

Air Quality & Brain Health

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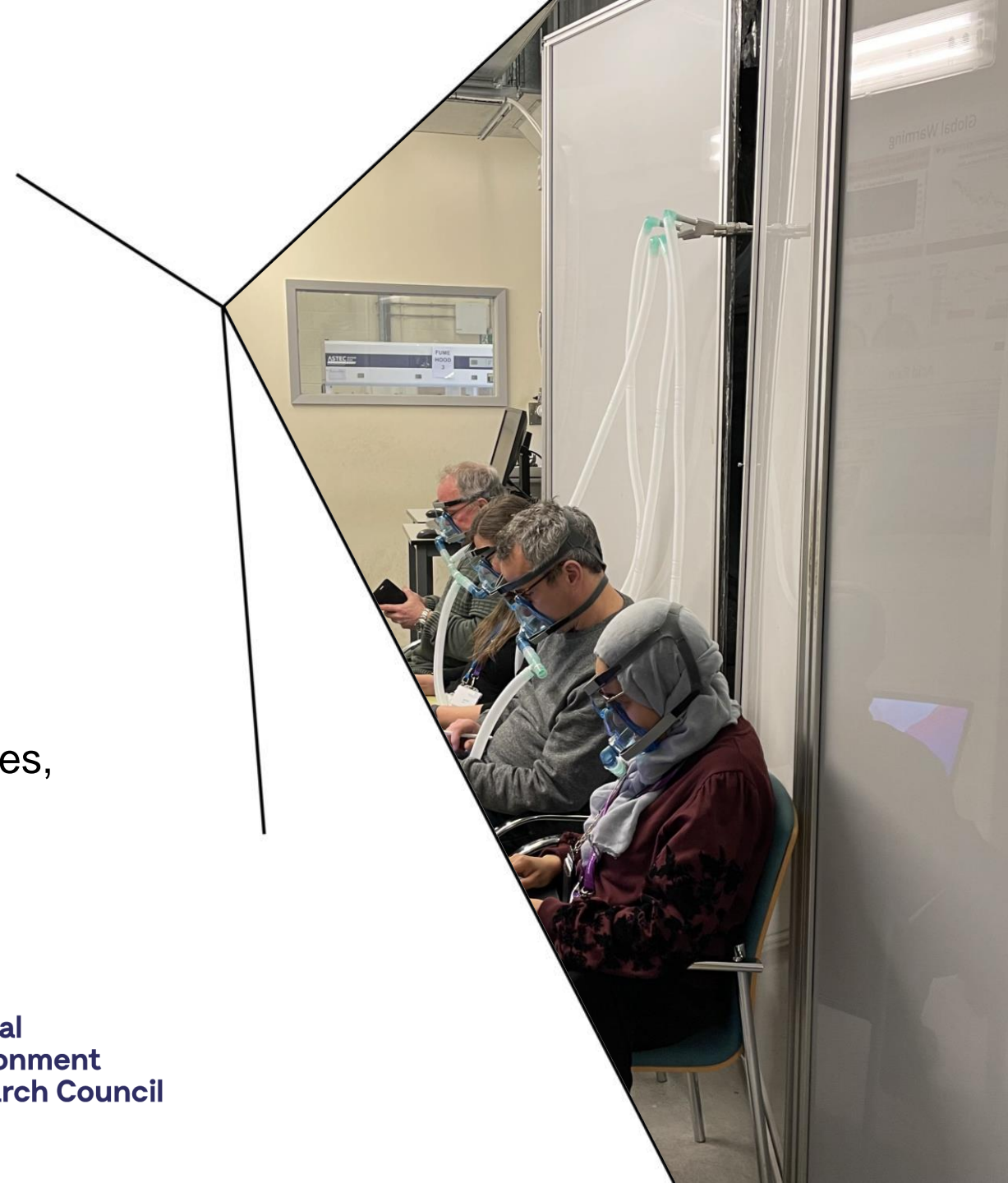
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Growing interest in air quality and cognition

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Opinion
Air pollution

Air pollution rots our brains. Is that why we don't do anything about it?

