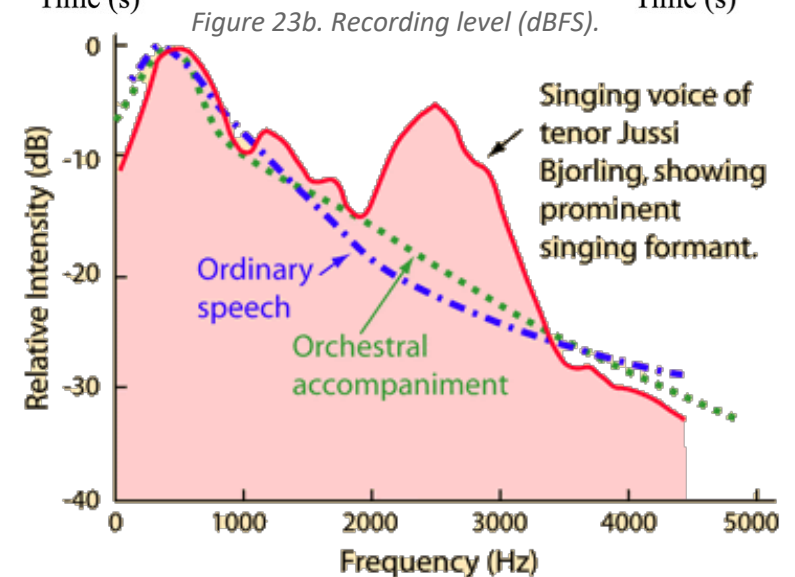
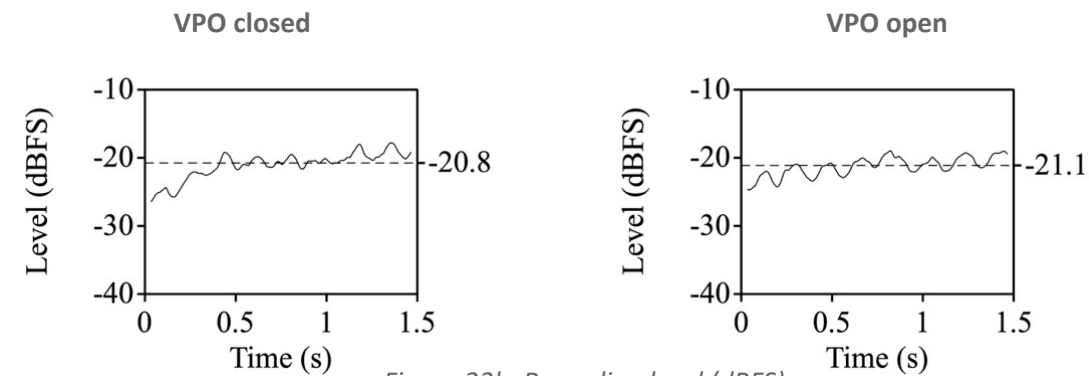
