Impacts of air pollution on children's health

Ioar Rivas

ioar.rivas@idaea.csic.es

IR0000032 – ITINERIS, Italian Integrated Environmental Research Infrastructures System
(D.D. n. 130/2022 - CUP B53C22002150006) Funded by EU - Next Generation EU PNRR-Mission 4 "Education and Research" - Component 2: "From research to business" - Investment 3.1: "Fund for the realisation of an integrated system of research and innovation infrastructures"

Finanziato dall'Unione europea NextGenerationEU
Ministero dell'Università e della Ricerca
Italiadomani

Outline

- A note on PM size and chemical composition
- Which are the mechanisms explaining the effects of air pollution on health?
- The DOHaD concept
- Impacts of air pollution on children’s health
  - Respiratory health
  - Birth outcomes
  - Neurodevelopment
- Take home message

Let’s start with a poll!

Join at menti.com | use code 2517 0309

Mentimeter

Instructions

Go to

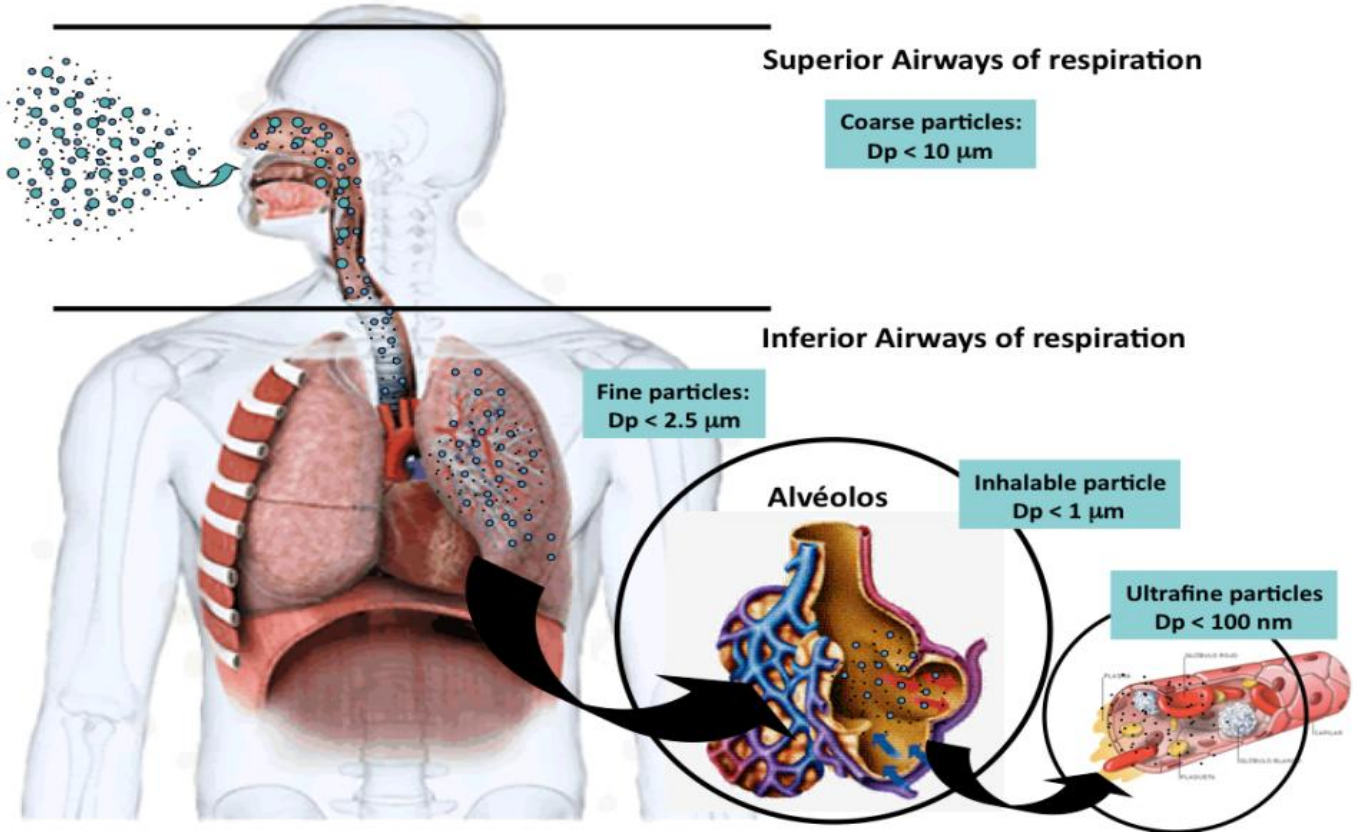
www.menti.com

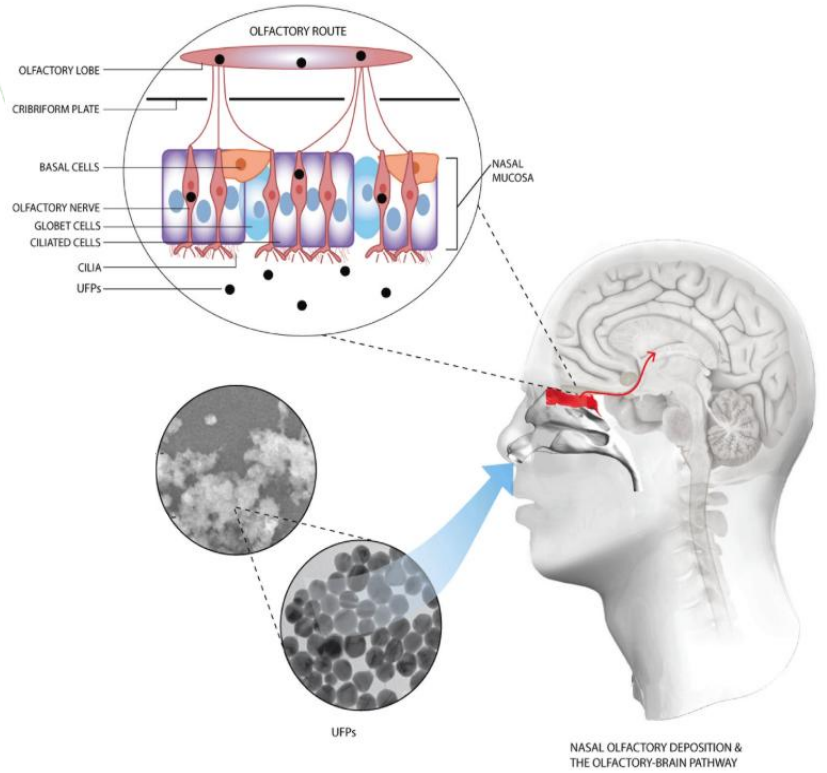
Enter the code

2517 0309

Or use QR code

PM: size matters





PM: chemical composition too

Mineral

Al_2O_3, Mg, Ti, Fe, K, SiO_2, CO_3^{2-}, P, Ca

Carbonaceous compounds

Organic matter and elemental carbon

Secondary aerosols

