

# Challenges in Realistic Respiratory Audio AI for Healthcare

Dr. Georgios Rizos



# We need cheap early-warning systems

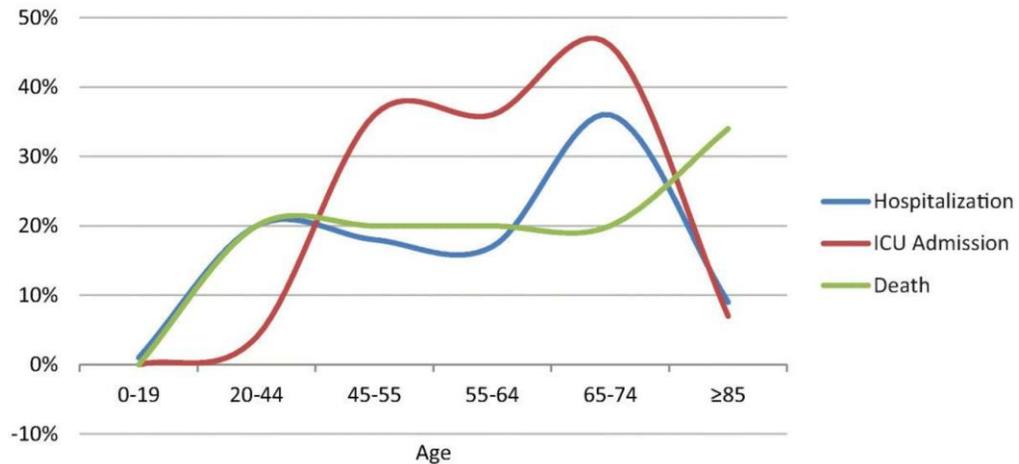


	Direct costs <sup>#</sup> € bn	Indirect costs <sup>1</sup> € bn	Monetised value of DALYs lost € bn	Total costs € bn
COPD	23.3	25.1	93.0	141.4
Asthma	19.5	14.4	38.3	72.2
Lung cancer	3.35	NA	103.0	106.4
TB	0.54 <sup>#</sup>	#	5.37	5.9
OSAS	5.2	1.9	NA	7.1
Cystic fibrosis	0.6	NA	NA	0.6
Pneumonia/ALRI	2.5	NA	43.5	46.0
<b>Total</b>	<b>55.0</b>	<b>41.4</b>	<b>283.2</b>	<b>379.6</b>

# Robust AI that leaves no one behind

## COVID-19:

Hospitalization, ICU Admission and Death (Feb. 12 – Mar. 16, 2020)



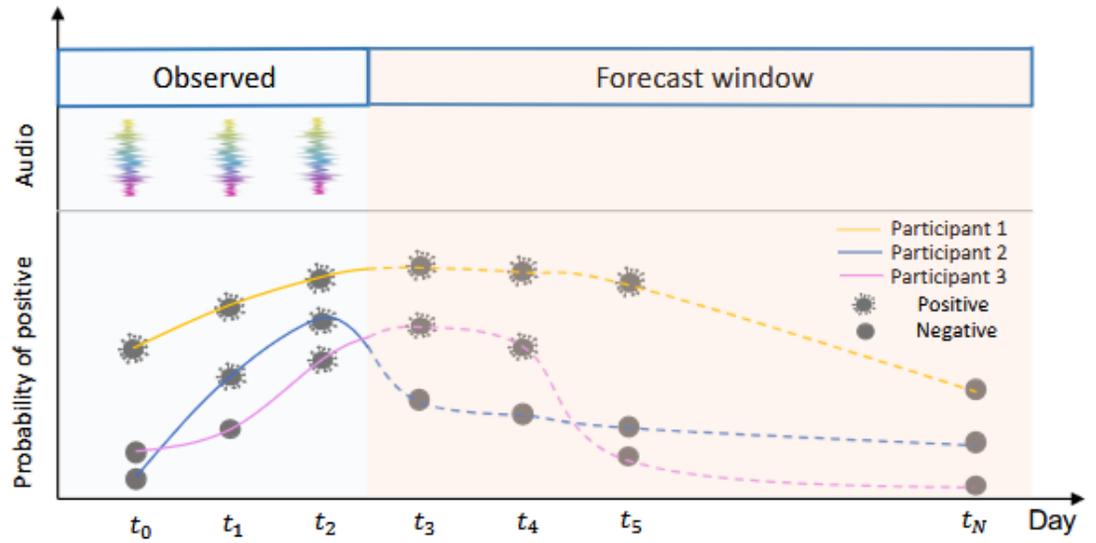
Gender Classifier	Darker Male	Darker Female	Lighter Male	Lighter Female	Largest Gap
Microsoft	94.0%	79.2%	100%	98.3%	20.8%
FACE++	99.3%	65.5%	99.2%	94.0%	33.8%
IBM	88.0%	65.3%	99.7%	92.9%	34.4%