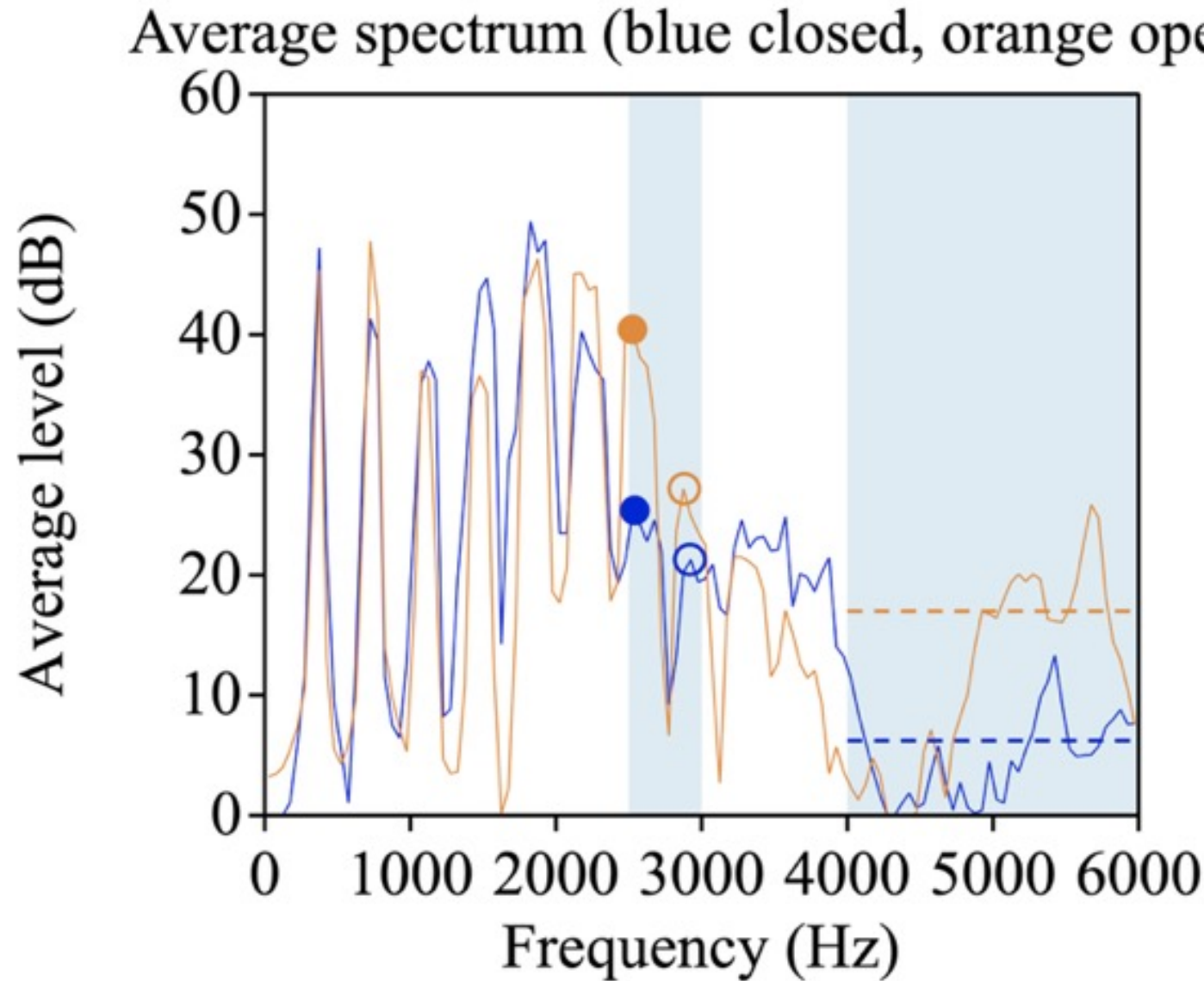


