# Scaling data collection and analysis of respiratory sounds

Cecilia Mascolo

UNIVERSITY OF CAMBRIDGE

# Automated Sound based Diagnostics

# covid-19-sounds.org

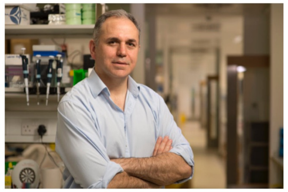
UNIVERSITY OF CAMBRIDGE

**Cecilia Mascolo**

Cecilia is Professor of Mobile Systems. She is an expert in mobile health and mobile data analysis.

**Pietro Cicuta**

Pietro is Professor of Biological Physics at the Cavendish Laboratory, Cambridge.



**Andres Floto**

Andres is Professor of Respiratory Biology and Research Director of the Cambridge Centre for Lung Infection at Papworth Hospital.

## COVID-19 Sounds App

Upload short recordings of cough and breathing and report symptoms to help researchers from the University of Cambridge detect if a person is suffering from COVID-19. Healthy and *non-healthy* participants welcome.

GET IT ON Google Play | Download on the App Store

or use the **online form**

### COVID-19 Sounds: A Large-Scale Audio Dataset for Digital COVID-19 Detection

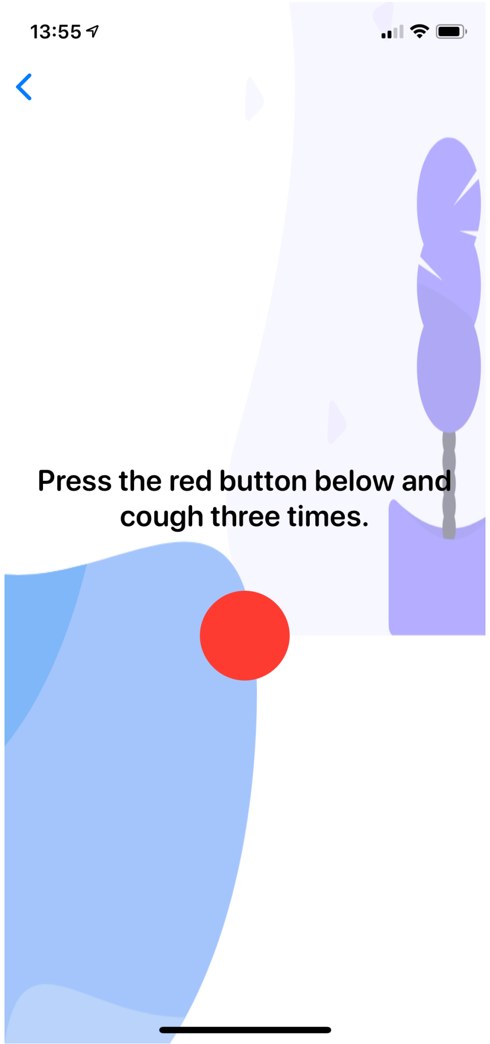
*Tong Xia, Dimitris Spathis, Chlo{\"e} Brown, J Ch, Andreas Grammenos, Jing Han, Apinan Hasthanasombat, Erika Bondareva, Ting Dang, Andres Floto, Pietro Cicuta, Cecilia Mascolo*

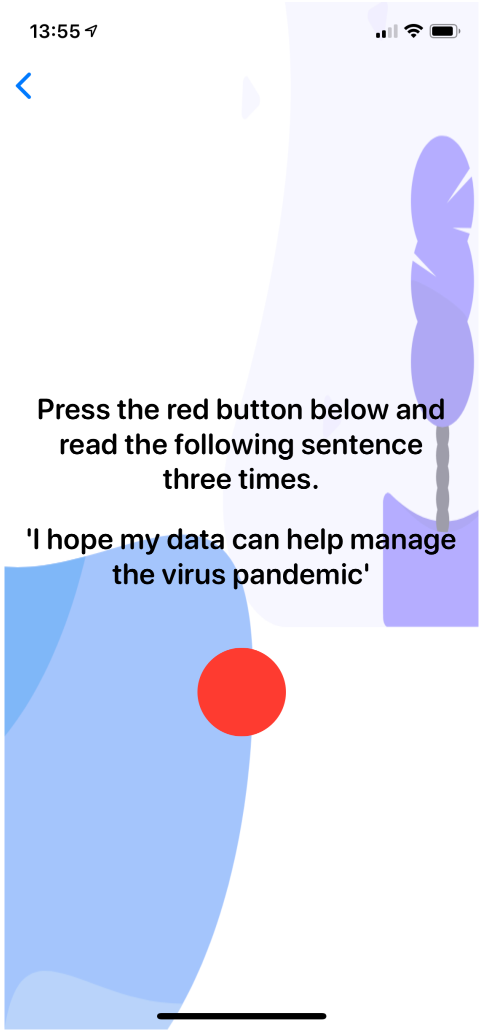
20 Aug 2021 (modified: 30 Sep 2021) NeurIPS 2021 Datasets and Benchmarks Track (Round 2) Readers: Everyone Show Bibtex

