Uncovering Pediatric Sleep Apnea Patterns: Deep Learning and Explainable Artificial Intelligence Insights from Airflow and Oximetry Signals

veronica.barroso@uva.es

Verónica Barroso-García [1,2], Jorge Jiménez-García [1,2], Gonzalo C. Gutiérrez-Tobal [1,2], David Gozal [3], and Roberto Hornero [1,2]

[1] *Biomedical Engineering Group, University of Valladolid, Valladolid, Spain*
[2] *Centro de Investigación Biomédica en Red en Bioingeniería, Biomateriales y Nanomedicina (CIBER-BBN), Spain*
[3] *Office of The Dean, Joan C. Edwards School of Medicine, Marshall University, Medical Center Drive, Huntington, WV, USA*

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INTRODUCTION

BACKGROUND

- Pediatric Obstructive Sleep Apnea (OSA) is a highly prevalent respiratory disorder characterized by recurrent apnea and/or hypopnea episodes during sleep
- Polysomnography (PSG) is the gold standard diagnosis test, but its cost, complexity, discomfort, and limited availability contribute to underdiagnosis of the disease

OBJECTIVES

- To assess the diagnostic performance of an explainable deep-learning model capable of estimating the childhood OSA severity from airflow (AF) and oximetry (SpO_2) signals
- To identify novel patterns of AF and SpO_2 that contribute to the OSA detection

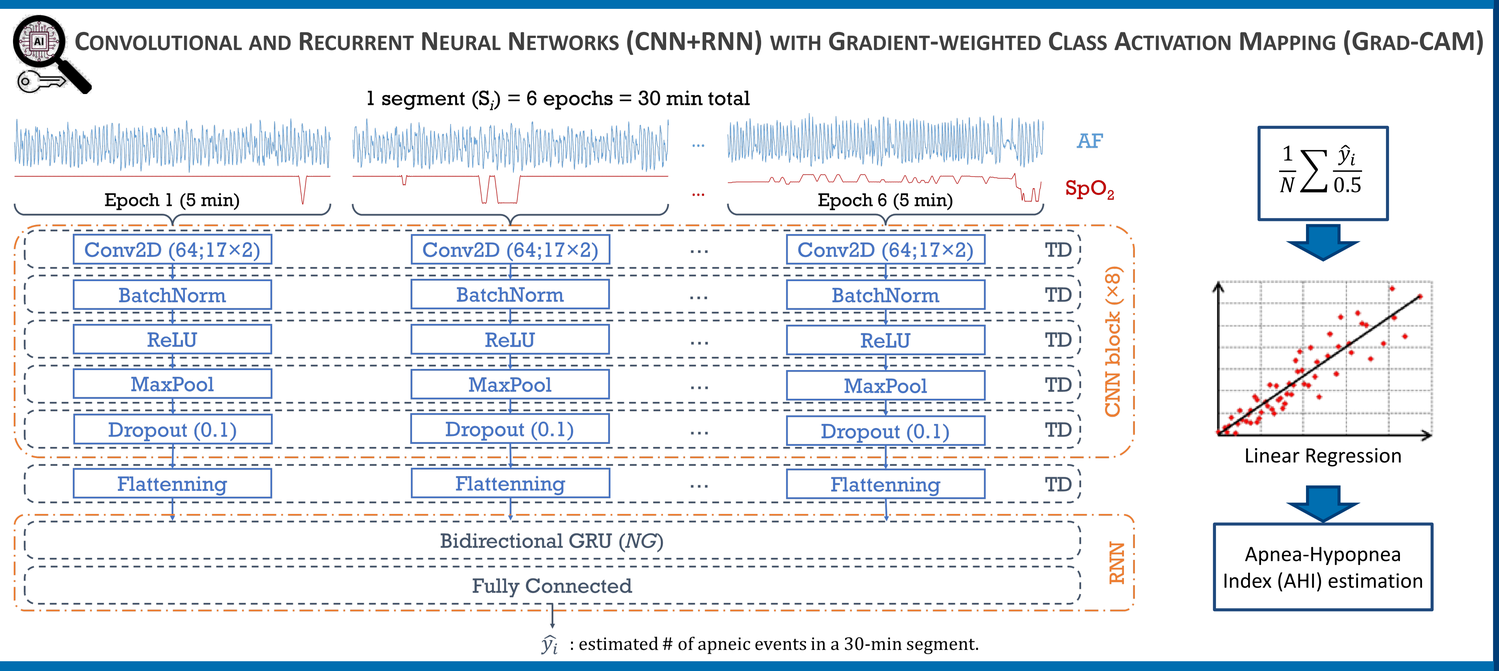
MATERIALS AND METHODS

SUBJECTS

Childhood Adenotonsillectomy Trial (CHAT)
Comer Children's Hospital from University of Chicago (UofC)
LeBonheur Children's Hospital from University of Tennessee (UofT)