Open-port recording.

Limitations

I picked one pair for the biggest difference.
I am not a classical singer.
I heard other changes in my singing, so I cannot attribute the difference to VPO alone.

Singer's Formant Task: Results



After Sundberg, *The Acoustics of the Singing Voice*
Singer's formant comparison (Nave, no date).

Figure 23c. Average spectrum.

Limitations

Moisture

Condensation built up over the long session



Figure 26. Condensation in the cannula.

Connections

Tube not fully seated on the sensor; fragile connectors; short tube held in my hand



Tube-to-sensor connection.

Prong position

Prongs about 1 cm; the nasal valve begins 1-1.5 cm inside (Nigro et al., 2009, p. 308)

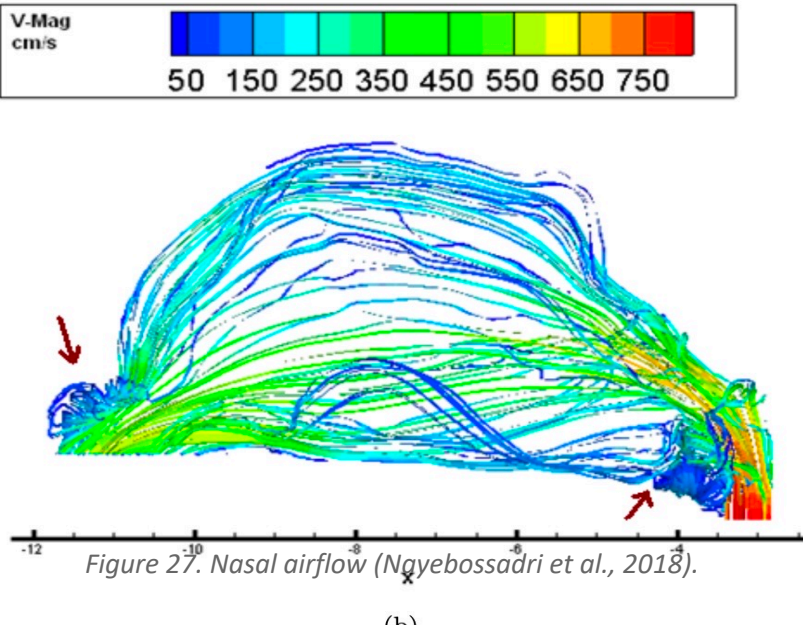


Figure 27. Nasal airflow (Nayebossadri et al., 2018).

Limitations, continued

FREQUENCY RESPONSE

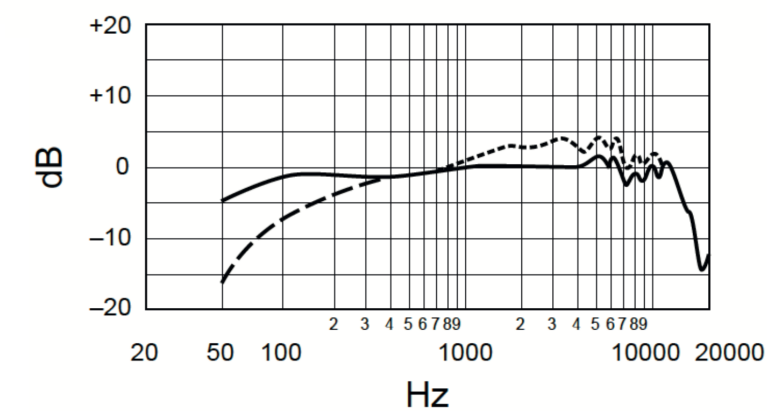


Figure 30. SM7B frequency response (Shure Incorporated, 2023).

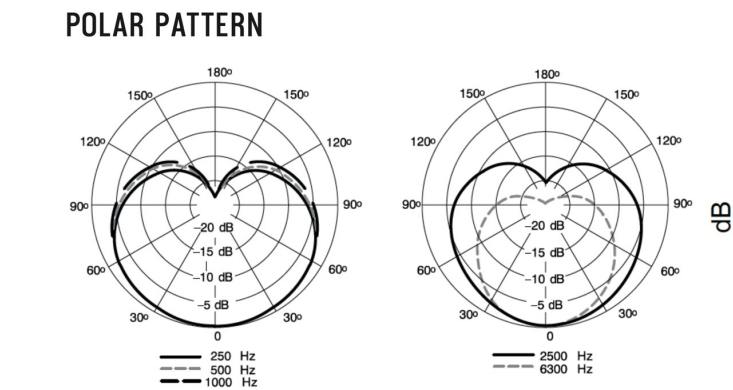


Figure 29. SM7B polar pattern (Shure Incorporated, 2023).

No reference instrument

I can't say how accurate the readings are

SM7B presence boost

Left on by accident. A bump in the upper midrange, over much of the singer's formant region (Figure 30)

SM7B microphone distance

Response varies with distance and placement; small movements may have changed levels between takes (Figure 29)

Subject VPO control

I watched the live graph for feedback; **many takes went unused**

Insider and unblinded

I designed the device, sang, and listened. Knew what the outcome of the tests might be.