James Bridle

Mon 24 Sep 2018 06.00 BST

1,741 | 405

Human cognitive ability is being damaged not just by CO2 and lead, but the way social media feeds us information, making us shockingly ill-equipped to clean up the air we breathe



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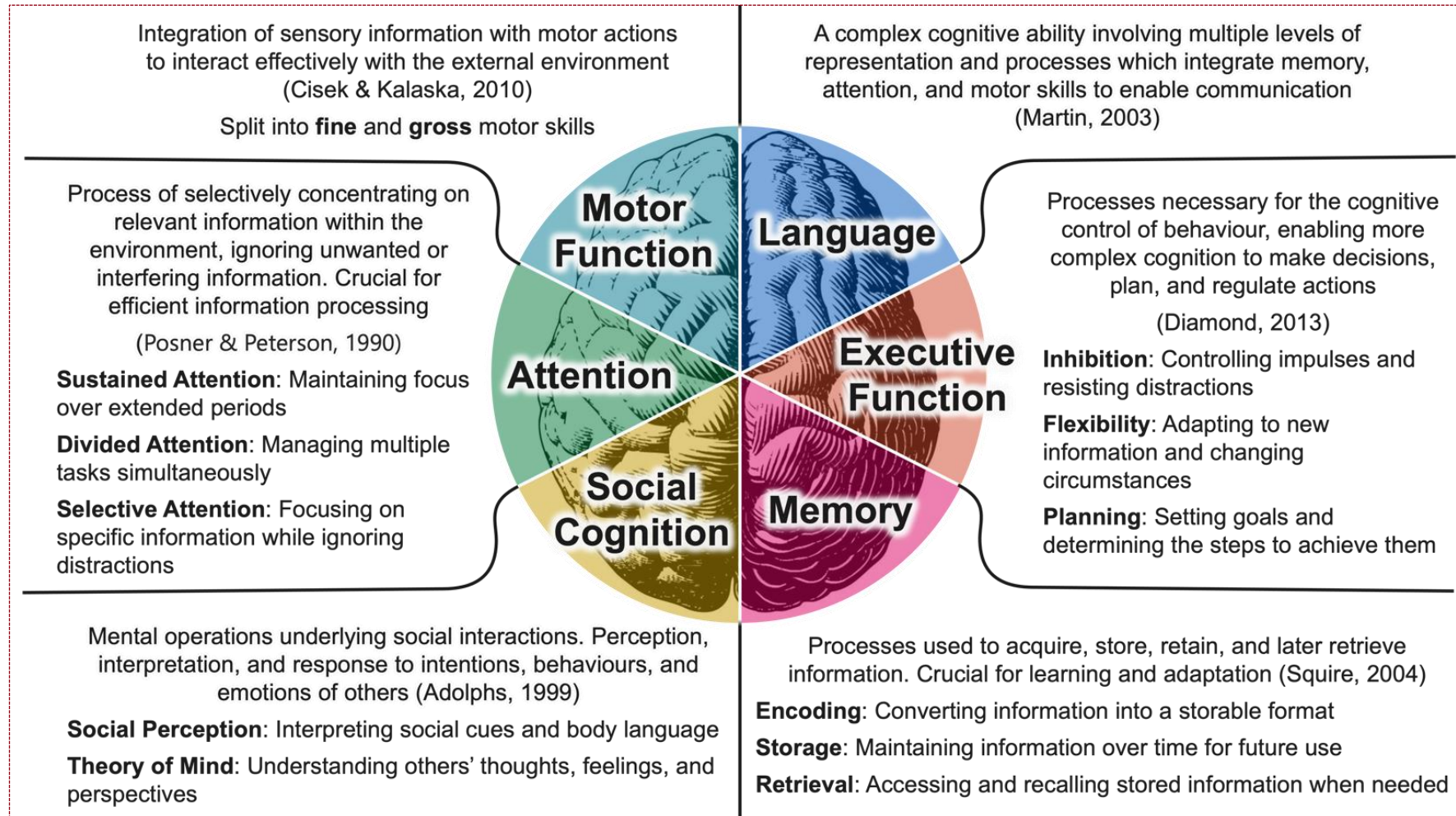
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Air Quality, Climate Change and 21st Century Crime?