NH_4^+, SO_4^{2-}, NO_3^-, orgánicos

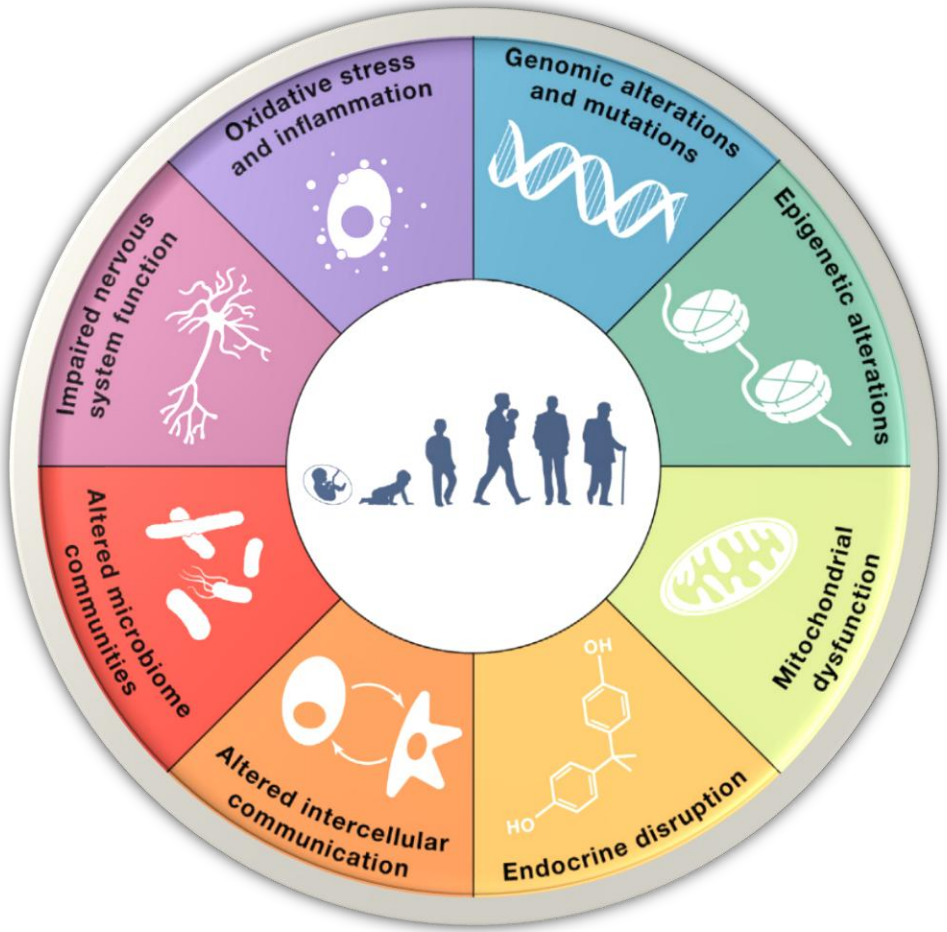
Marine aerosol

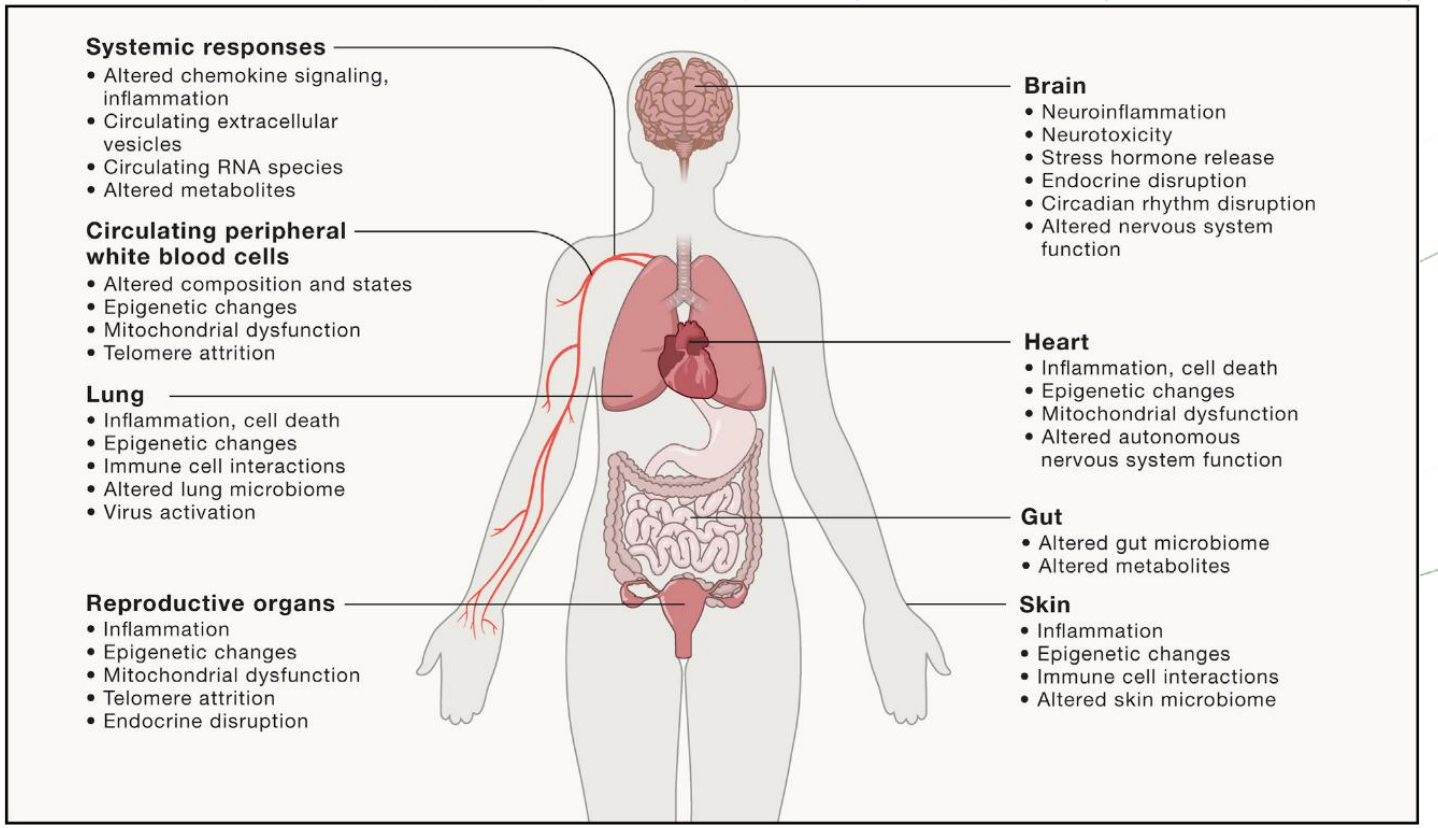
Na^+, Cl^-

Trace elements

As, Ba, Bi, Cd, Ce, Co, Cr, Cs, Cu, Dy, Er, Ga, Gd, Ge, Hf, La, Li, Mn, Mo, Nd, Ni, Pb, Pr, Rb, Sb, Sc, Se, Sm, Sn, Sr, Ta, Th, Ti, Tl, U, V, W, Yb, Zn, Zr

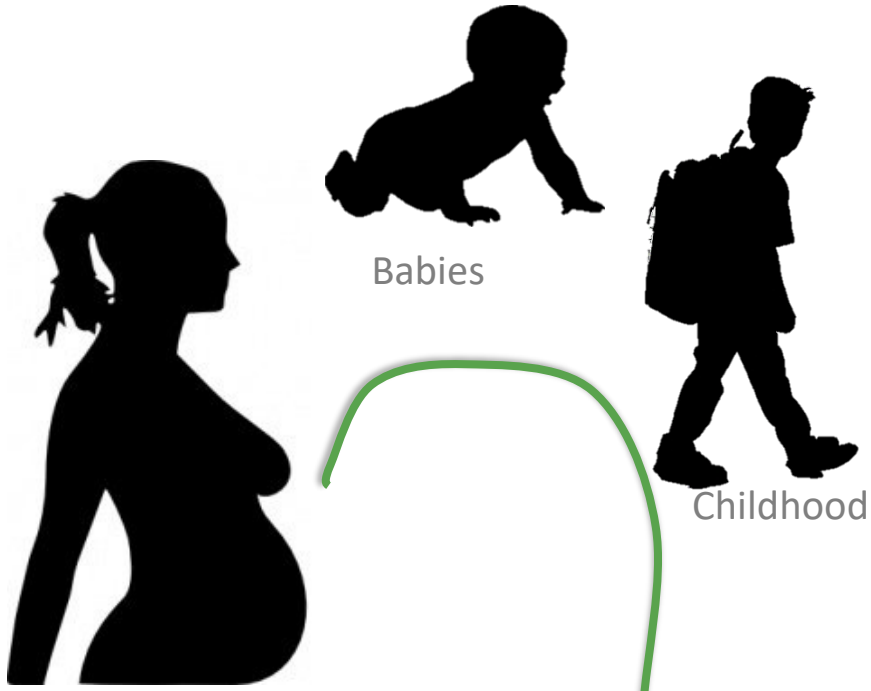
Which are the mechanisms of the health effects of air pollution?





Peters and Nawrot.(2021). Hallmarks of environmental insults. Cell, 184, 1455-1468.

Different grades of susceptibility



Babies

Childhood

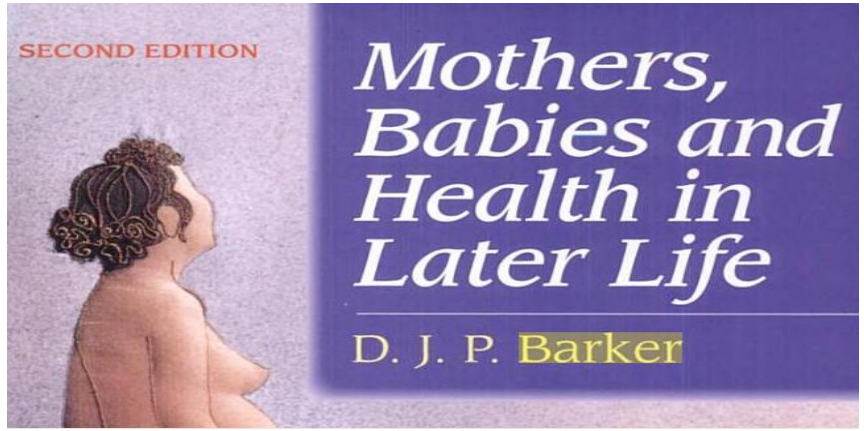
Pregnant individuals
Fetuses

Periods of larger susceptibility

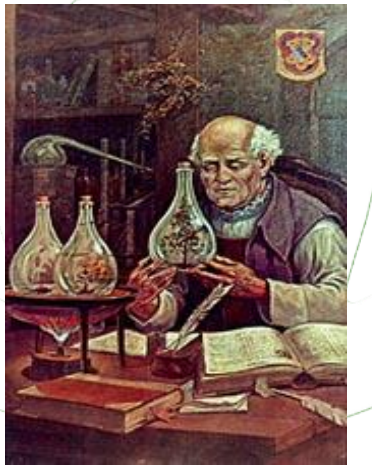
Elderly

But also…

Developmental Origins of Health and Diseases (DOHaD)



…from "the ***dose*** makes the poison" to "the ***timing*** makes the poison"



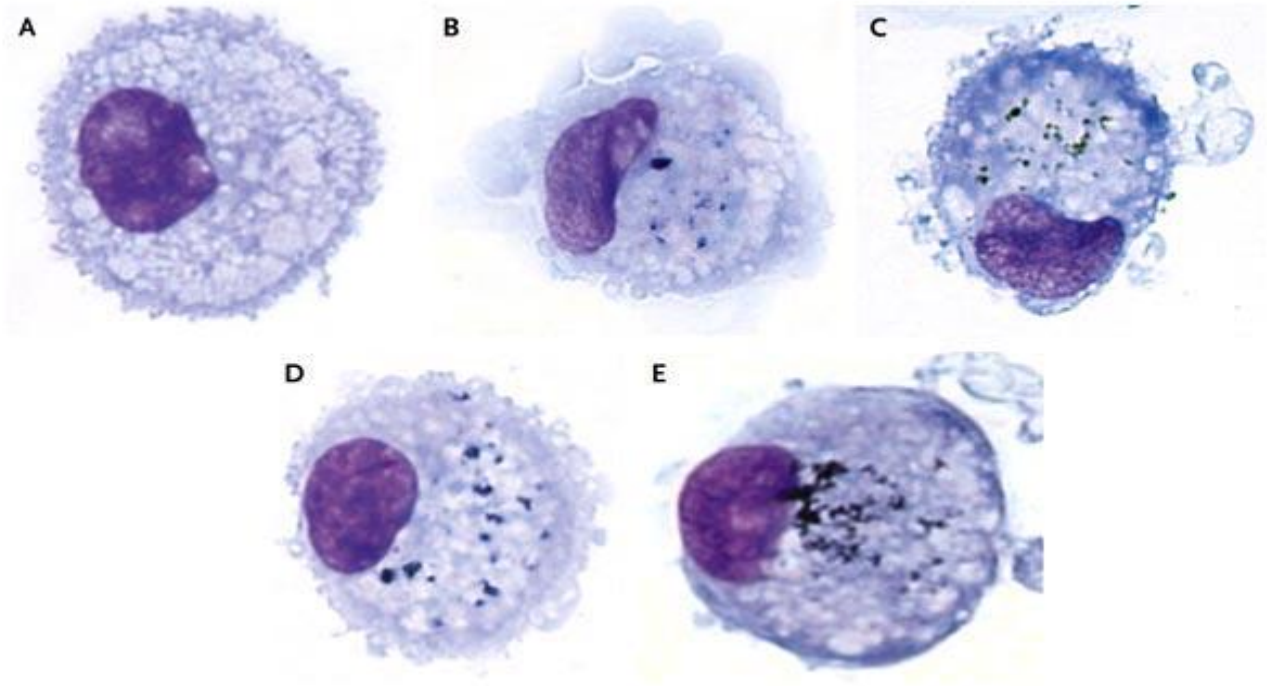
Developmental Origins of Health and Diseases **- Barker, 1980's**

In *utero* and **early postnatal stressors**, including environmental contaminant exposures, can **permanently change the body's structure, physiology, and metabolism**, predisposing individuals to the **development** of serious chronic **pathologies later in life**.