**Keywords:** audio dataset, respiratory sounds, COVID-19, mobile health, machine learning for health

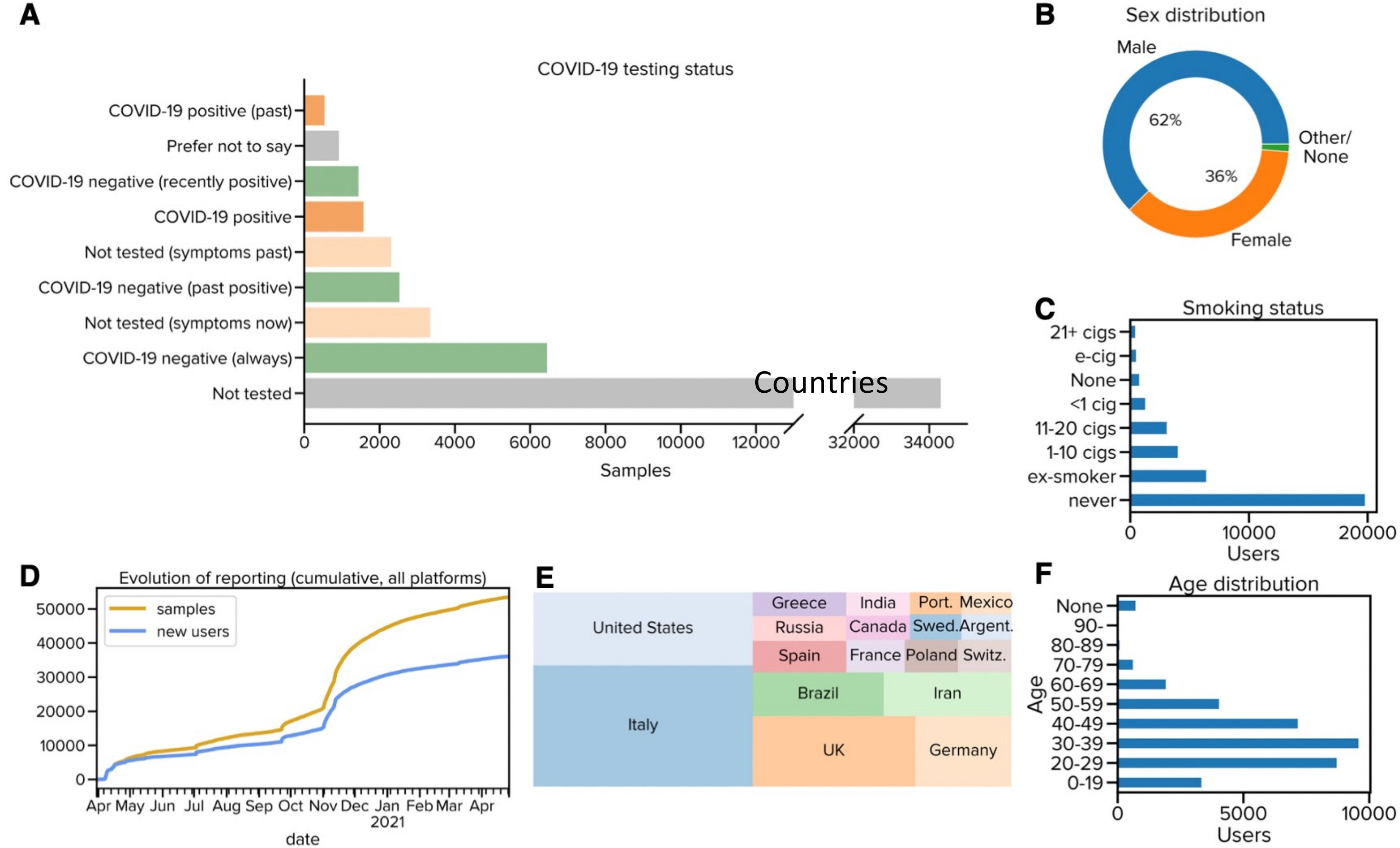
**Abstract:** Audio signals are widely recognised as powerful indicators of overall health status, and there has been increasing interest in leveraging sound for affordable COVID-19 screening through machine learning. However, there has also been scepticism regarding the initial efforts, due to perhaps the lack of reproducibility, large datasets and transparency which unfortunately is often an issue with machine learning for health. To facilitate the advancement and openness of audio-based machine learning for health, we release a dataset consisting of 53,449 audio samples (over 552 hours in total) crowd-sourced from 36,116 participants through our COVID-19 Sounds app\footnote{\url{http://covid-19-sounds.org}}. Given its scale, this dataset is comprehensive in terms of demographics and spectrum of health conditions. It also provides participants' self-reported COVID-19 testing status. To the best of our knowledge, COVID-19 Sounds is the largest available dataset of COVID-19 respiratory sounds. It is also unique, as it consists of three modalities including breathing, cough, and voice recordings. Additionally, in this paper, we report on several benchmarks for two principal research tasks: respiratory symptoms prediction and COVID-19 prediction. For these tasks we demonstrate performance with a ROC-AUC of over 0.7, confirming both the promise of machine learning approaches based on these types of datasets as well as the reliability of our data for such tasks. We describe a realistic experimental setting that hopes to pave the way to a fair performance evaluation of future models. In addition, we reflect on how the released dataset can help to scale some existing studies and enable new research directions, which inspire and benefit a wide range of future works.


13:55
Press the red button below and breathe in and out as deeply as you can five times. Please do so in a quiet environment.


13:55
Press the red button below and cough three times.

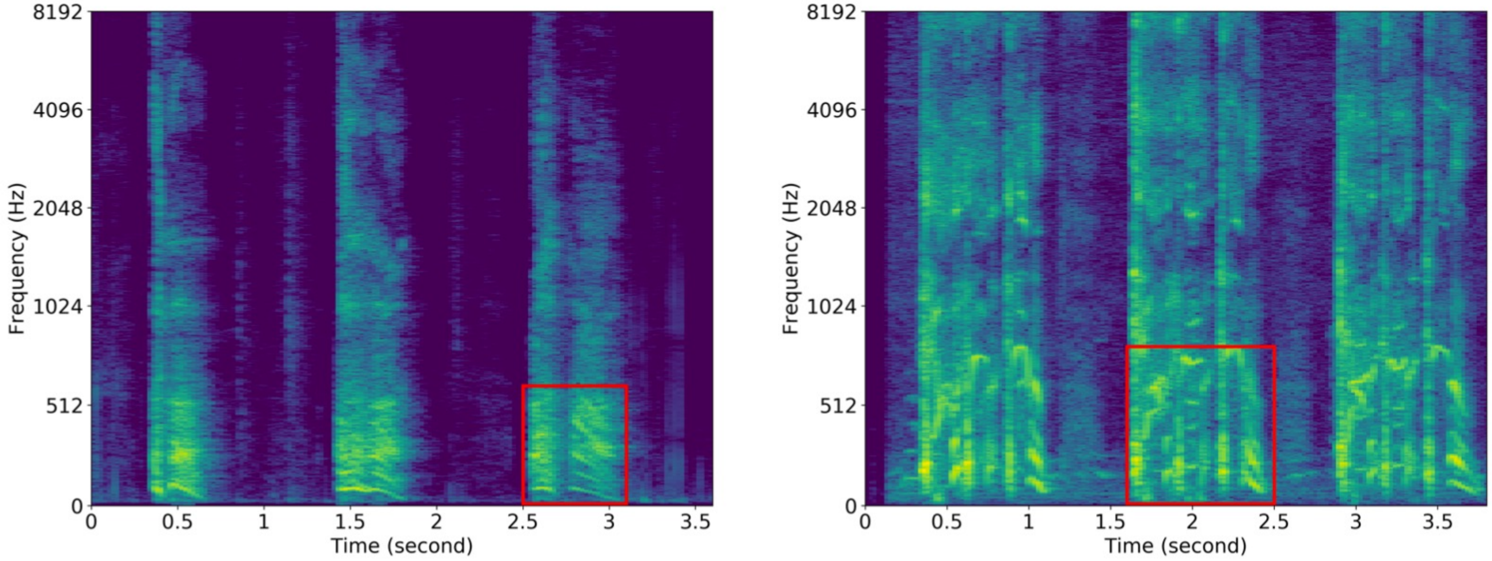

13:55
Press the red button below and read the following sentence three times.
'I hope my data can help manage the virus pandemic'