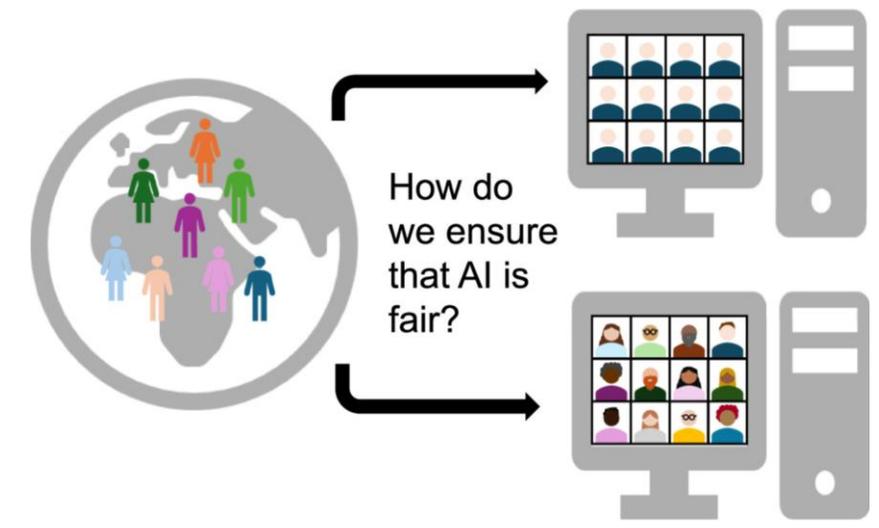
Sanyaolu et al. "Comorbidity and its impact on patients with COVID-19", SN comprehensive clinical medicine 2020

Buolamwini and Gebru "Gender shades: Intersectional accuracy disparities in commercial gender classification" Conference on fairness, accountability and transparency 2018