Impacts on the respiratory system

Presence of carbon in airway macrophages in healthy children exposed to traffic

Healthy children (8-15 years old) exposed to different traffic levels



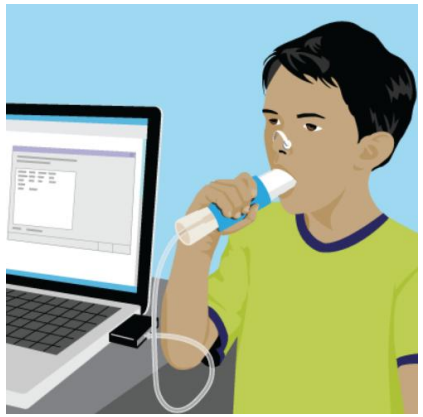
Each increase in primary PM10 of 1.0 µg per cubic meter was associated with an increase of 0.10 µm2 (95 percent confidence interval, 0.01 to 0.18) in the carbon content of airway macrophages

Figure: Representative Images of Carbon in Airway Macrophages from Healthy Children. Panel A shows a macrophage with no carbon. Increasing levels of carbon are shown in Panels B through E (PM10). N=64 children.

Kulkarni et al. (NEJM 2006)

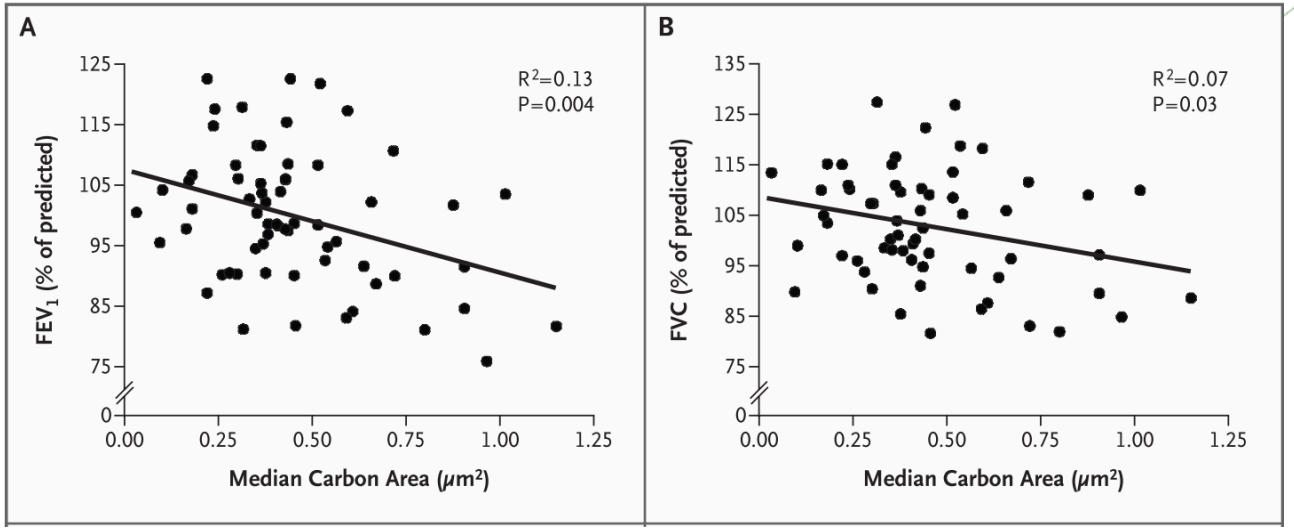
Impacts on the respiratory system

Carbon in airway macrophages impairs lung function in healthy children (8-15 years)



Spirometry:

Forced expiratory volume in one second (**FEV_1**): how much air a person can exhale during the first second of a forceful breath
Forced Vital Capacity (**FVC**): Total amount of air a person can forcibly exhale from their lungs after taking the deepest possible breath

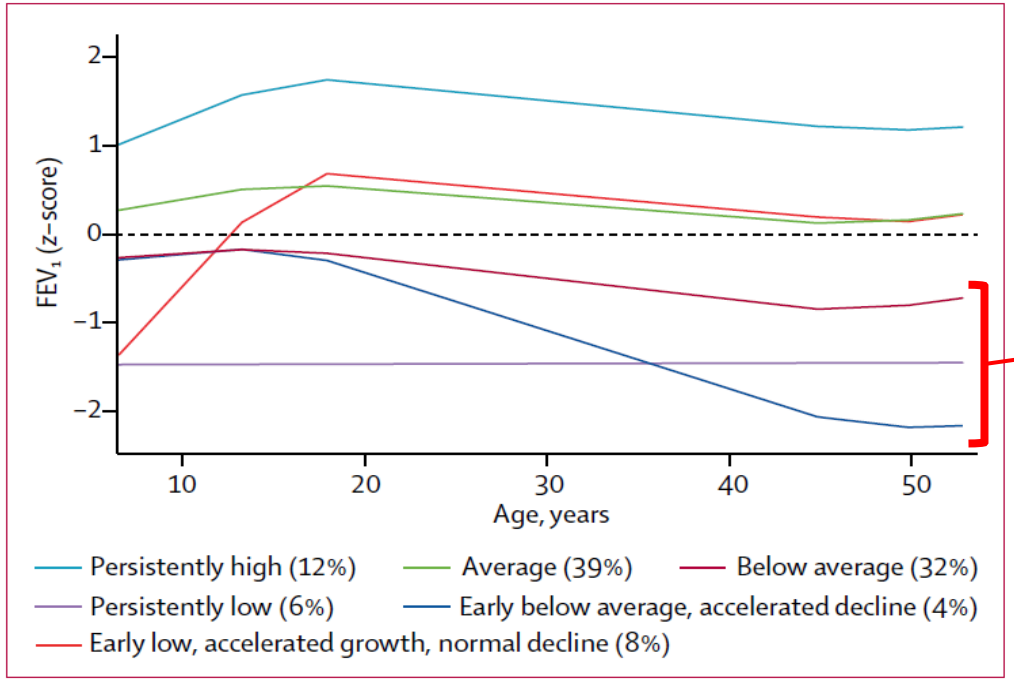


Each increase of 1.0 µm2 in carbon content was associated with a reduction of 17% in FEV1 and of 12.9% in FVC.

Why is it important to study the determinants of lung function development?

Childhood predictors of lung function trajectories and future COPD risk: a prospective cohort study from the first to the sixth decade of life

Dinh S Bui, Caroline J Lodge, John A Burgess, Adrian J Lowe, Jennifer Perret, Minh Q Bui, Gayan Bowatte, Lyle Gurrin, David P Johns, Bruce R Thompson, Garun S Hamilton, Peter A Frith, Alan L James, Paul S Thomas, Deborah Jarvis, Cecilie Svanes, Melissa Russell, Stephen C Morrison, Iain Feather, Katrina J Allen, Richard Wood-Baker, John Hopper, Graham G Giles, Michael J Abramson, Eugene H Walters, Melanie C Matheson, Shyamali C Dharmage**



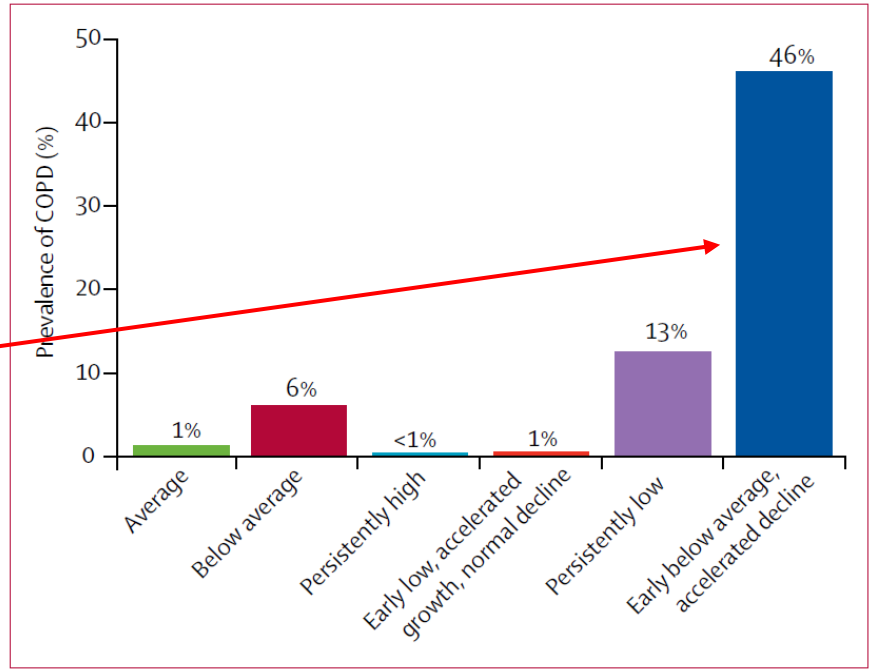
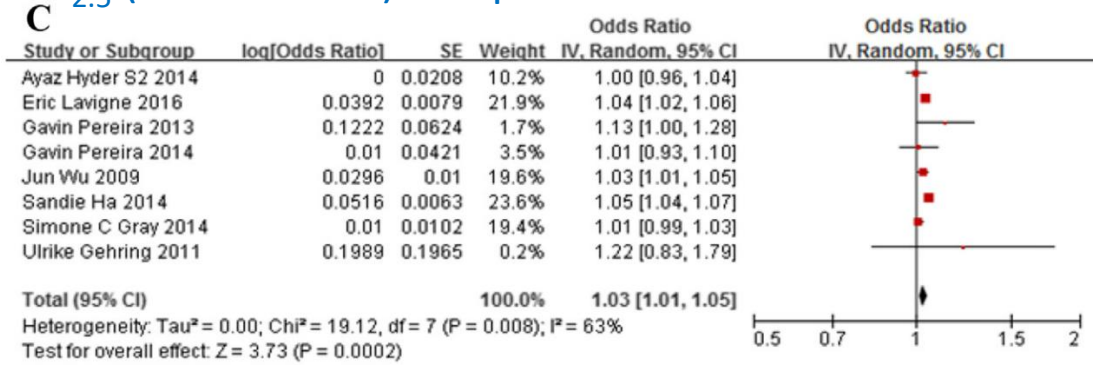


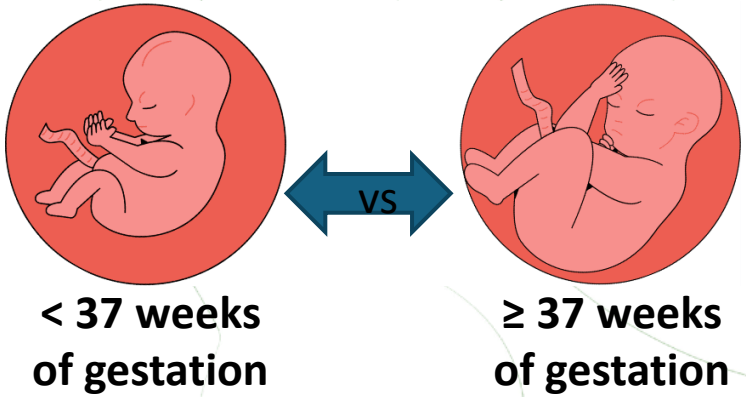
Figure 2: **Prevalence of COPD among six lung function trajectories at 53 years**
COPD=chronic obstructive pulmonary disease.