# Numbers



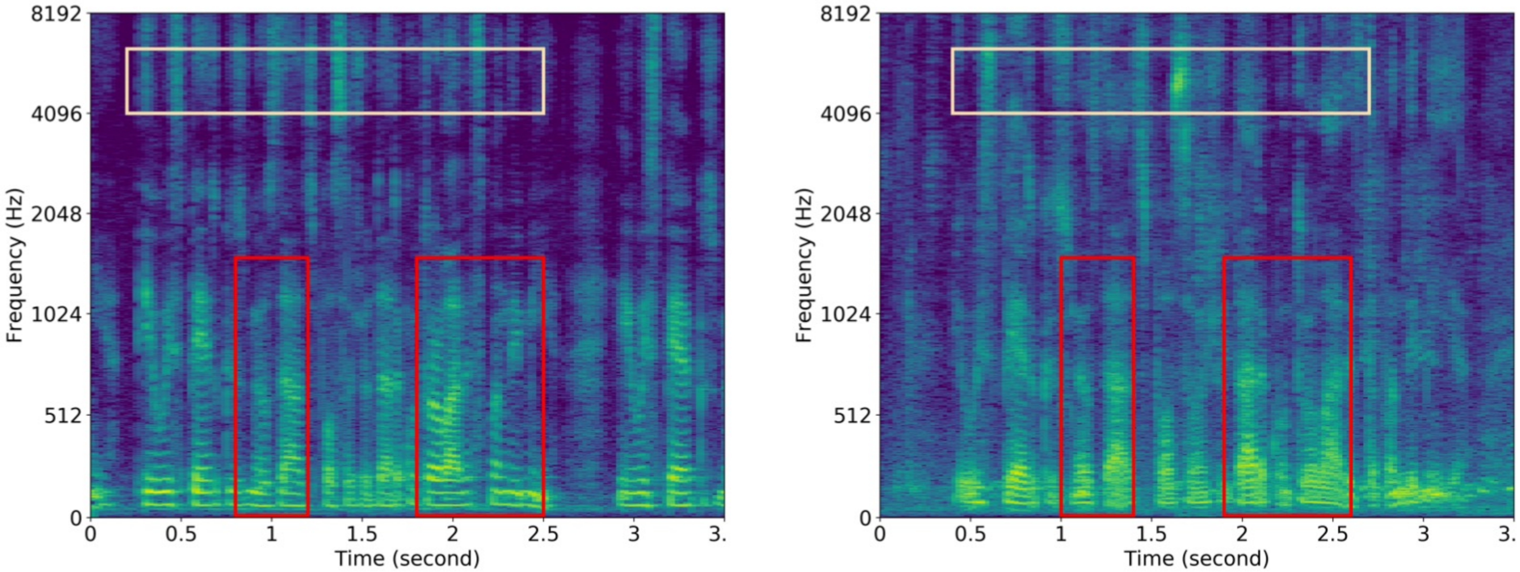
A
COVID-19 testing status
COVID-19 positive (past)
Prefer not to say
COVID-19 negative (recently positive)
COVID-19 positive
Not tested (symptoms past)
COVID-19 negative (past positive)
Not tested (symptoms now)
COVID-19 negative (always)
Not tested
0 2000 4000 6000 8000 10000 12000 32000 34000
Samples
Countries
B
Sex distribution
Male
62%
Other/ None
36%
Female
C
Smoking status
21+ cigs
e-cig
None
<1 cig
11-20 cigs
1-10 cigs
ex-smoker
never
0 10000 20000
Users
D
Evolution of reporting (cumulative, all platforms)
samples
new users
50000 40000 30000 20000 10000 0
Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr
2021
date
E
United States
Italy
Greece
India
Port.
Mexico
Russia
Canada
Swed.
Argent.
Spain
France
Poland
Switz.
Brazil
Iran
UK
Germany
F
Age distribution
None
90-
80-89
70-79
60-69
50-59
40-49
30-39
20-29
0-19
Age
0 5000 10000
Users