# A) Personalised respiratory progression



# B) Fair respiratory AI



# C) Looking forward



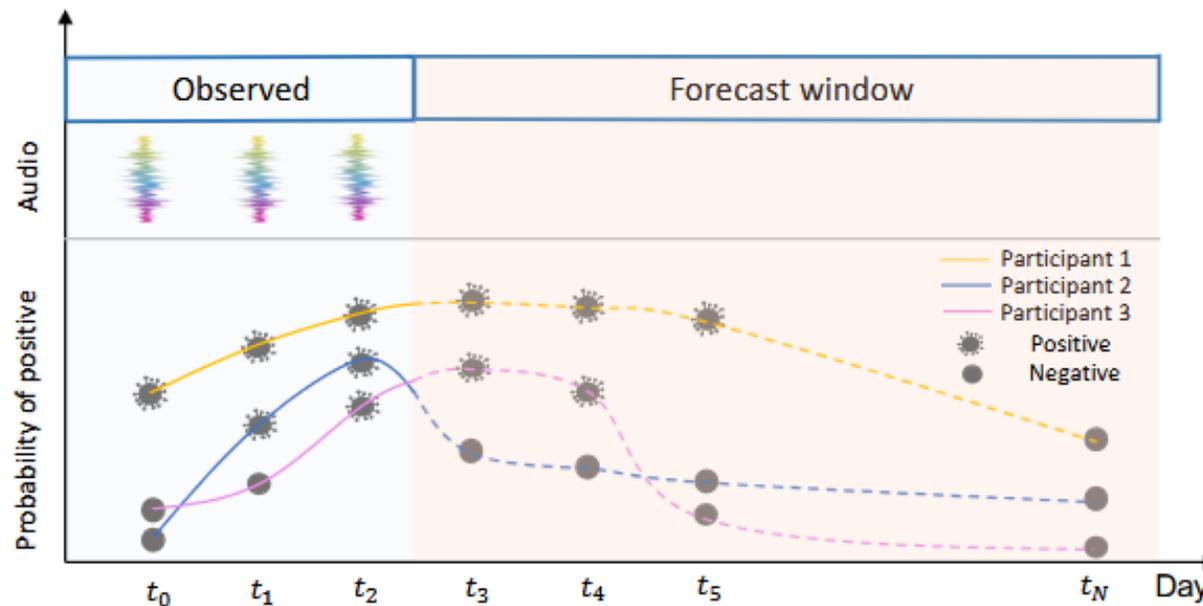
jplenio on pixabay

Dang et al. "Conditional neural ODE processes for individual disease progression forecasting: a case study on COVID-19", SIGKDD 2023

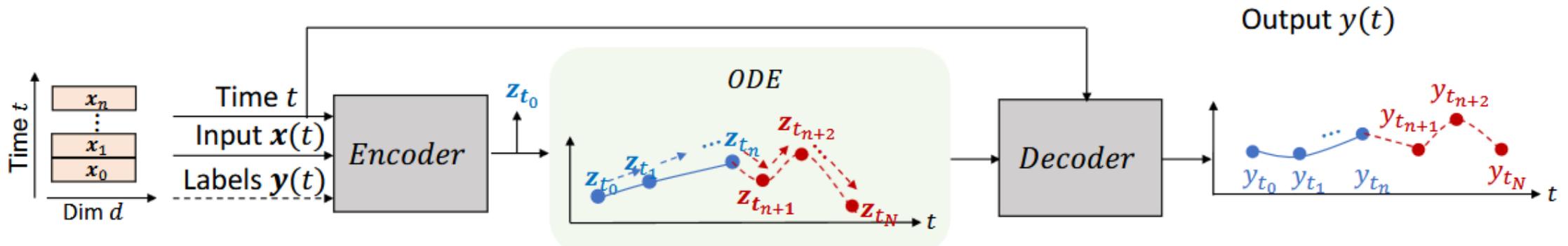
Carey et al. "Fairness in AI for healthcare", Future Healthcare Journal, 2024

# Individual disease progression forecasting

- Based on a few past observations
- Irregularly sampled time-series
- Data sparsity
- Personalised to individual



# CNDP: Conditional Neural ODE processes



# CNDP: COVID-19 test case

- Mobile-sourced longitudinal dataset
- 212 participants -- F/M/U: 110/90/12
- Each participant submitted: 5-385 samples