Bui et al, Lancet 2018

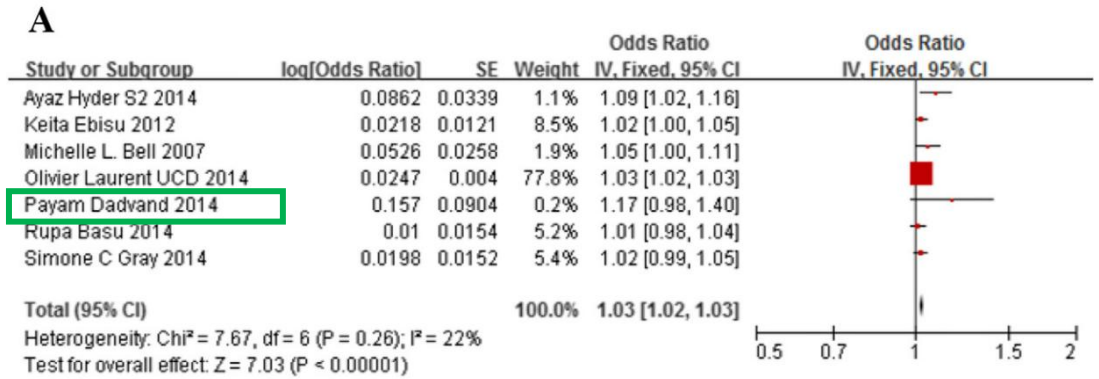
Air pollution and birth outcomes

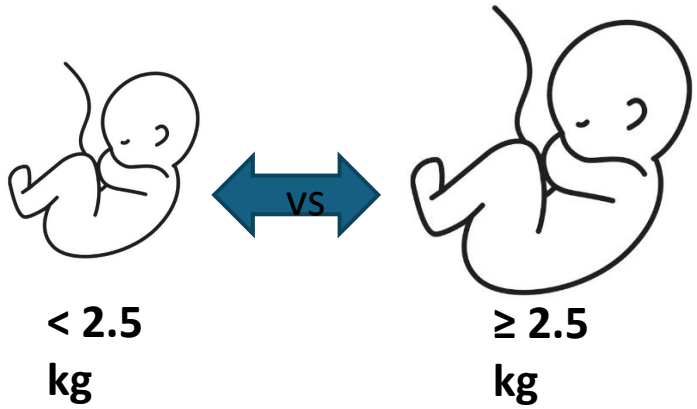
$PM_{2.5}$ (IQR increase) and preterm birth





$PM_{2.5}$ (IQR increase) and term low birth weight





Li et al. (2017). Association between ambient fine particulate matter and preterm birth or term low birth weight: An updated systematic review and meta-analysis. Environ. Pollut. 227, 596–605.

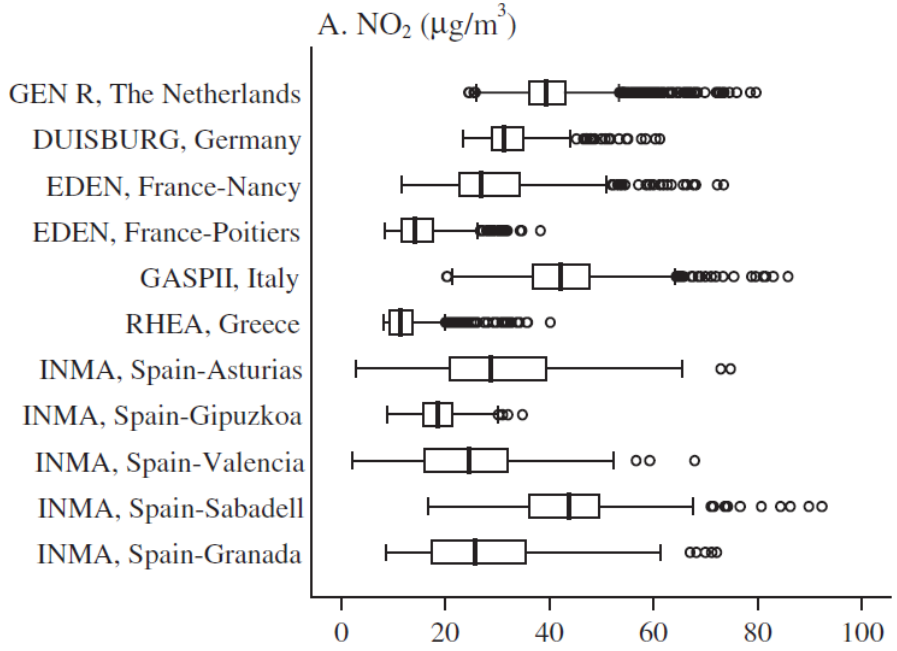
Air pollution and psychomotor development

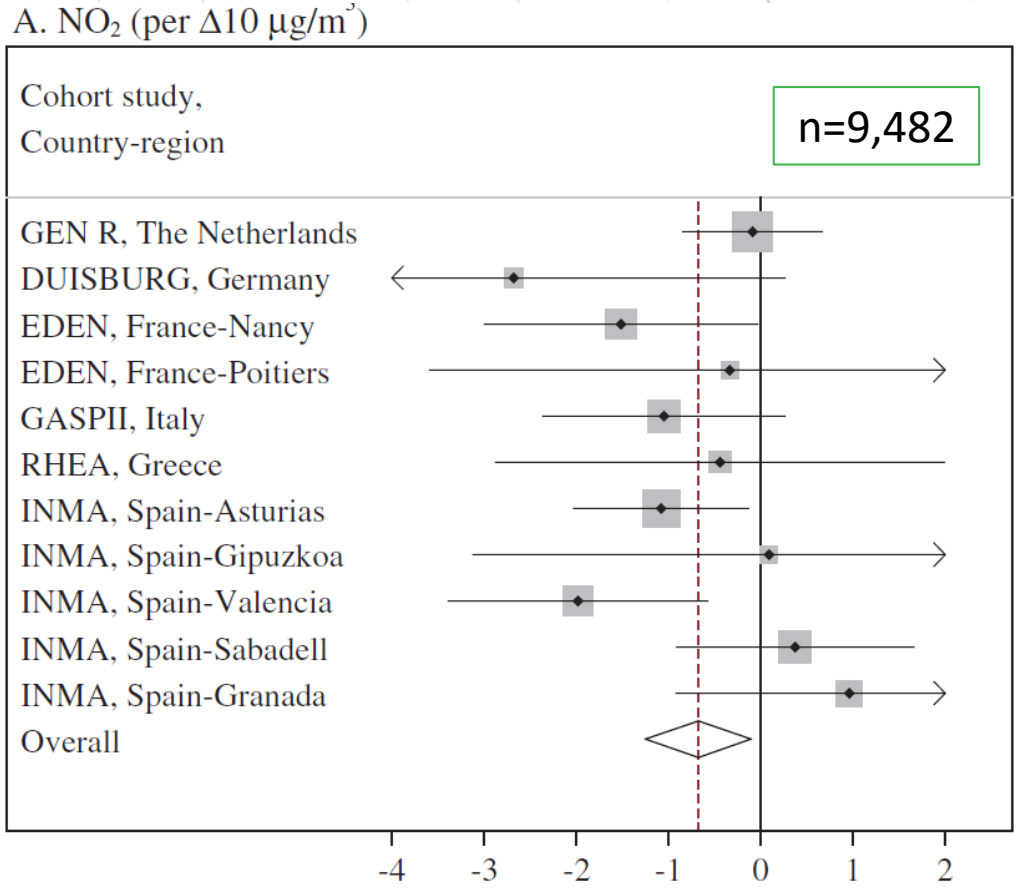
1-6 years

COGNITIVE AND PSYCHOMOTOR DEVELOPMENT

Reduction of 0.68 points of **psychomotor development** (95% CI= −1.25, −0.11) per increase of 10 µg/m^3 in NO_2

Air pollution in pregnancy





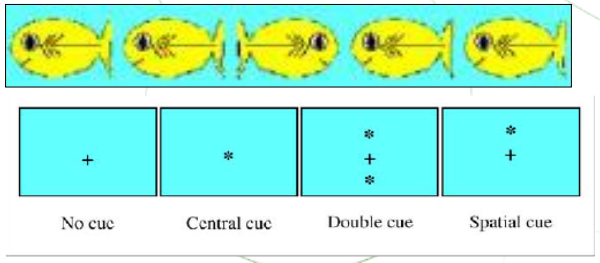
Guxens et al, Epidemiology 2014

Air pollution and cognitive development

The BREATHE project

39 schools in Barcelona, **indoor** and **outdoor** air quality assessment (2012)