# Coughs…




(a) Healthy Cough (b) COVID Cough

# Voice

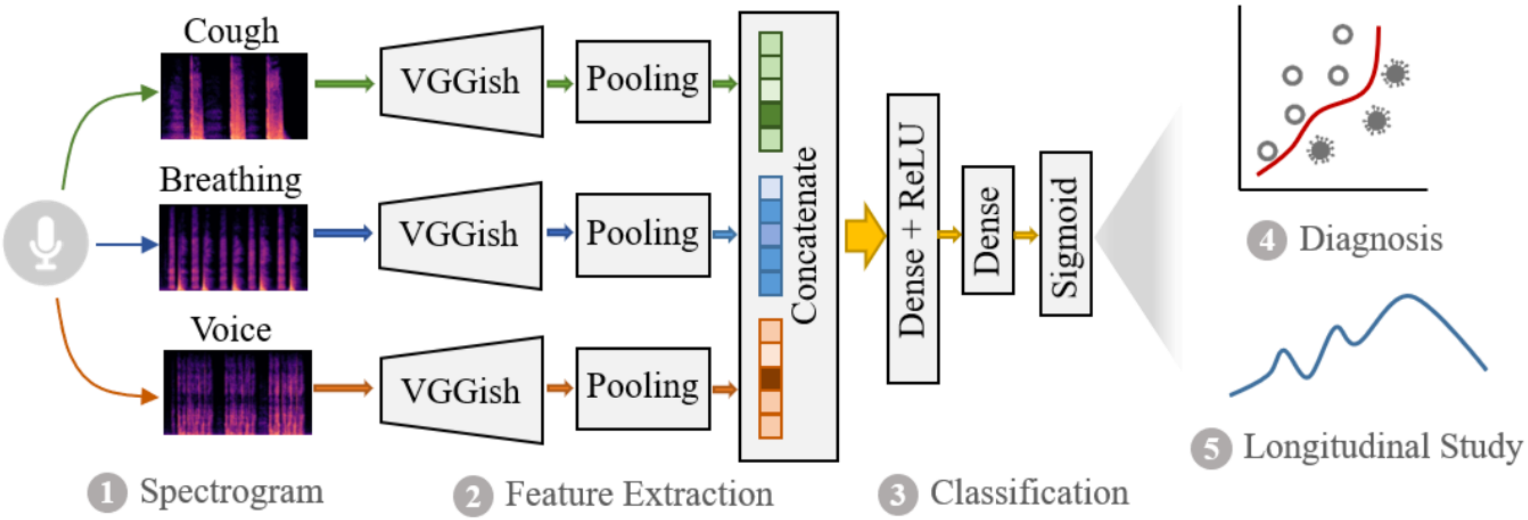



(a) Healthy Voice (b) COVID Voice


Detection of COVID-19 through the analysis of vocal fold oscillations, Mahmoud Al Ismail, Soham Deshmukh, Rita Singh, arXiv:2010.10707,
Interpreting glottal flow dynamics for detecting COVID-19 from voice, Soham Deshmukh, Mahmoud Al Ismail, Rita Singh, arXiv:2010.10707.

# “COVID-19 Positives” Detection

Task: Distinguishing COVID-19 positive users from COVID-19 negative, irrespective of the symptoms.



# Evaluating Listening Performance for COVID-19 Detection by Clinicians and Machine Learning: Comparative Study

Jing Han [1]; Marco Montagna [2]; Andreas Grammenos [1]; Tong Xia [1]; Erika Bondareva [1]; Chloë Siegele-Brown [3]; Jagmohan Chauhan [3]; Ting Dang [1]; Dimitris Spathis [1]; R Andres Floto [4]; Pietro Cicuta [5]; Cecilia Mascolo [1]

Article | Authors | Cited by | Tweetations (9) | Metrics



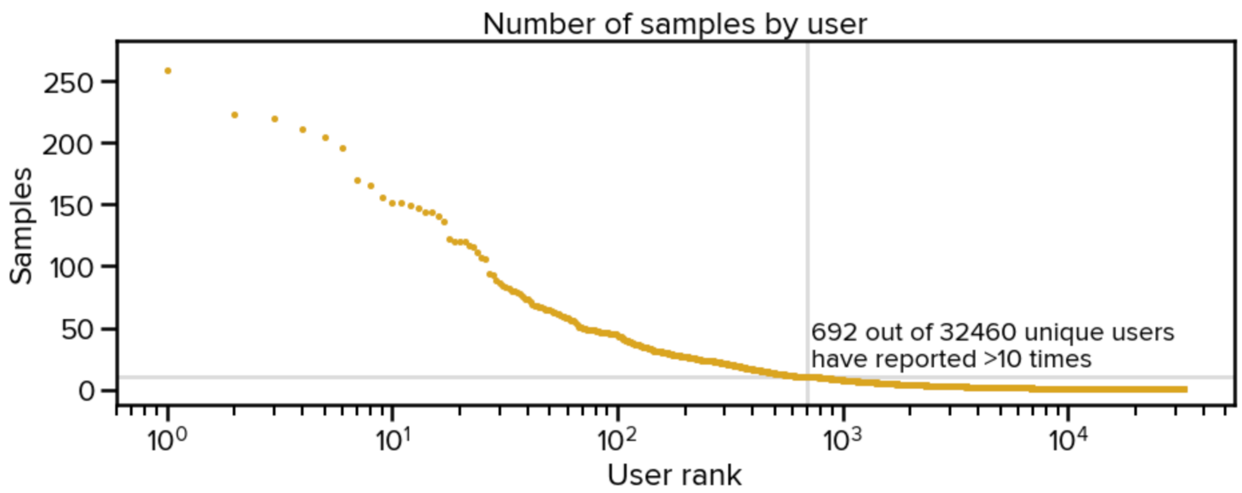
## Abstract

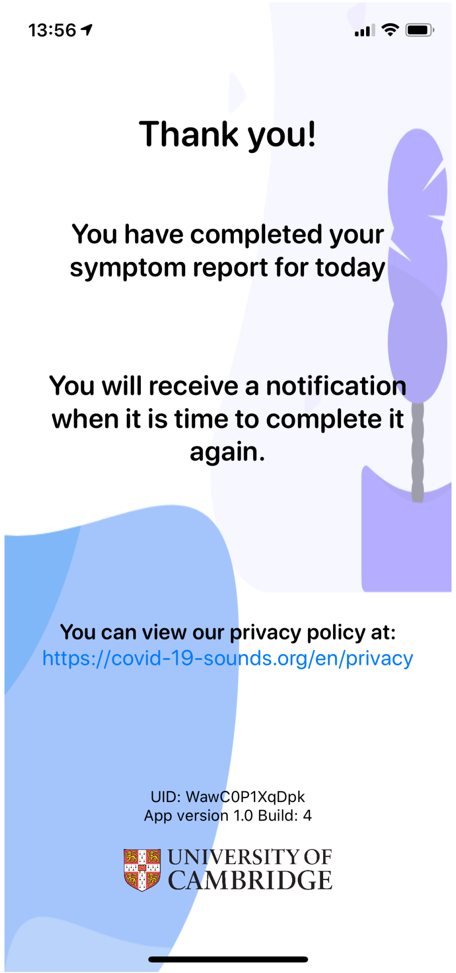

**Background:**
To date, performance comparisons between men and machines have been carried out in many health domains. Yet machine learning (ML) models and human performance comparisons in audio-based respiratory diagnosis remain largely unexplored.

**Objective:**
The primary objective of this study was to compare human clinicians and an ML model in predicting COVID-19 from respiratory sound recordings.

**Methods:**
In this study, we compared human clinicians and an ML model in predicting COVID-19 from respiratory sound recordings. Prediction performance on 24 audio samples (12 tested positive) made by 36 clinicians with experience in treating COVID-19 or other respiratory illnesses was compared with predictions made by an ML model trained on 1162 samples. Each sample consisted