Uncalibrated

Relative pressure at the naris; **not a like-for-like comparison** with Gill et al. (2020)

Singer's formant

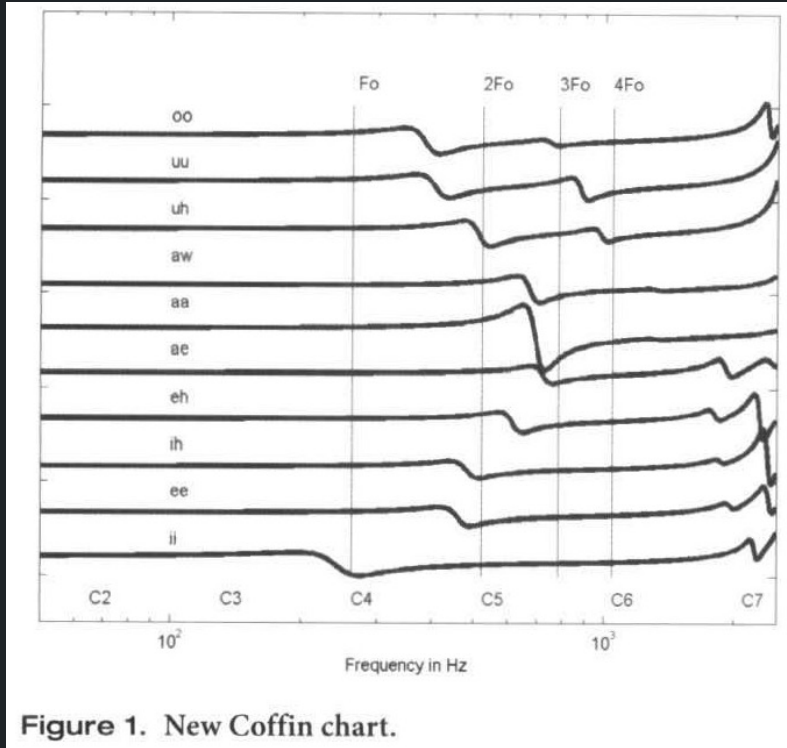
Not a classical singer; one pair picked for the biggest difference; AI assistance with the Praat figures (Anthropic, 2026; Boersma, Weenink and Shchupak, 2026)

Evaluation Against the Criteria

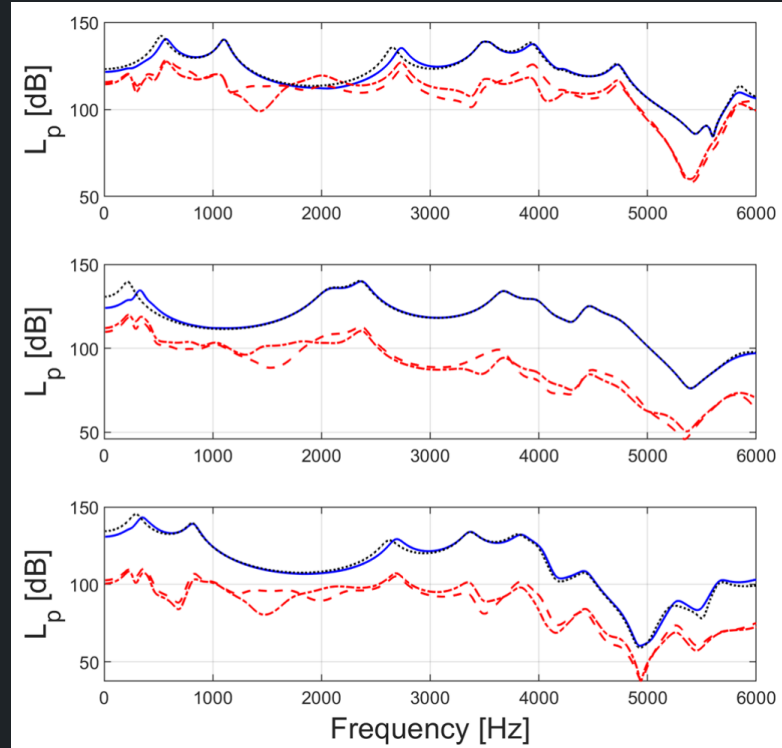
Criterion	Result
Assessed on the final build only (Iteration 2.1)	
Cost and accessibility	Pass
Assessed through the tasks: qualitative	
Practical usability, comfort and ethics	Pass
Assessed through the tasks: quantitative	
Sensitivity	Pass
Responsiveness	Pass
Graded rather than binary output	Pass
Reliability	Partial
Established during sensor and platform selection	
Evidence-based	Pass
Open hardware and software	Pass
Potential for future development	Pass

Reliability across sessions still needs testing, and moisture needs serious attention.