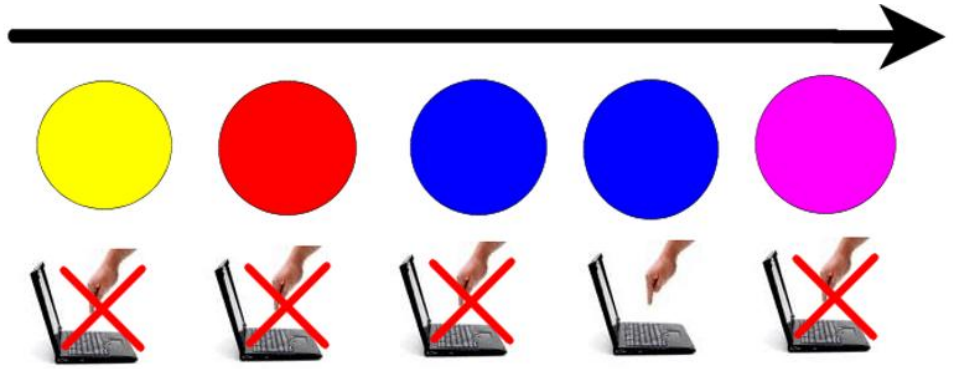
2897 children 7-10 years old
4 tests each (~ 10,700 tests)



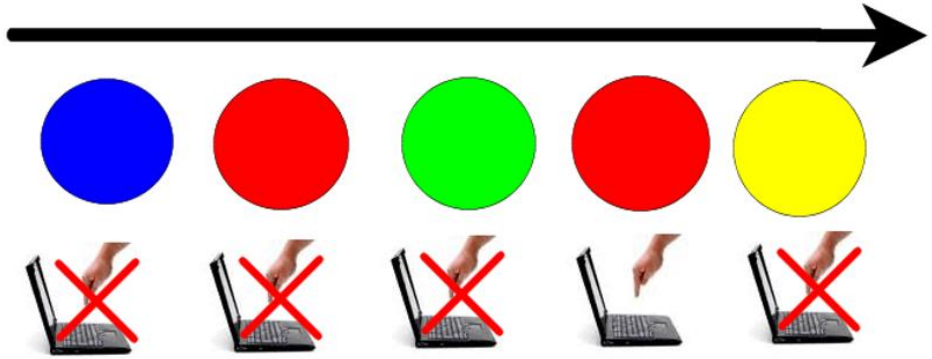
Rivas, I., Querol, X., Wright, J., & Sunyer, J. (2018). *Environment International*, 121, 199–206.

N-back task for evaluating working memory

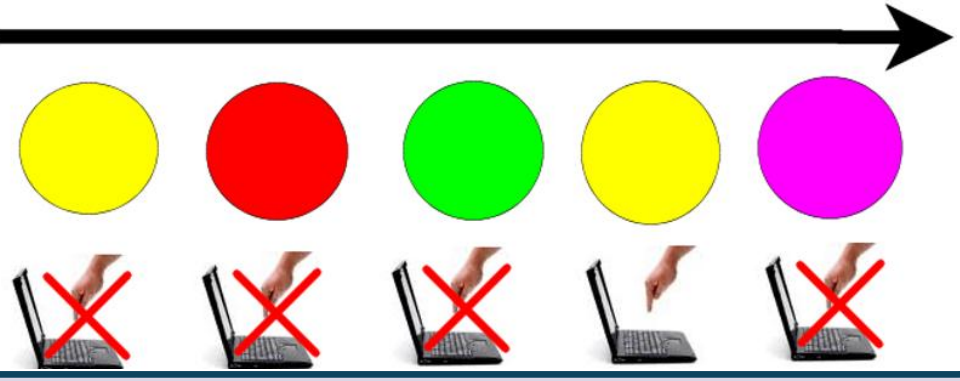
1-back



2-back



3-back



Time to play!!!

- This is an example of an onlin n-back task ‘game’. Let’s try it:

https://www.braingymmer.com/en/brain-games/n_back/play/

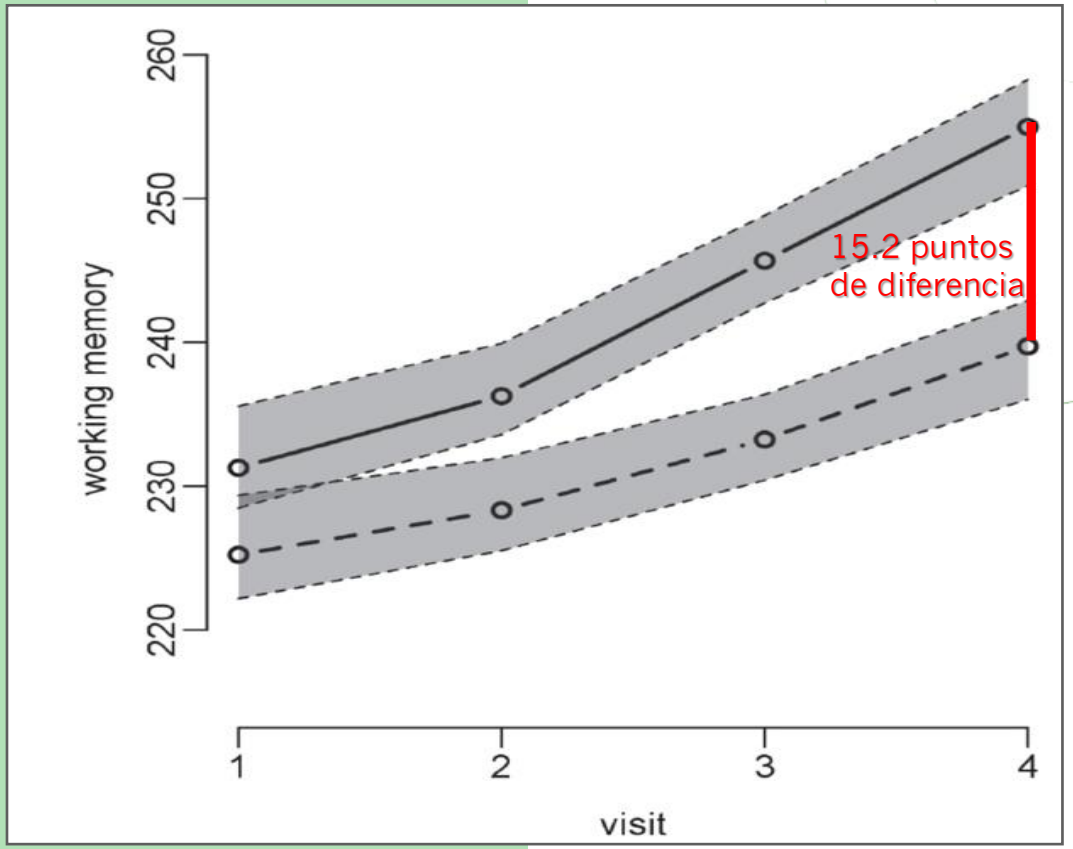
Air pollution and cognitive development

BREATHE Brain Air School investigation

Estudio en escuelas de Barcelona

11,5%

En las escuelas con **baja contaminación**, la memoria de trabajo aumentó un 11.5% en un año**.**



Sunyer PLOS Med 2015

7,4%

En las escuelas con **más contaminación** aumentó en menor medida, un 7.4%.

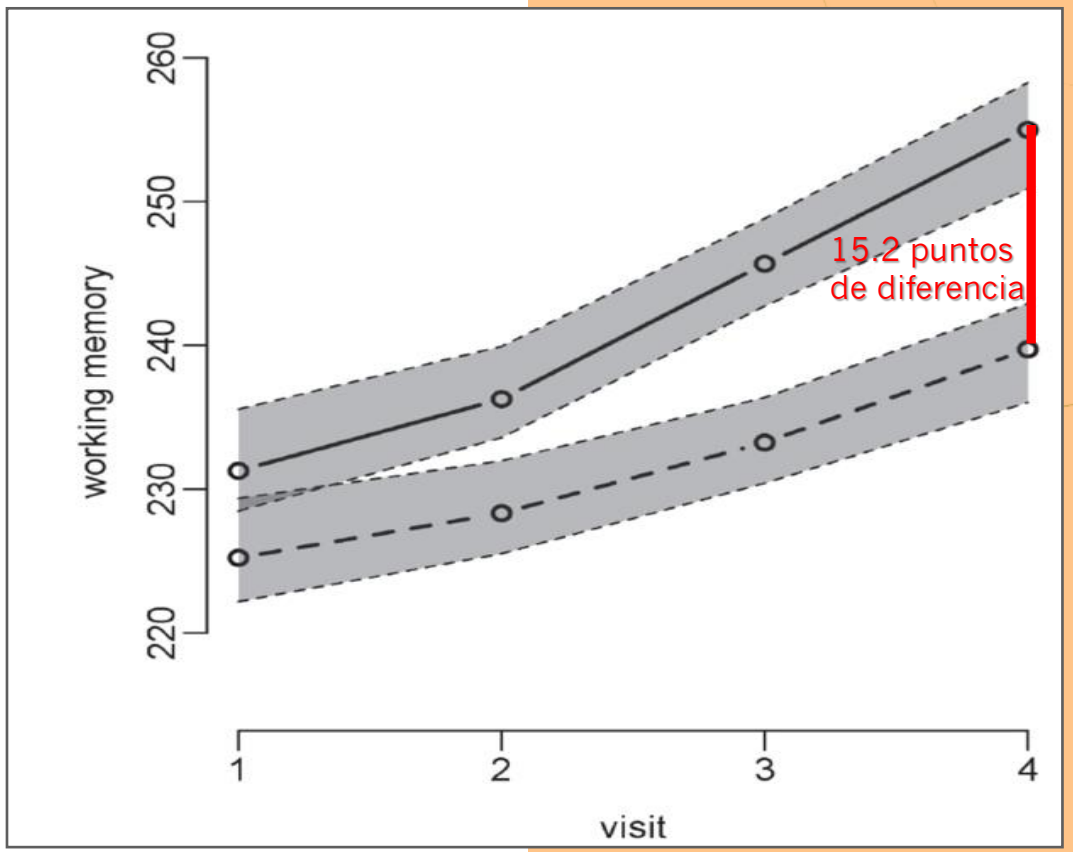
Air pollution and cognitive development

BREATHE Brain Air School investigation

Estudio en escuelas de Barcelona

11,5%

En las escuelas con **baja contaminación**, la memoria de trabajo aumentó un 11.5% en un año.