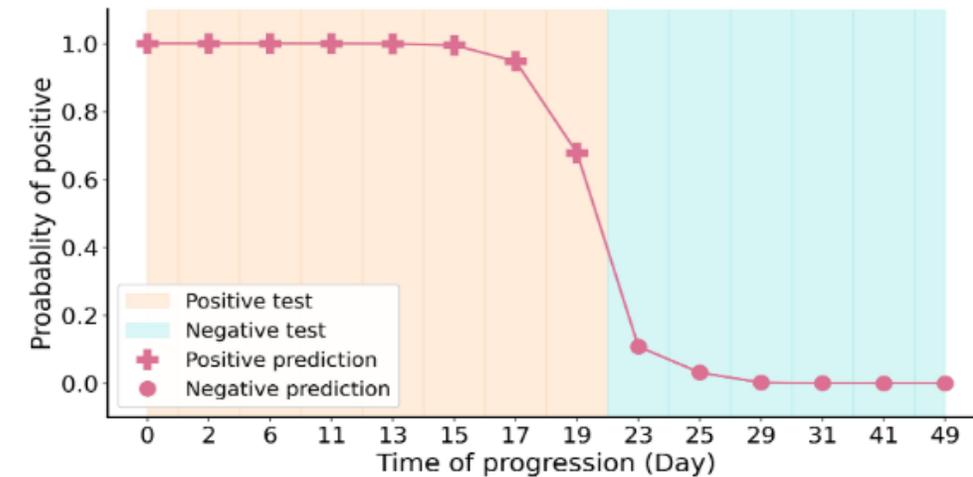
	Forecasting	Systems	UAR	Sensitivity	Specificity
Audio only	One-step-ahead	RNN $\Delta t_1$	75.5(71.0-79.5)	73.4(65.6-80.5)	77.6(73.9-81.2)
	Multi-step-ahead	RNN $\Delta t_{all}$	74.7(70.3-78.8)	73.4(65.5-81.0)	75.9(72.2-79.8)
		RNN-VAE	74.8(70.5-78.9)	75.0(67.0-82.2)	74.7(70.8-78.3)
		Transformer	75.3(70.3-78.9)	72.7(64.8-80.0)	76.8(73.0-80.7)
		CNDPs	77.1(72.6-80.9)	76.6(68.6-83.6)	77.6(73.8-81.3)
CNDPs <sub>l</sub>	78.1(74.0-81.8)	78.9(71.2-85.7)	77.2(73.1-80.9)		
Audio + Labels	Multi-step-ahead	RNN $\Delta t_{all}^{\hat{y}}$	82.5(78.8-85.9)	84.4(78.0-90.4)	80.5(76.9-83.9)
		RNN-VAE $^{\hat{y}}$	75.1(70.5-79.2)	73.4(65.4-80.6)	76.8(73.0-80.7)
		Transformer $^{\hat{y}}$	77.9(73.6-81.5)	79.7(72.5-86.2)	75.9(72.1-79.9)
		CNDPs $^{\hat{y}}$	88.3(84.8-91.5)	84.4(78.0-90.3)	92.3(89.7-94.5)
		CNDPs <sub>l</sub> $^{\hat{y}}$	93.6 (90.8-96.1)	90.6(85.2-95.2)	96.7(94.9-98.2)

## COVID-19 Sounds App

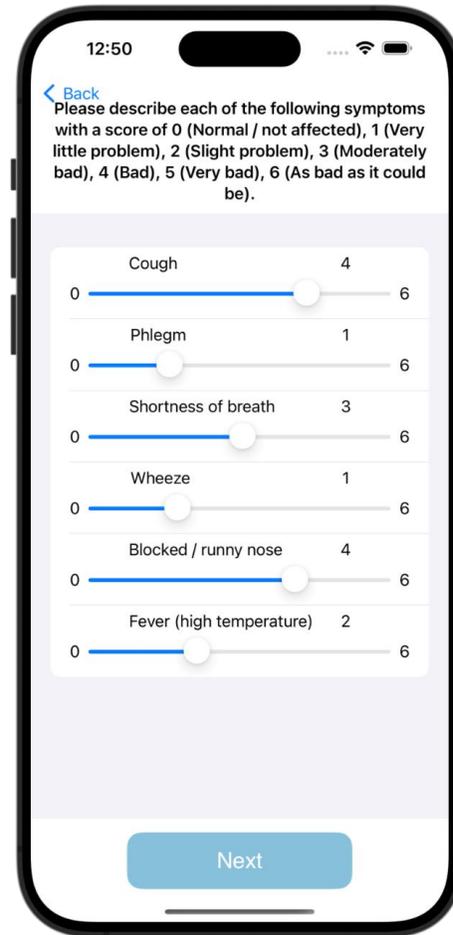
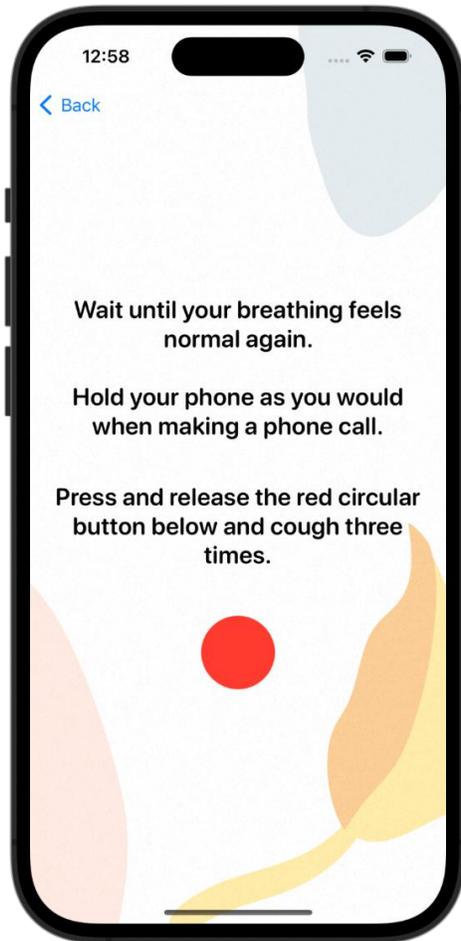
Upload short recordings of cough and breathing and report symptoms to help researchers from the University of Cambridge detect if a person is suffering from COVID-19. Healthy and *non-healthy* participants welcome.