Pedagogical Implications: The VP as an Articulator



The new Coffin vowel chart. Titze (2007, p. 200), Figure 1.



Vampola, Horáček and Laukkanen (2021, p. 2157), Figure 3. [a:], [i:], [u:], without VPO (dotted black), with VPO (blue), at the nostrils (red).

The trace gave me feedback while I explored.

That sent me back to the literature. **Could the velopharyngeal port work as an articulator?** Another way to shape vowels?

“What is often forgotten, however, is that the velopharyngeal valve is an articulator, just like the tongue and lips. As such, there is also a learned component to velopharyngeal function” (Kummer, 2011, p. 152).

Future Design Proposals

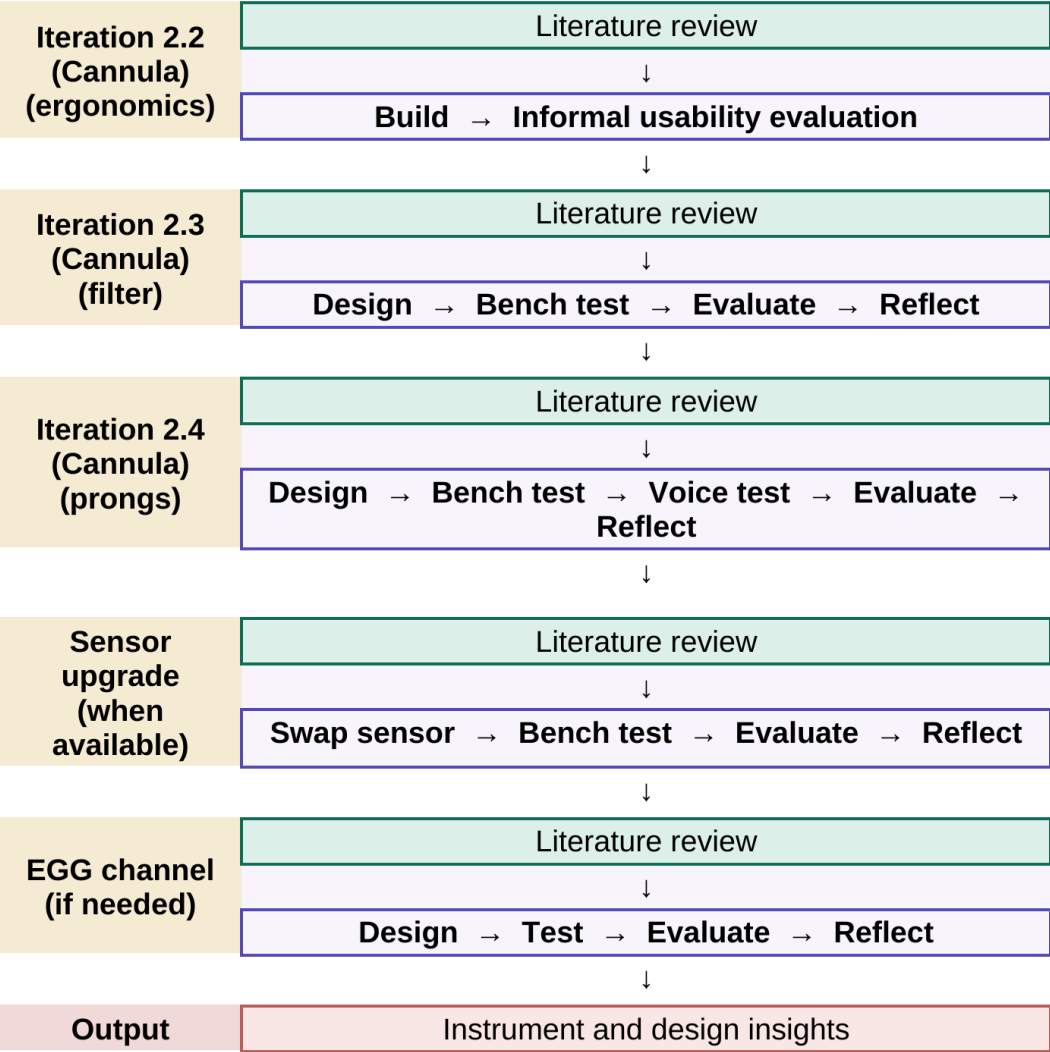


Figure 31. Proposed future iterations.