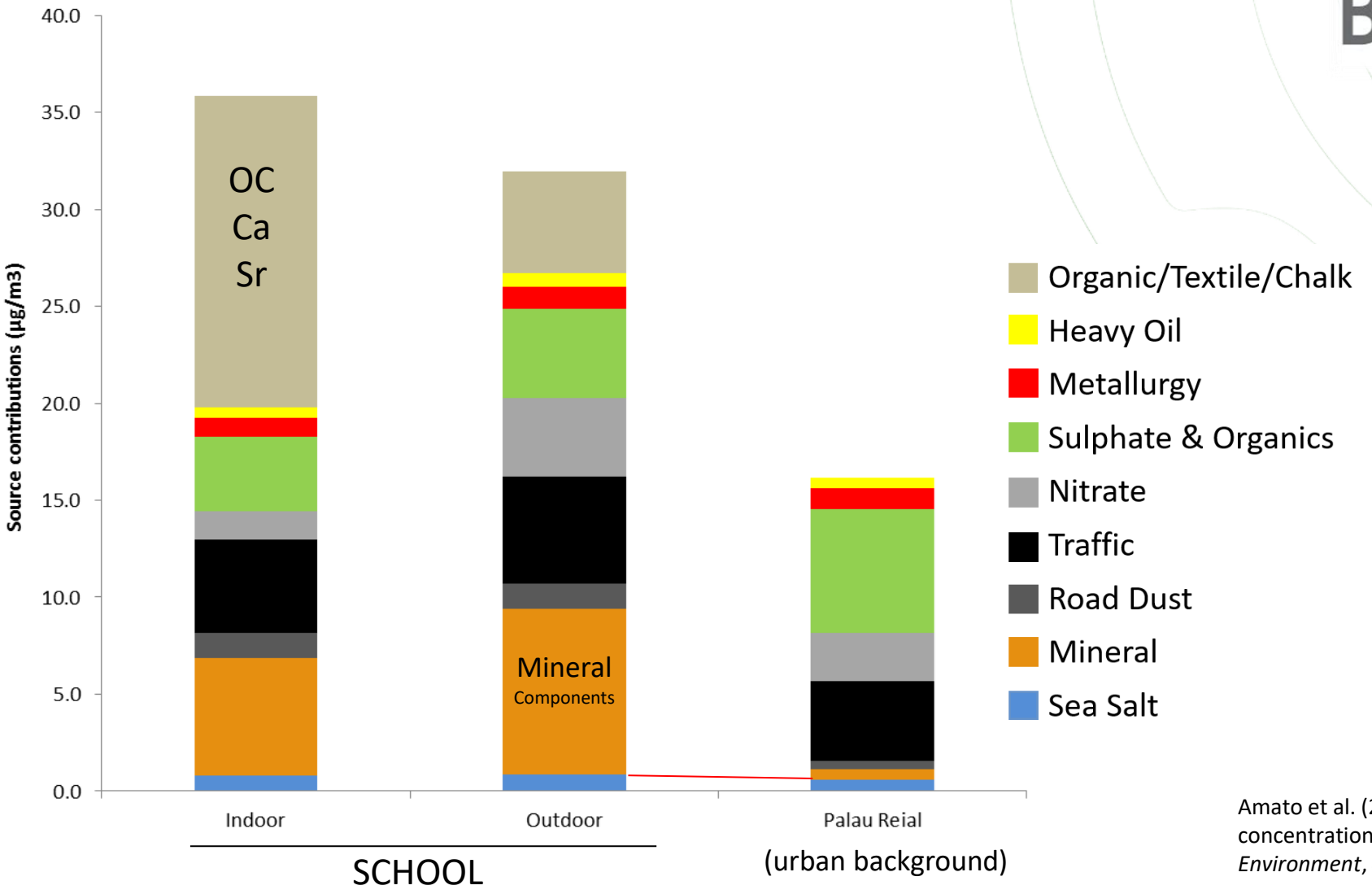


Sunyer PLOS Med 2015

7,4%

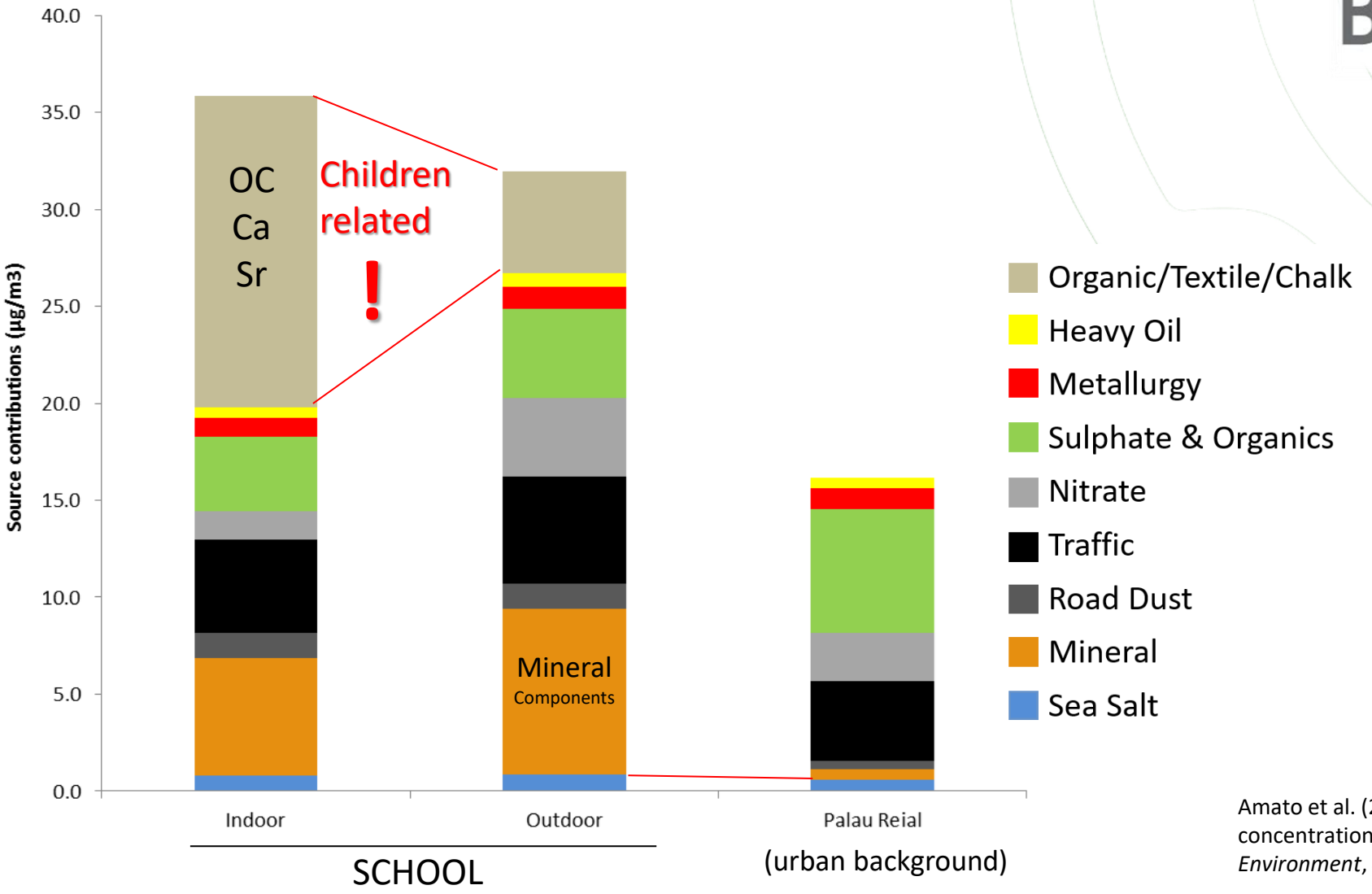
En las escuelas con **más contaminación** aumentó en menor medida, un 7.4%.

Sources of air pollution in schools



Amato et al. (2014). Sources of indoor and outdoor PM2.5 concentrations in primary schools. *Science of the Total Environment*, *490*, 757–765.

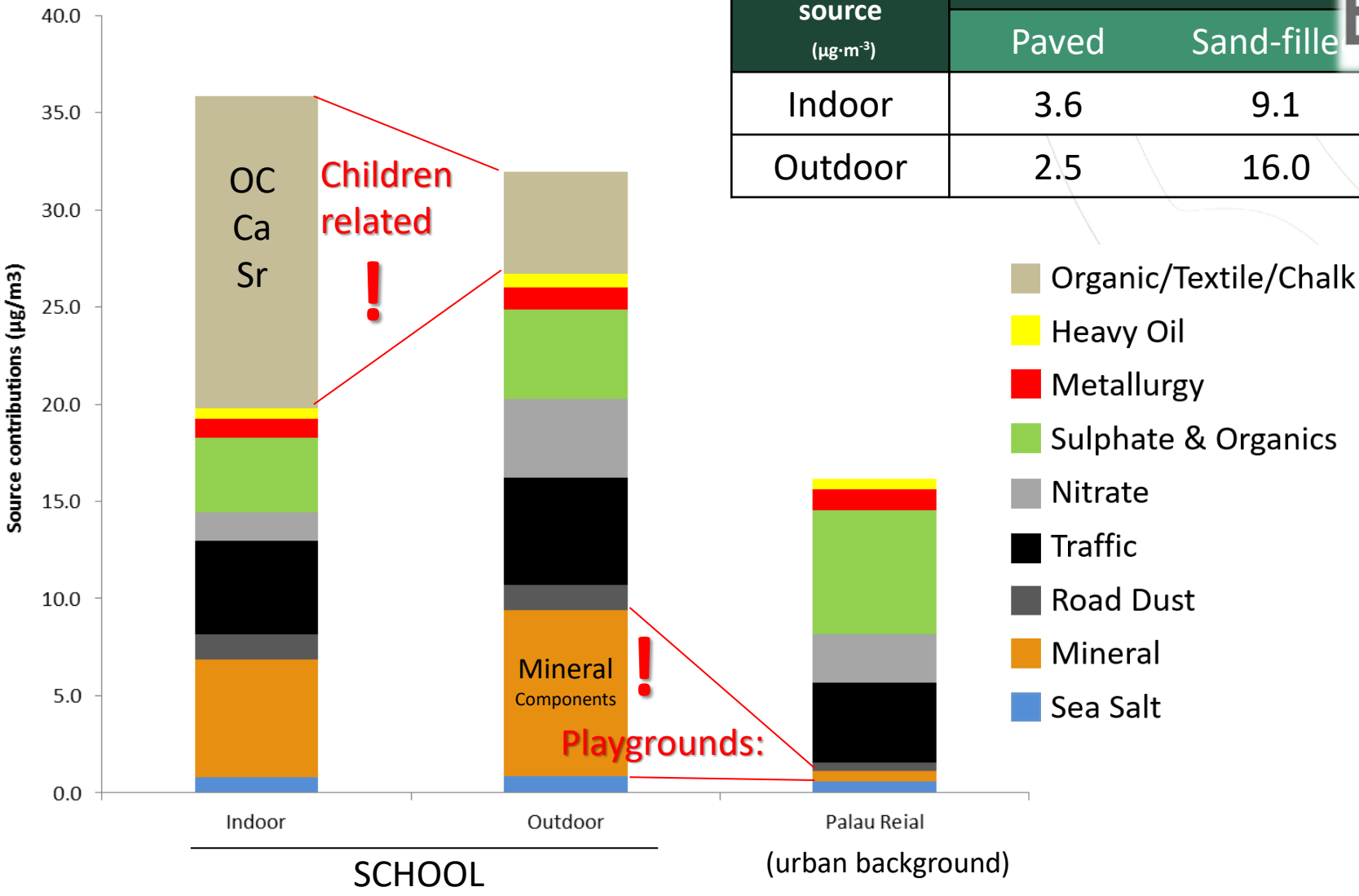
Sources of air pollution in schools



Amato et al. (2014). Sources of indoor and outdoor PM2.5 concentrations in primary schools. *Science of the Total Environment*, *490*, 757–765.