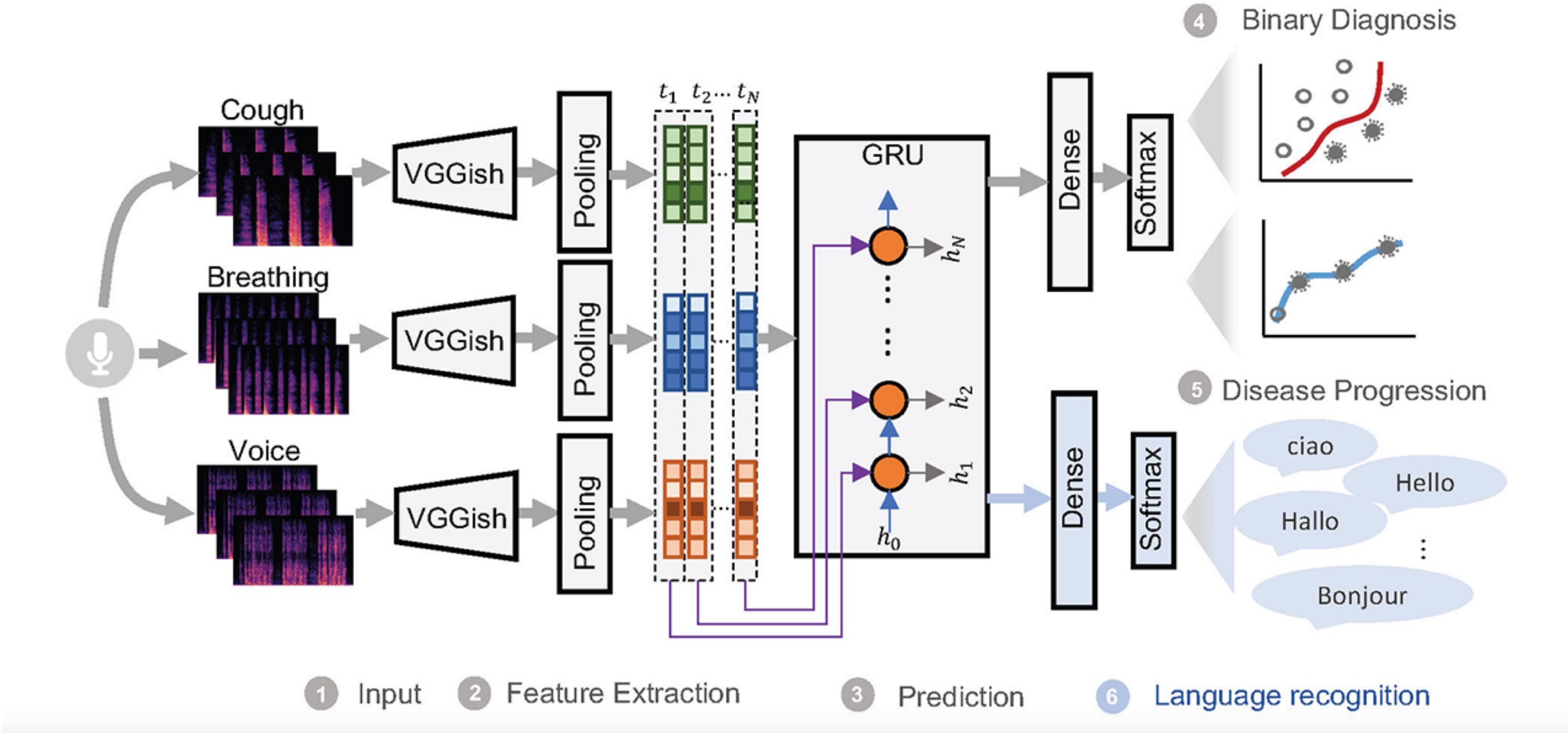
# Progression



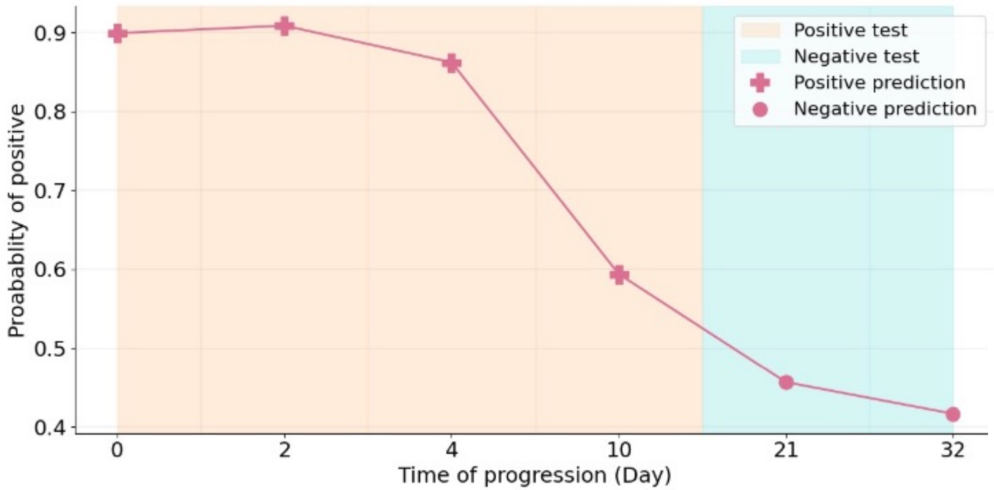



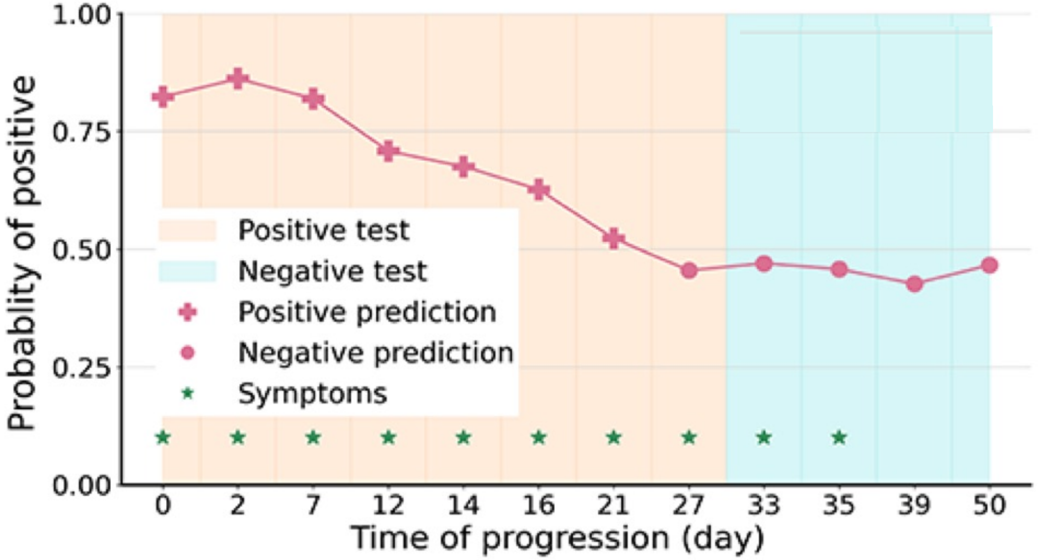

T. Dang, J. Han, T. Xia, D. Spathis, E. Bondareva, C. Brown, J. Chauhan, A. Hasthanasombat, A. Grammenos, A. Floto, P. Cicuta, C. Mascolo. Exploring Longitudinal Cough, Breath, and Voice Data for COVID-19 Disease Progression Prediction via Sequential Deep Learning: Model Development and Validation.
In Journal of Medical Internet Research (JMIR). 2022