Next iterations

2.2 Increase cannula tube length, add housing

2.3 A moisture filter

2.4 Improve cannula prong length and shape

Then a better sensor, and an EGG channel only if needed/wanted

A question for teacher training

Could teachers learn to hear the difference between VPO and “nasal timbre”, with nasal flow feedback? (Perna, 2020)

Complete Vocal Technique has reported high listener agreement in identifying its vocal modes (Complete Vocal Institute, 2017), and opening the VPO is already part of their method.

35

DBR Outputs

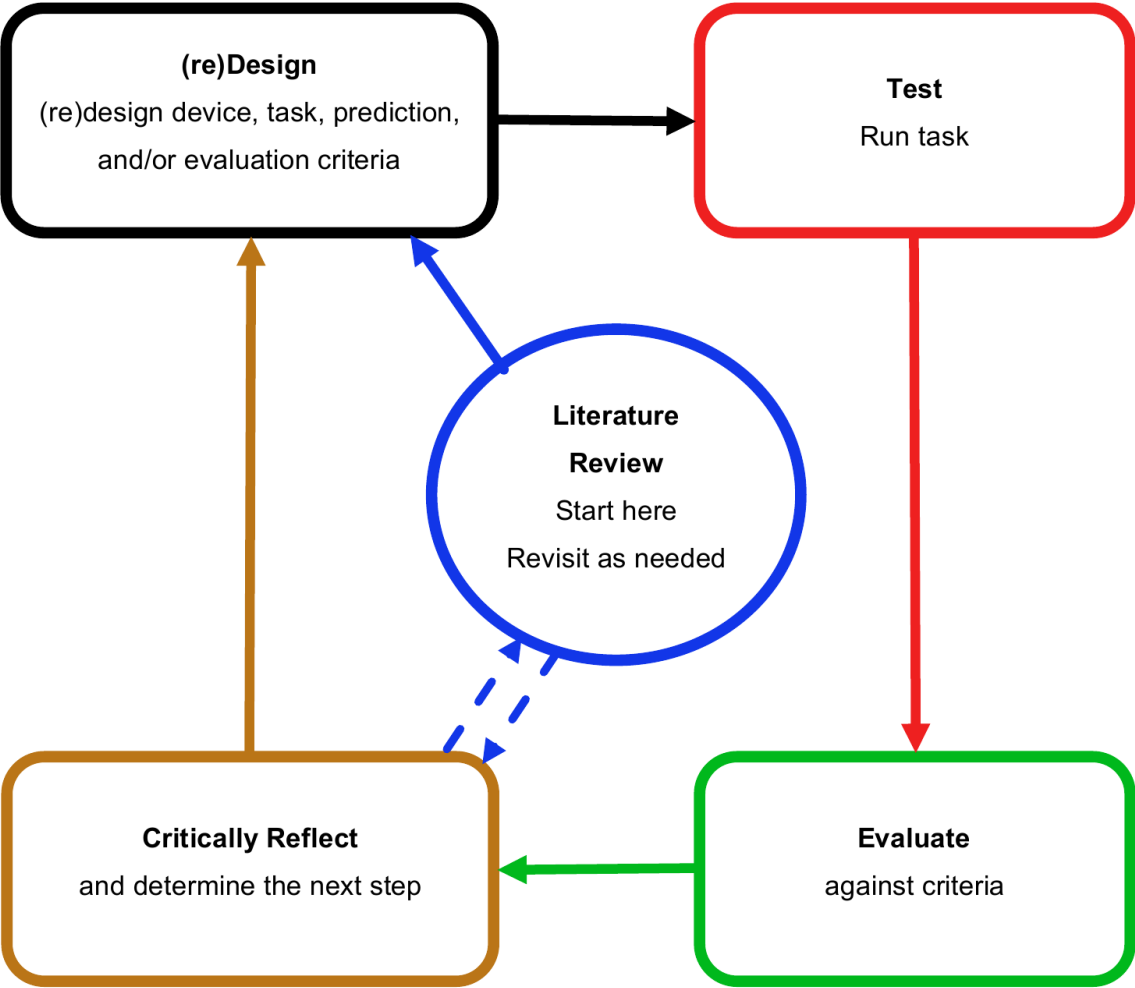


Figure 10. The NTAD development cycle.