Sources of air pollution in schools

Mineral source (µg·m^{-3})	Type playground:	
	Paved	Sand-fille
Indoor	3.6	9.1
Outdoor	2.5	16.0



Amato et al. (2014). *STOTEN*, *490*, 757–765.

Time to guess!

Join at menti.com | use code 6507 8644

Mentimeter

Instructions

Go to

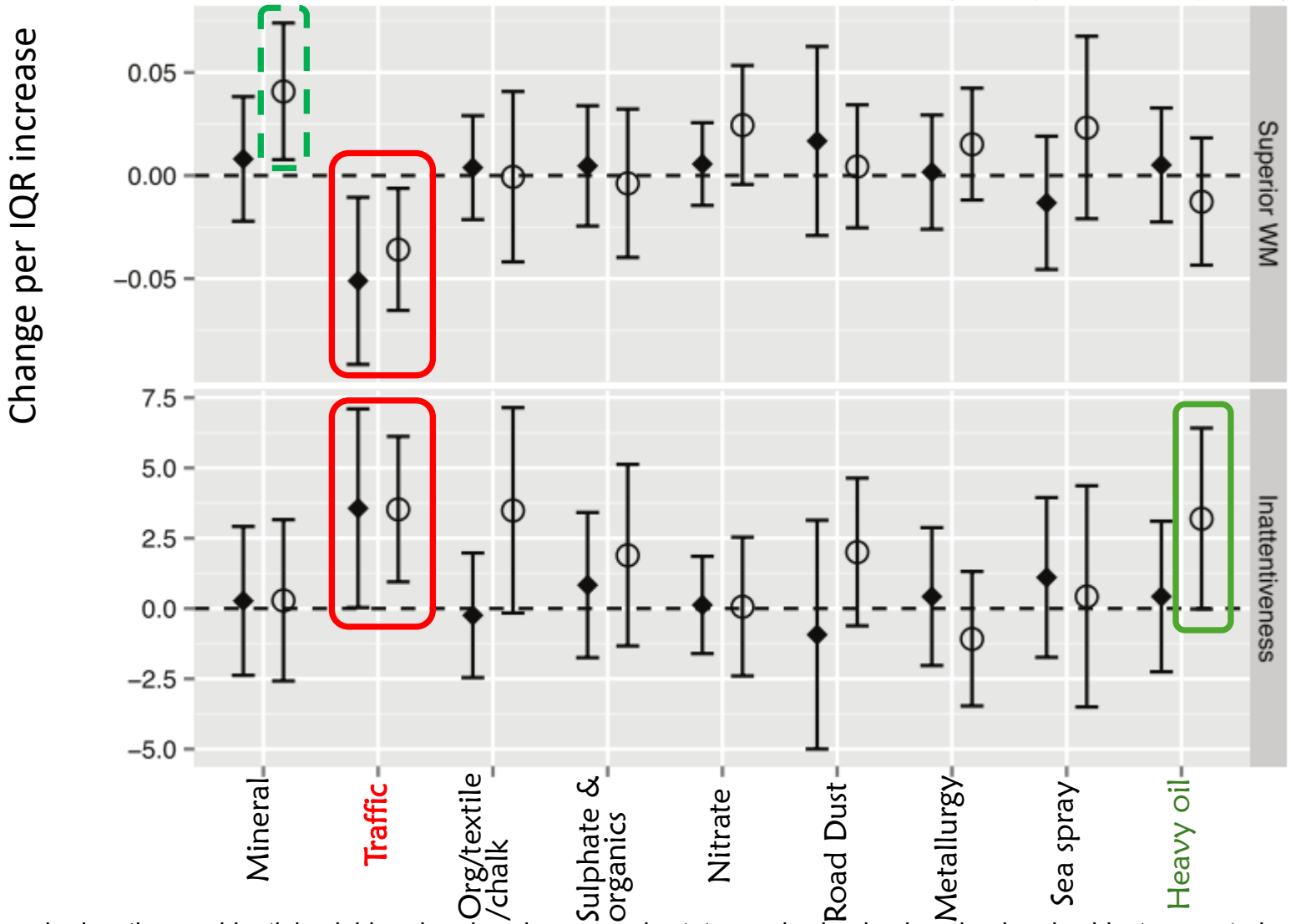
www.menti.com

Enter the code

6507 8644

Or use QR code

Air pollution and cognitive development



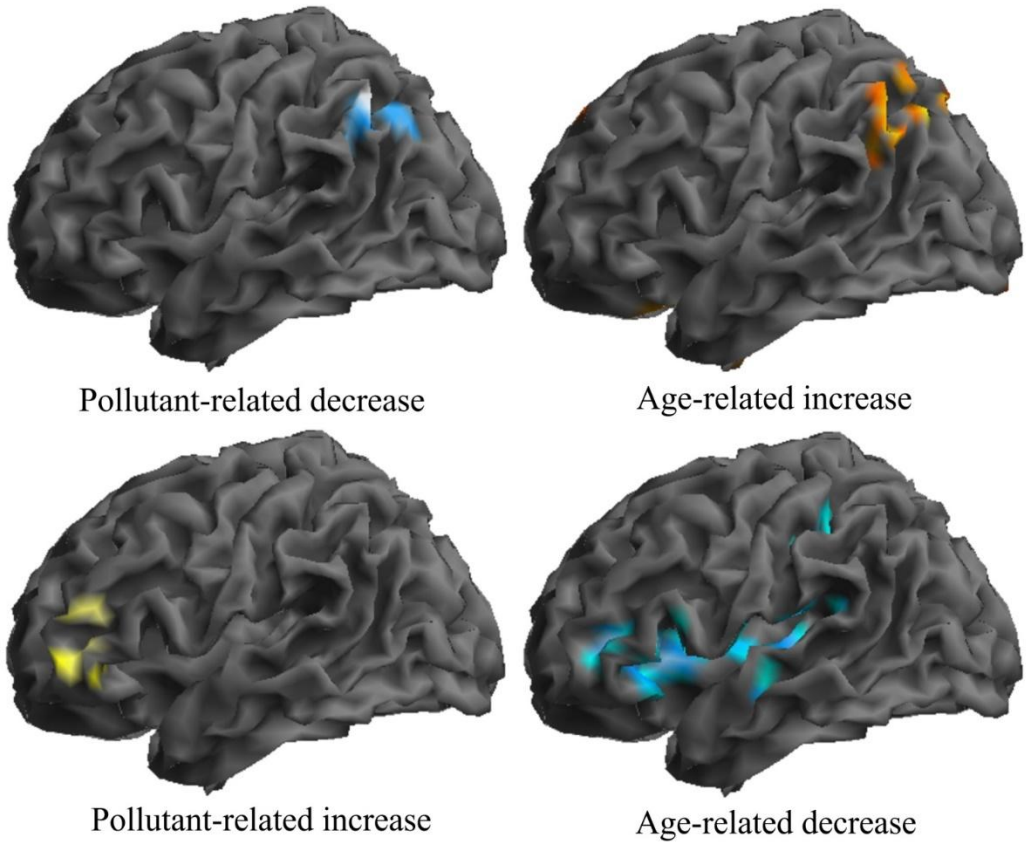
◆ indoor

○ outdoor

Basagaña et al. (2016). *Environmental Health Perspectives*, *124*(April), 1630–1636.

Adjusted for sex, maternal education, residential neighbourhood socio-economic status and school pair; school and subject as nested random effects.

Air pollution and brain connectivity



3D rendering display of urban pollution and age effects in the medial frontal seedmap

BREATHE Brain Air School investigation

Traffic air pollution associated with:

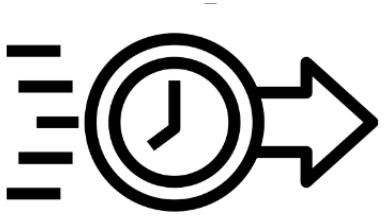
- brain changes of a functional nature, with no evident effect on brain anatomy, structure or membrane metabolites.

- lower functional integration and segregation in key brain networks relevant to both inner mental processes and stimulus-driven mental operations

Age and performance (motor response speed) both showed the opposite effect to that of pollution, thus indicating that higher exposure is associated with slower brain maturation

Air pollution and cognitive development

Some unanswered questions:

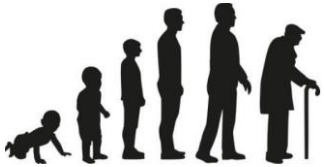


Are these effects on cognition/brain **permanent**?

When did the effects start taking place?

As early as conception? Even before?

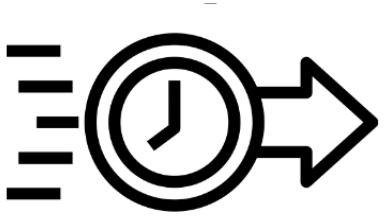
Postnatally?



What is the role of placenta and (parental) genetics?

Air pollution and cognitive development

Some unanswered questions:

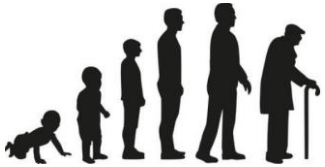


Are these effects on cognition/brain **permanent**?