# Architecture



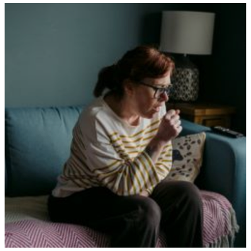
# Progression



## Can AI diagnose patients with severe respiratory tract infections?

**Researchers using AI to identify patients at risk of developing severe respiratory tract infections have just won support from UK Research and Innovation.**



**The RELOAD study - REspiratory disease progression through LOngitudinal Audio Data machine learning - is being funded as part of a new government mission to support AI innovation to speed up health research.**

**The project will use AI to analyse the sounds of patients' breathing and speech and diagnose those who are at risk of becoming severely ill.**

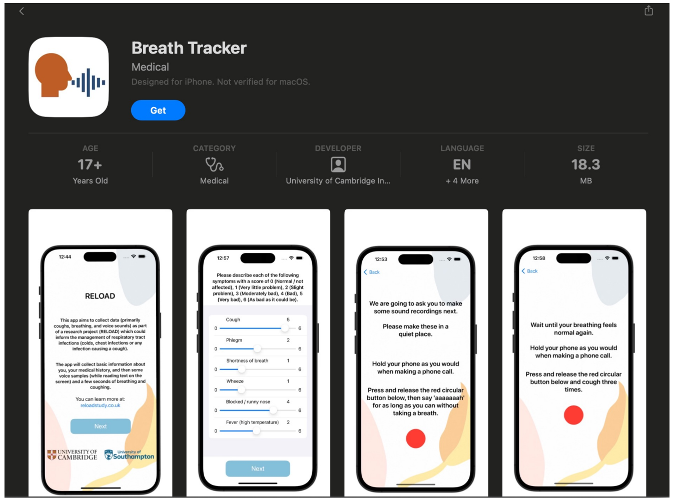
It is one of 22 new projects that Michelle Donelan, Secretary of State for Science and Technology, revealed last week would receive funding to explore how to develop and use AI in health.

> *Identifying patients at higher risk could reduce hospital admissions, cases of severe illness and the number who die.*
>
> — *Cecilia Mascolo*

The Principal Investigator on the RELOAD project is **Cecilia Mascolo**, Professor of Mobile Systems here. The collaborative project also includes **Professor Pietro Cicuta** in the Cambridge University Department of Physics; **Professor Nick Francis**, head of the Medical School at Southampton University; and **Professor Anna Barney**, Professor of Biomedical Acoustic Engineering at Southampton University.

### Collected Data

441 recordings with RTI out of 809.
178 users RTI-positive (once or more) out of 463.
39 users with 3 + RTI episodes.




RELOAD

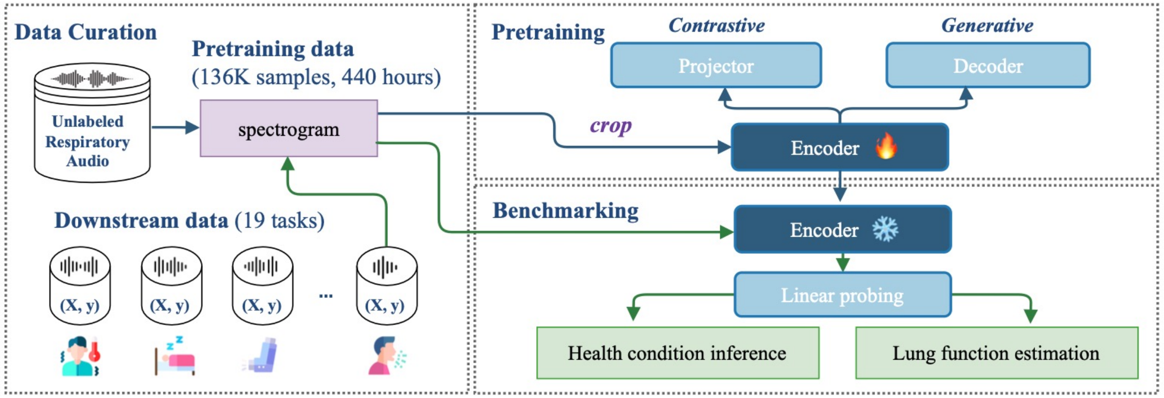
**Welcome to the RELOAD Study website.**

**RELOAD: RE**spiratory disease progression through **LO**ngitudinal **A**udio **D**ata machine learning.

**What is the RELOAD study about?**
You are being invited to participate in the RELOAD study. This study will explore whether sounds, such as breathing, speaking and coughing, can be used to predict whether someone with a cough caused by infection is likely to get better or worse. The study is being run by researchers at the University of Southampton and the University of Cambridge, and is sponsored by the University of Southampton.

**Why is this study important?**
Respiratory Tract Infections (RTIs) (coughs and colds) are the most common cause of illness and the most common reason patients visit a GP. Around half of all antibiotic prescriptions are for RTIs. The illness they cause is usually mild, but in some cases can become severe. Most people with an RTI get better without needing treatment. However, we need to notice quickly when people are getting seriously ill. If we do not, the effect on them and on healthcare services could be serious.