	CHAT (Training)	CHAT (Validation)	CHAT (Test)	UofC (Validation)	UofC (Test)	UofT (Test)
Subjects (*n*)	1006 (61.4%)	326 (19.9%)	306 (18.7%)	584 (60.0%)	390 (40.0%)	545 (100.0%)
Age (years)	7.0 [2.0]	7.0 [2.0]	6.9 [2.0]	6.0 [5.0]	5.5 [6.0]	7.2 [7.6]
Males (*n*)	471 (46.8%)	156 (47.9%)	134 (43.8%)	346 (59.2%)	253 (64.9%)	293 (53.8%)
BMI (Kg/m²)	17.4 [6.1]	17.1 [6.4]	17.6 [6.0]	17.7 [6.6]	18.2 [5.9]	19.5 [12.1]
AHI (events/h)	2.6 [4.8]	2.4 [4.6]	2.3 [5.1]	4.1 [8.3]	3.3 [6.5]	2.3 [5.8]
No OSA (*n*)	219 (21.8%)	69 (21.2%)	67 (21.9%)	96 (16.4%)	75 (19.2%)	176 (32.3%)
Mild OSA (*n*)	496 (49.3%)	168 (51.5%)	148 (48.4%)	229 (39.2%)	169 (43.3%)	207 (38.0%)
Moderate OSA (*n*)	160 (15.9%)	44 (13.5%)	49 (16.0%)	113 (19.4%)	63 (16.2%)	79 (14.5%)
Severe OSA (*n*)	131 (13.0%)	45 (13.8%)	42 (13.7%)	146 (25.0%)	83 (21.3%)	83 (15.2%)
Segments (*n*)	114,873	37,155	34,771	58,985	39,467	56,303

CONVOLUTIONAL AND RECURRENT NEURAL NETWORKS (CNN+RNN) WITH GRADIENT-WEIGHTED CLASS ACTIVATION MAPPING (GRAD-CAM)



RESULTS

		CNN + RNN			
		No-OSA	Mild	Moderate	Severe
PSG	No-OSA	110	197	10	1
	Mild	43	359	101	20
	Moderate	2	46	71	72
	Severe	0	6	28	174

AHI threshold	Sensitivity (%)	Specificity (%)	Accuracy (%)
1 event/h	95.12	34.59	79.60
5 events/h	86.47	84.30	85.00
10 event/h	83.65	90.99	89.76

Intraclass correlation coefficient = 0.88
4-class accuracy = 57.58%
4-class Cohen's kappa = 0.39

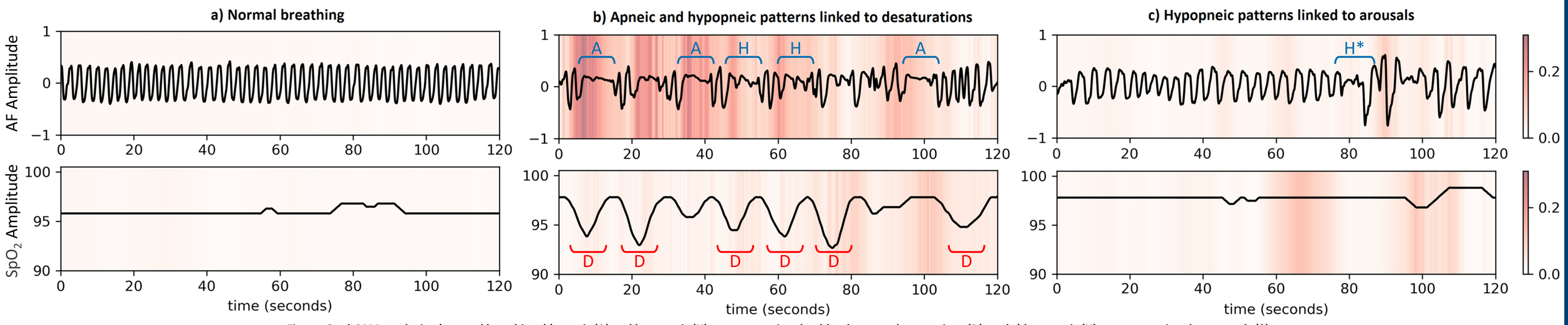


Figure. Grad-CAM results in a) normal breathing; b) apneic (A) and hypopneic (H) events associated to blood oxygen desaturations (D); and c) hypopneic (H) events associated to arousals (*)

CONCLUSIONS

- The improvement over conventional techniques, along with pointing out the AF and SpO2 regions that most contribute to the model prediction, highlights the effectiveness and reliability of combining deep-learning strategies and these signals for simplifying the pediatric OSA diagnosis
- Our proposal could be a powerful tool to automatically identify the OSA-linked respiratory patterns and contribute to its interpretation

A promising PSG alternative to provide early, objective, and accurate diagnosis of pediatric OSA

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