When did the effects start taking place?

As early as conception? Even before?

Postnatally?



What is the role of placenta and (parental) genetics?

Air pollution and cognitive development

www.projectebisc.org/

Birth cohort:

- **1080** mothers and their offspring recruited (Prenatal period: Oct 2018 – Oct 2021)
- **1033** children - Postnatal follow-ups ongoing

BiSC SUMMARY N = 1080

PREGNANCY

ANTHROPOMETRIC MEASURES & BLOOD PRESSURE
(1st and 3rd trimesters)

QUESTIONNAIRE
SES, life style, clinical data, residence, mental health, COVID-19 (all trimesters)

BIOLOGICAL SAMPLES
Urine, blood, vaginal & rectal swaps, hair, nails (1st and/or 3rd trimesters)

NEURODEVELOPMENT
Memory & attention - computer test (3rd trimester)

FETUS EVALUATION
Anthropometry & placental function (all trimesters)
Echocardiography, neurosonography (3rd trimester)

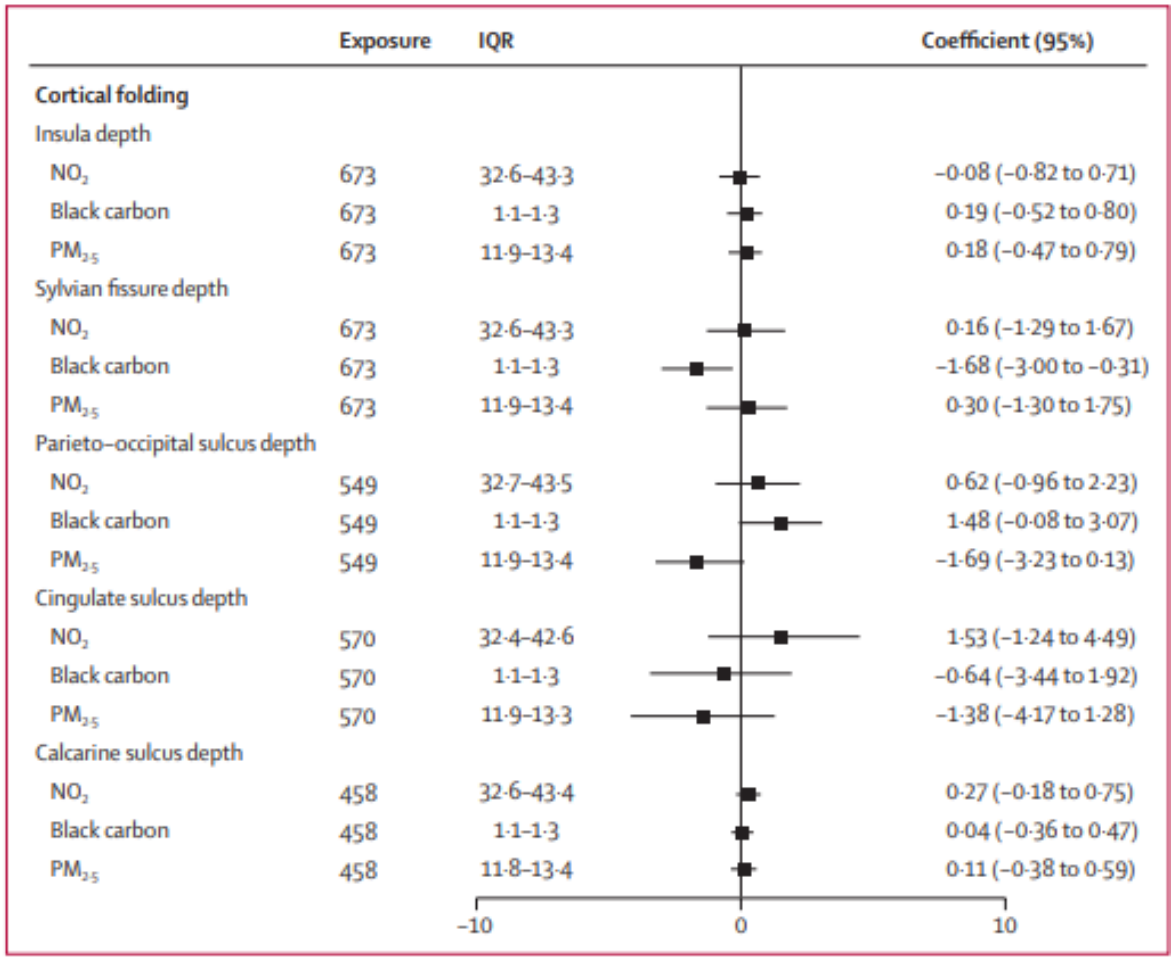
ENVIRONMENTAL EXPOSURES
(home & personal exposure; 1st and 3rd trimesters)
Noise, BC, NO2, PM2.5
Temperature & humidity
Physical activity, sleep, GPS
Home characterization

POSTNATAL

	BIRTH	27d	2m	6/8m	12m	18m
	ANTHROP. & APGAR					
	Cord blood Placenta Meconium Mater. blood			Urine Stool		Urine Stool
		MRI		Bayley*, IBQ-R, Eye-tracking, DP3 & CDI-I		Bayley, CBCL, MCHAT, Eye-tracking
	Lactation, diet, lifestyle, residence, child health & sleep, etc		Lactation, diet, lifestyle, child health & sleep, change of residence, COVID-19, among other information (including health card at 18m)			
				NO2 passive sampler		NO2 passive sampler
			EPDS COVID-19	COVID-19	EPDS COVID-19	EPDS COVID-19

*Bayley at the age of 6 months was stopped due to COVID-19 pandemic, N=100

Air pollution and cognitive development



	Exposure	IQR	Coefficient (95%)
Cortical folding			
Insula depth			
NO_2	673	32·6–43·3	−0·08 (−0·82 to 0·71)
Black carbon	673	1·1–1·3	0·19 (−0·52 to 0·80)
$PM_{2·5}$	673	11·9–13·4	0·18 (−0·47 to 0·79)
Sylvian fissure depth			
NO_2	673	32·6–43·3	0·16 (−1·29 to 1·67)
Black carbon	673	1·1–1·3	−1·68 (−3·00 to −0·31)
$PM_{2·5}$	673	11·9–13·4	0·30 (−1·30 to 1·75)
Parieto–occipital sulcus depth			
NO_2	549	32·7–43·5	0·62 (−0·96 to 2·23)
Black carbon	549	1·1–1·3	1·48 (−0·08 to 3·07)
$PM_{2·5}$	549	11·9–13·4	−1·69 (−3·23 to 0·13)
Cingulate sulcus depth			
NO_2	570	32·4–42·6	1·53 (−1·24 to 4·49)
Black carbon	570	1·1–1·3	−0·64 (−3·44 to 1·92)
$PM_{2·5}$	570	11·9–13·3	−1·38 (−4·17 to 1·28)
Calcarine sulcus depth			
NO_2	458	32·6–43·4	0·27 (−0·18 to 0·75)
Black carbon	458	1·1–1·3	0·04 (−0·36 to 0·47)
$PM_{2·5}$	458	11·8–13·4	0·11 (−0·38 to 0·59)
			−10 0 10

	Exposure	IQR	Coefficient (95%)
Cerebrospinal fluid spaces			
Anterior lateral ventricles width			
NO_2	471	32·6–43·4	2·34 (−0·24 to 4·75)
Black carbon	471	1·1–1·3	3·52 (0·81 to 6·24)
$PM_{2·5}$	471	11·8–13·3	3·80 (1·09 to 6·68)
Posterior lateral ventricles width			
NO_2	657	32·5–43·1	0·13 (−1·26 to 1·47)
Black carbon	657	1·1–1·3	−0·21 (−1·40 to 0·89)
$PM_{2·5}$	657	11·9–13·3	0·28 (−1·17 to 1·78)
Third ventricle width			
NO_2	681	32·6–43·2	0·56 (−2·36 to 3·46)
Black carbon	681	1·1–1·3	1·65 (−0·64 to 4·00)
$PM_{2·5}$	681	11·9–13·4	0·06 (−2·47 to 2·89)
Cisterna magna width			
NO_2	613	32·8–43·2	3·06 (1·62 to 4·75)
Black carbon	613	1·1–1·3	1·74 (0·22 to 3·54)
$PM_{2·5}$	613	11·9–13·4	0·83 (−1·67 to 2·90)
Others			
Corpus callosum length			
NO_2	672	32·6–42·9	−0·20 (−0·83 to 0·42)
Black carbon	672	1·1–1·3	−0·07 (−0·54 to 0·40)
$PM_{2·5}$	672	11·9–13·4	0·43 (−0·10 to 0·94)
			−10 0 10

Figure 2: **Adjusted percentage difference in brain morphological structures associated with one IQR increase in exposure to NO_2, $PM_{2·5}$, and black carbon in the multipollutant models**

Percentage difference are adjusted for fetal sex (female *vs* male), parity (multiparous *vs* nulliparous), maternal education (with university degree *vs* without university degree), ethnicity (White European *vs* other), active smoking during pregnancy (no *vs* yes), passive smoking during pregnancy (no *vs* yes), alcohol consumption during pregnancy (no *vs* yes), and gestational age at ultrasound (days), and the rater and hospital as random effects.

Gómez-Herrera et al. (2025). The Lancet Planetary Health 9 (6), e480-e490.

Take home message

- The **composition and size of particulate matter (PM)** are critical for health impacts: different components have varying levels of toxicity, and particle size determines how deeply they can penetrate the body.
- Exposure to air pollution **during in *utero* and early childhood** can shape long-term health outcomes, in line with the **DOHaD framework**.
- There are **windows of heightened vulnerability**, such as during **childhood**, when rapid developmental processes make the body more susceptible to environmental insults.
- Robust evidence links **air pollution to adverse effects on multiple systems**, including respiratory health, birth outcomes (e.g., low birth weight), neurodevelopment, and beyond.

THANKS!

IR0000032 – ITINERIS, Italian Integrated Environmental Research Infrastructures System
(D.D. n. 130/2022 - CUP B53C22002150006) Funded by EU - Next Generation EU PNRR-Mission 4 “Education and Research” - Component 2: “From research to business” - Investment 3.1: “Fund for the realisation of an integrated system of research and innovation infrastructures”

Finanziato dall'Unione europea NextGenerationEU
Ministero dell'Università e della Ricerca
Italiadomani