# Open Respiratory Acoustic Foundation Model

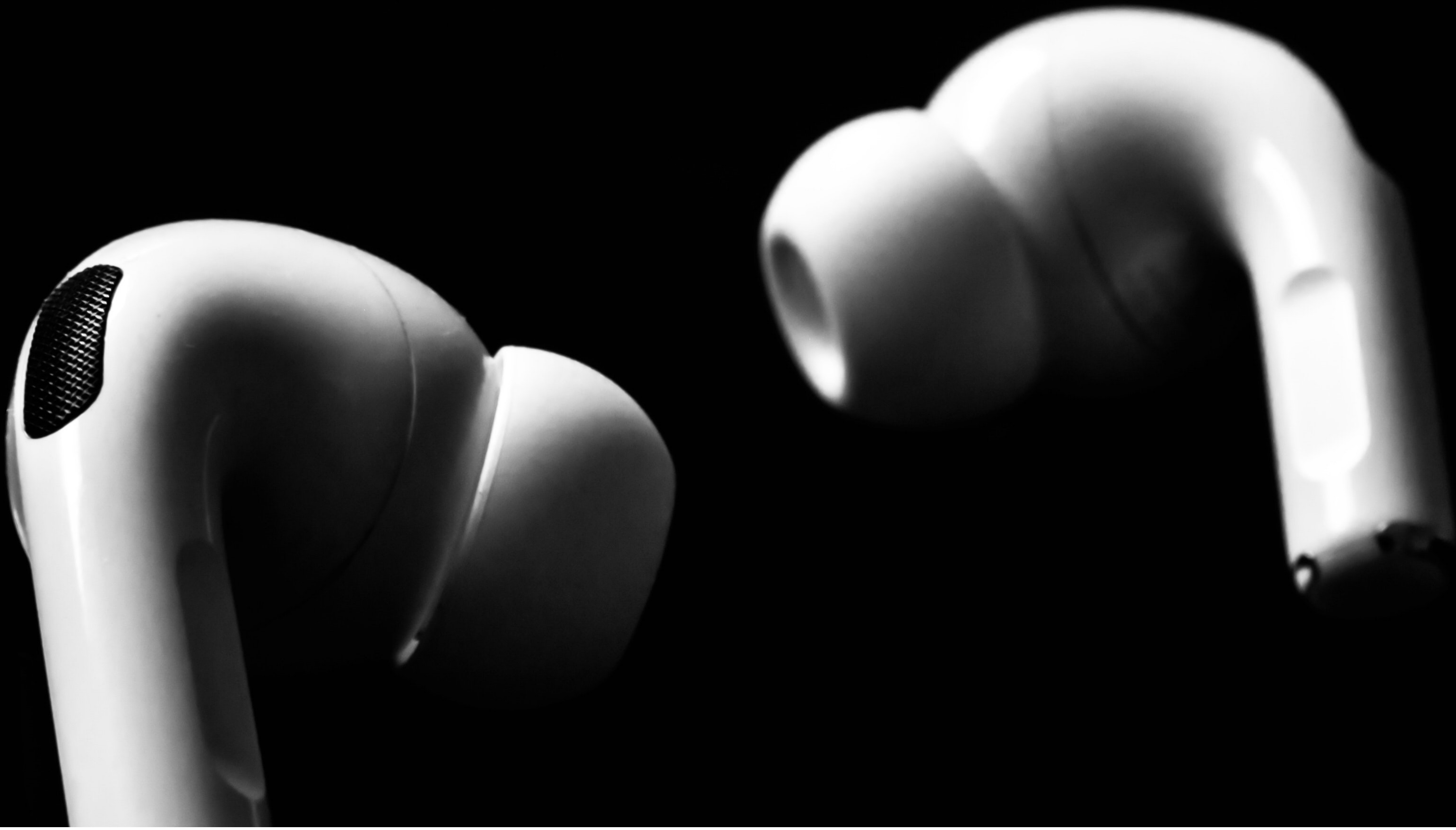



| Dataset | ID | Task | Modality | #Sam. (#Sub.) | Data Distribution |
|---|---|---|---|---|---|
| UK COVID-19 [12] | T1 | Covid / Non-covid | Exhalation | 2500 (2500) | 840 / 1660 |
| | T2 | Covid / Non-covid | Cough | 2500 (2500) | 840 / 1660 |
| VID-19 Sounds [69] | T3 | Symptomatic / Healthy | Breath | 4138 (3294) | 2029 / 2109 |
| | T4 | Symptomatic / Healthy | Cough | 4138 (3294) | 2029 / 2109 |
| CoughVID [47] | T5 | Covid / Non-covid | Cough | 6175 (n/a) | 547 / 5628 |
| | T6 | Female / Male | Cough | 7263 (n/a) | 2468 / 4795 |
| ICBHI [51] | T7 | COPD / Healthy | Lung sounds | 828 (90) | 793 / 35 |
| Coswara [7] | T8 | Smoker / Non-smoker | Cough | 948 (n/a) | 201 / 747 |
| | T9 | Female / Male | Cough | 2496 (n/a) | 759 / 1737 |
| KAUH [23] | T10 | Obstructive / Healthy | Lung sounds | 234 (79) | 129 / 105 |
| espiratory@TR [2] | T11 | COPD severity | Lung sounds | 504 (42) | 72 / 60 / 84 / 84 / 204 |
| SSBPR [70] | T12 | Body position recognition | Snoring | 7468 (20) | 1638 / 1454 / 1269 / 1668 / 1439 |
| MMlung [44] | T13 | FVC | Deep breath | 40 (40) | 3.402 ± 1.032 L |
| | T14 | FEV1 | Deep breath | 40 (40) | 2.657 ± 0.976 L |
| | T15 | FEV1/FVC | Deep breath | 40 (40) | 0.808 ± 0.190 L |
| | T16 | FVC | O Vowels | 40 (40) | 3.402 ± 1.032 L |
| | T17 | FEV1 | O Vowels | 40 (40) | 2.657 ± 0.976 L |
| | T18 | FEV1/FVC | O Vowels | 40 (40) | 0.808 ± 0.190 L |
| NoseMic [9] | T19 | Respiratory rate | Breath | 1297 (16) | 13.915 ± 3.386 bpm |

| Data name | Collected by | SR | Modality | #Sample | Duration (s) | Crop (s) |
|---|---|---|---|---|---|---|
| COVID-19 Sounds [69] | Microphone | 16~44.1kHz | Induced cough (3 times) | 40866 | 6.1[2.6~11.2] | 2 |
| | | | Deep breath (5 times) | 36605 | 20.5[9.7~31.6] | 8 |
| COVID UK [12] | Microphone | 48kHz | Induced cough (3 times) | 19533 | 4.1[2.1~9.2] | 2 |
| | | | Exhalation (5 times) | 20719 | 7.7[4.2~15.6] | 4 |
| COUGHVID [47] | Microphone | 48kHz | Induced cough (up to 10s) | 7179 | 6.9[2.4~9.9] | 2 |
| ICBHI [51] | Stethoscope | 4~44.1kHz | lung sound (several breath cycles) | 538 | 22.2[20.0~65.9] | 8 |
| HF LUNG [31] | Stethoscope | 4kHz | lung sound (several breath cycles) | 10554 | 15.0[15.0~15.0] | 8 |