or use the online form



# EPSRC RELOAD: Respiratory Tract Infections



 **RELOAD** Breath Tracker app

RELOAD: REspiratory disease progression through LOngitudinal Audio Data machine learning.



iOS

Android



By Evelyn Zhang

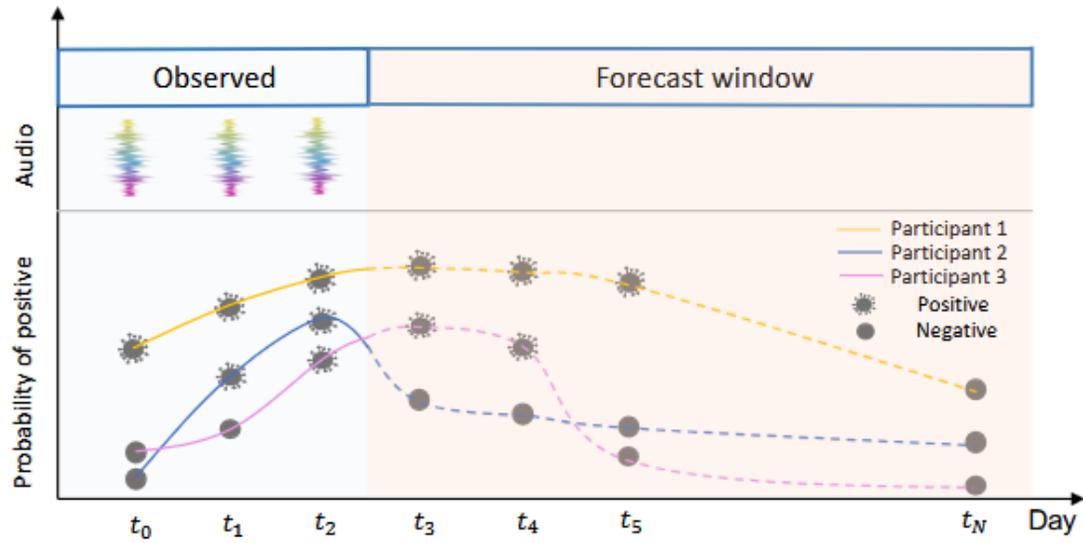
# CNDP: Respiratory Tract Infection test case

- Binary RTI detection
- Mobile-sourced longitudinal dataset
- 463 users (178 with at least 1 positive RTI)