Report section	Iteration	Contents	McKenney and Reeves (2012)	Reeves (2006, cited in Plomp, 2009)
Introduction		The problem in my teaching practice		1. Analysis of the practical problem
Literature Review		Claims about the VPO and how it is measured		
Methodology		Design cycle, evaluation criteria and tasks		2. Development of a solution
Findings	Feasibility Informal Qualitative	Literature review	Analysis and exploration	
		Sensor selection		
		Iteration 0 Design → Test → Evaluate → Reflect		Design and construction
	Preliminary Informal Qualitative	Literature review		
		Iteration 0.1 & 0.2 Design → Test → Evaluate → Reflect		
	Final designs Informal Qualitative	Literature review		
		Iteration 1.1 & 2.1 Design → Test → Evaluate → Reflect		
	Final designs Formal Quantitative	Iteration 2.1 Test → Evaluate → Reflect	Evaluation and reflection	
		Future iterations		Literature review
	Design			
Output	DBR cycle produced			
Conclusions		Conclusions and recommendations		4. Reflection to produce design principles

Figure 12. Outline of the DBR cycles.

Conclusion

- The device **improved my singing** and my ability to control my VPO
- The NTAD gives usable nasal feedback
- The new workflow taught me to **use Praat** for acoustic analysis
- The device has potential to be **incredibly valuable to singers and teachers** once ergonomics are addressed

“I finally feel like I have the tools, background, and ability to explore pedagogical concepts I’ve always been fascinated by.”

“I hope to bring this new spark into my work as an online voice influencer, a teacher, and a singer.”

Corrections since submission

In the report	Correction
Task 7, Critical Analysis	Upper harmonics did not rise after release. Mean 4-6 kHz level 13.1, 15.8, 11.2 dB (lowest after release).
Task 7, last sentence	“The singer’s formant was affected, ~~but in a clear linear manner.~~ ” What I meant: the effect is shown clearly (Figure 25c).
Figures 23b and 25b, “Loudness”	Recording level in dBFS, not loudness.
Figure 18b beside Gill et al.	My circles are medians with ranges; Gill’s are means with standard deviations.
Figure 21, lower panel (take 23, straight tone)	Trace drawn about 47 ms early (pictured below)
Task 5, “hours apart (VERIFY)”	Takes 13 and 23 were 5 h 7 min apart.

Found when I re-checked my figures against the raw data after submission. None changes the conclusion that the prototype gave usable nasal-pressure feedback.

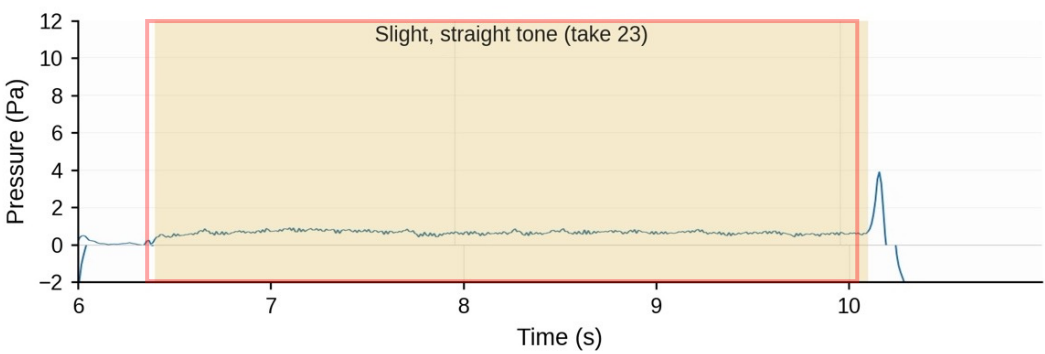
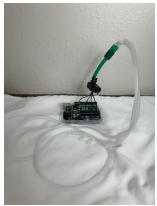


Figure 21, lower panel, as submitted. **Red outline:** corrected window position (about 47 ms earlier).

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