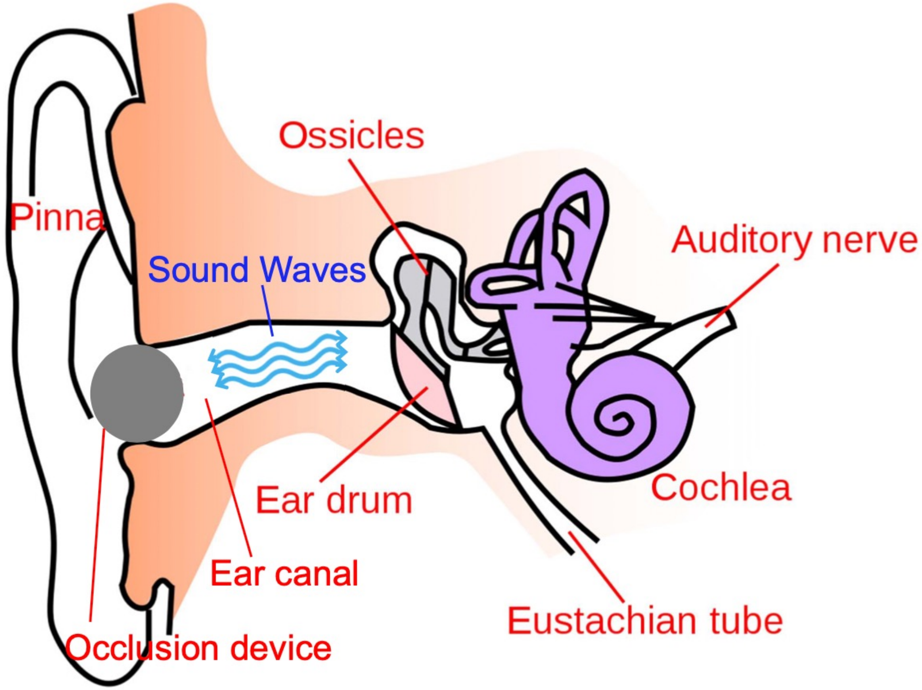

Zhang Y, Xia T, Han J, Wu Y, Rizos G, Liu Y, Mosuily M, Chauhan J, Mascolo C. Towards open respiratory acoustic foundation models: Pretraining and benchmarking. In Thirty-eighth Conference on Neural Information Processing Systems Datasets and Benchmarks Track, 2024.
Zhang Y, Xia T, Saeed A, Mascolo C. RespLLM: Unifying Audio and Text with Multimodal LLMs for Generalized Respiratory Health Prediction. In Machine Learning for Health, 2024, PMLR.

# In-Ear-based Sensing: The Next Frontier

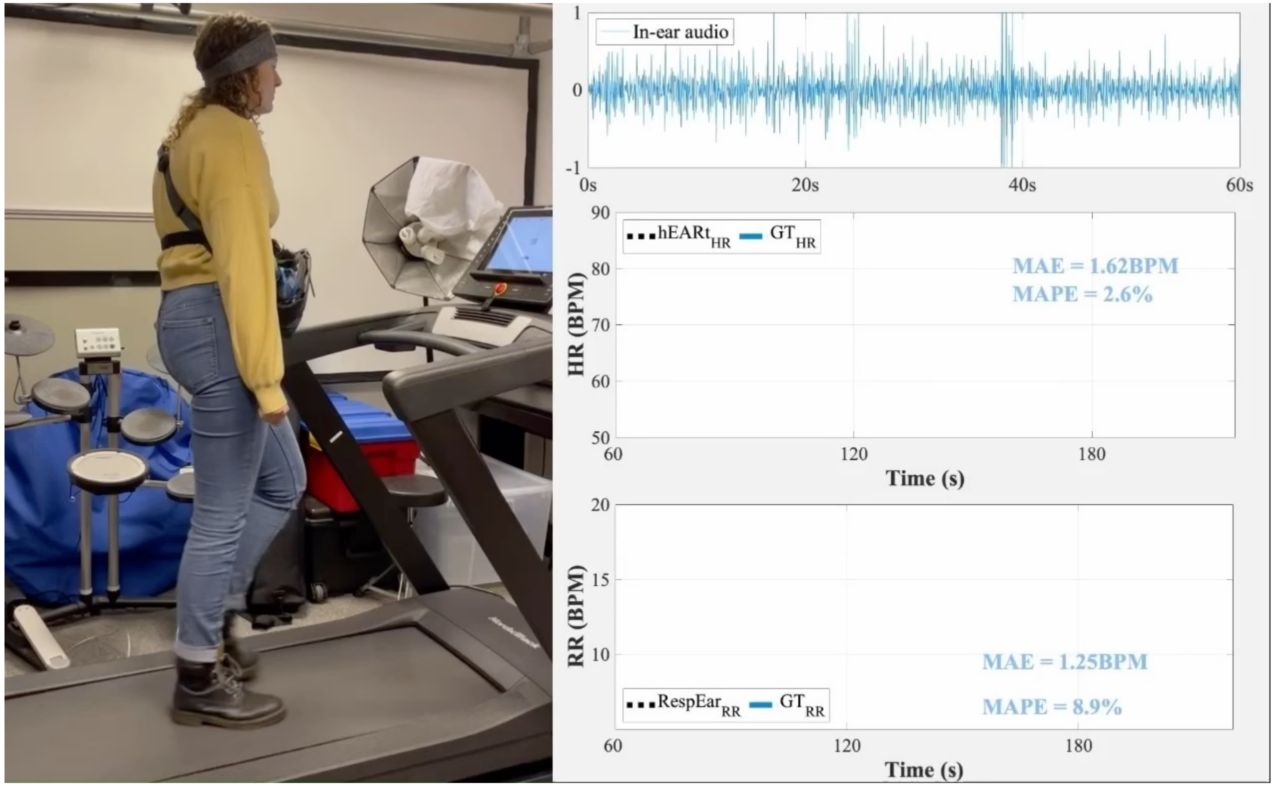


# Occlusion Effect





# Vital Signs while Walking (and Running)




**RespEar: Earable-Based Robust Respiratory Rate Monitoring.** Y. Liu, K. Butkow, J. Stuchbury-Wass, A. Pullin, D. Ma, C. Mascolo. In Procs of 23rd Int. Conf. on Pervasive Computing and Communications (PerCom 2025).

Thanks!

Cecilia Mascolo

cm542@cam.ac.uk

www.cl.cam.ac.uk/~cm542

https://mobile-systems.cl.cam.ac.uk

Thanks to:

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