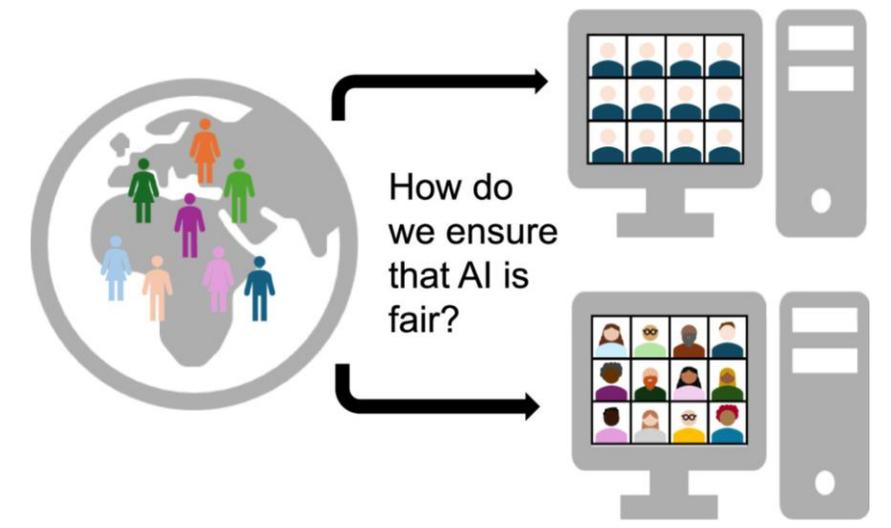
Approach	AU-ROC
PANN features + Gaussian Process	.779
CNDP	<b>.850</b>



# A) Personalised respiratory progression



# B) Fair respiratory AI



# C) Looking forward



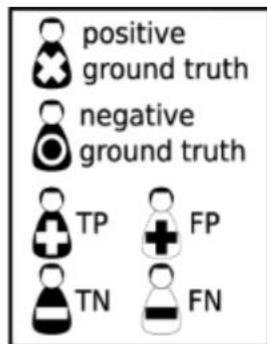
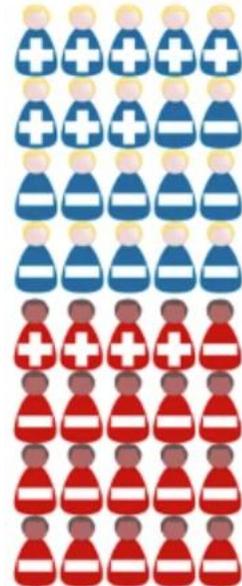
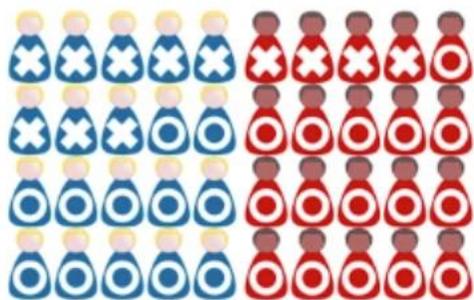
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# Fairness definitions

Ground truth    Model prediction



## Group fairness

- Minimise  $\Delta$  AU-ROC,  $\Delta$  ECE

## Max-min fairness

- Maximise Worst AU-ROC, Worst ECE

# Fair methods usually need sensitive info...

...to unlearn bias

- Is this a problem?
  - a. Confidential, or not shared
  - b. Whac-a-mole effect
  - c. Unknown bias dimensions a-priori



Wikipedia

# Group-agnostic methods for audio

- Selected experiments setup:
  - Wav2Vec 2.0 Base encoder
  - UK COVID-19 data subset
- Revisiting robust methods:
  - Weight averaging (SWAD)
  - Flatness seeking (SAM)
  - Model Ensembles

#	Train	Devel	Test	F/M	A1/A2/A3
positive	366	204	314	532/352	378/419/87
negative	634	296	686	909/707	449/697/470
$\Sigma$	1,000	500	1,000	1,441/1,059	827/1,116/557

## Binary COVID-19 detection

Method	UAR $\uparrow$	worst-UAR $\uparrow$	$\Delta$ -UAR $\downarrow$	ECE $\downarrow$	worst-ECE $\downarrow$	$\Delta$ -ECE $\downarrow$
W2V2B	.640 $\pm$ .047	.616 $\pm$ .048	.114 $\pm$ .013	.075 $\pm$ .036	.157 $\pm$ .047	.115 $\pm$ .045
W2V2B + SAM	.640 $\pm$ .057	.611 $\pm$ .053	.103 $\pm$ .017	.060 $\pm$ .056	.138 $\pm$ .052	.087 $\pm$ .054
E-W2V2B	.653	.642	.122	.106	.160	.080
E-W2V2B + SAM	.676	.668	.089	.020	.078	.039



**SUBMITTED**

## Future pandemics?

**Disease X**

“as the COVID-19 pandemic demonstrated,  
infectious diseases do not respect borders”



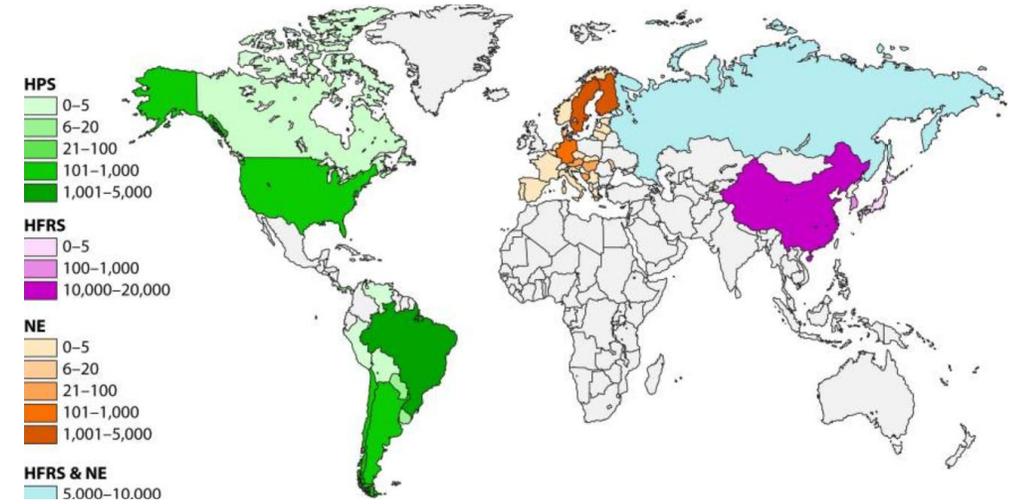
# Rare and deadly diseases?

**B B C**

What is hantavirus, disease that killed Gene Hackman's wife?

“The CDC reported 864 cases of hantavirus in the US between 1993 and 2022.”

“mortality rate is approximately 38%”



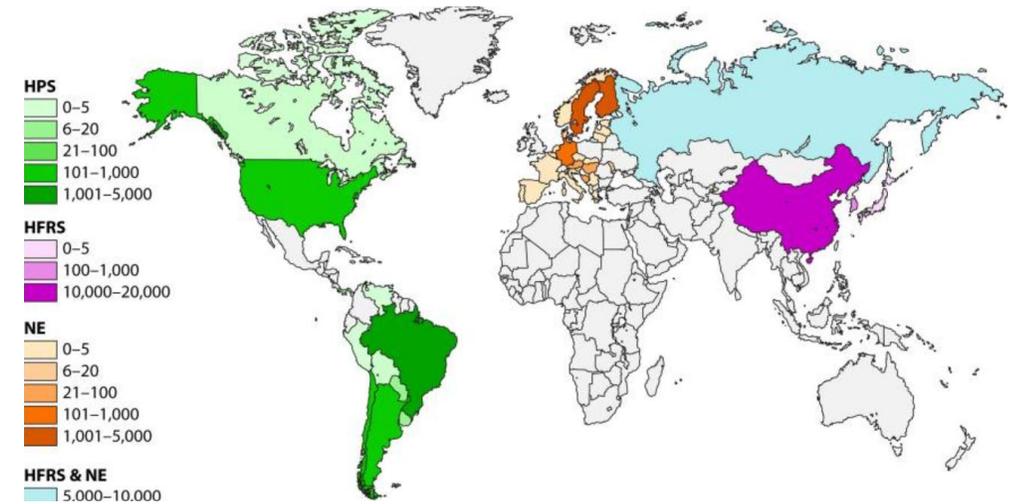
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**Cheap early-warning systems**

**Robust AI to leave no one behind**