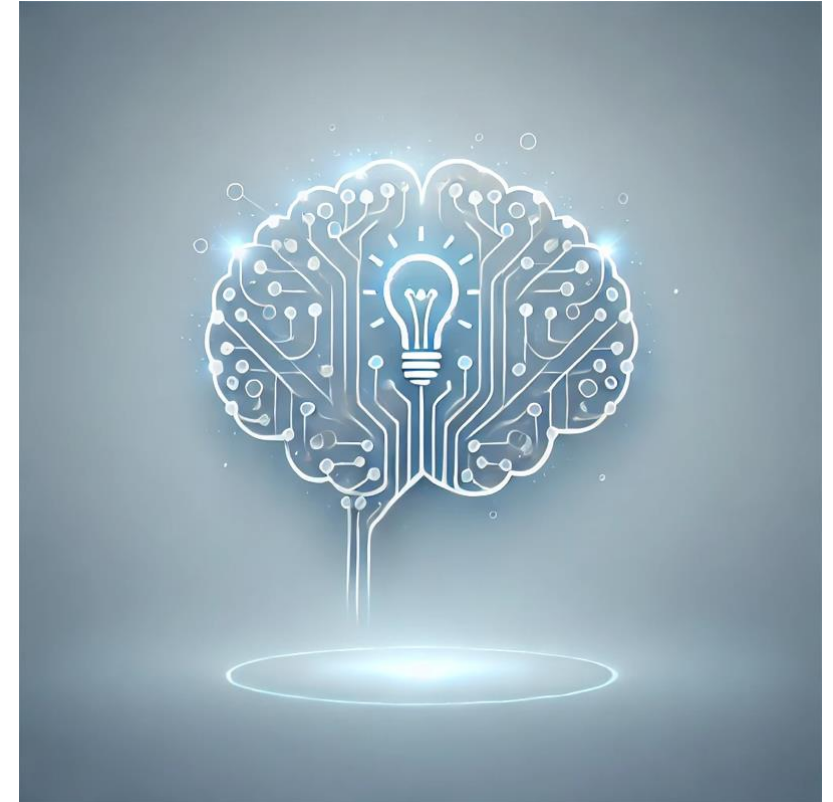
| Reference | Observation |
|--|--|
| Levy and Yagil (2011) J. Econ. Psych. 32(3), 374-283 | Air pollution is negatively related to stock returns |
| Heyes et al. (2016) NBER working paper 22753 | Decreased risk tolerance operating through pollution induced changes in mood or cognitive function |
| Herrnstadt et al. (2016) job market working paper | Air pollution increases violent crime in both Chicago (by 2.2%) and Los Angeles metro area (by 6.1%) |
| Chew et al. (2018), Does Haze Cloud Decision Making? A Natural Laboratory Experiment. Working paper. | Haze not only undermines health, but also clouds decision making. |

Cognitive Domains



Intelligence Quotient (IQ)

- Intelligence Quotient (IQ) typically represents an aggregated measure of performance on a battery of tests measuring different cognitive functions.
- Examples include:
 - the Wechsler Adult Intelligence Scale (WAIS)
 - Stanford-Binet Intelligence Scale
 - Universal Nonverbal Intelligence Test (UNIT)
- For the purposes of this presentation, we consider IQ and cognitive facets to be interchangeable, as evidence relating to one can be reasonably interpreted as evidence for the other.
- N.b. IQ tests are often unreliable and biased



WHO Report 2021

Executive Summary xiv:

“... the global prevalence of noncommunicable diseases (NCDs) as a result of population ageing and lifestyle changes has grown rapidly, and NCDs are now the leading causes of death and disability worldwide. NCDs comprise a broad range of diseases affecting the cardiovascular, **neurological**, respiratory and other organ systems.”

Page 11:

“Air pollution exposure may increase the incidence of and mortality from a larger number of diseases than those currently considered, such as **Alzheimer’s** and **other neurological diseases** (Peters et al., 2019).”

Page 13:

“... air pollution has now been implicated in the development or worsening of several health conditions not considered in previous research. These include, among others, asthma, diabetes, reproductive outcomes and **several neurocognitive end-points** (Yang B-Y et al., 2020; Paul et al., 2019; Thurston et al., 2017).”

Page 197:

Future research directions -- “Undertake research into a broader range of health end-points, as the list of organ systems and conditions possibly affected by air pollution is steadily increasing. Study the **neurological effects**, including the **effects on brain morphology** in young children and older people, on child development, and **on cognitive decline** and reduced ability to perform activities of daily life in older people.”



Critically, the need for more research is mentioned

Chronic Air Pollution Exposure



Adversely affects foetal brain development ([Guxens et al., 2019](#))
Impacts later cognitive performance and behaviour ([Tokuda et al., 2023](#))



Altered neurodevelopment ([Calderón-Garcidueñas et al., 2008](#))
Structural brain changes; slower brain maturation ([Pujol et al., 2016](#))



Neuroinflammation & CNS disease ([Block et al., 2009](#))
Mental Health – Risk of mood disorder ([Liu et al., 2021](#))



Accelerated cognitive ageing “a $2 \mu\text{gm}^{-3}$ increase in $\text{PM}_{2.5}$ was similar to ≈ 1 year of brain aging” ([Wilker et al., 2015](#))
Neurodegenerative disease onset & exacerbation ([Delgado-Saborit et al., 2021](#))



Acute Air Pollution Exposure

Temporary neuronal attenuation leading to the decline of multiple cognitive functions

Likely inflammatory mechanism

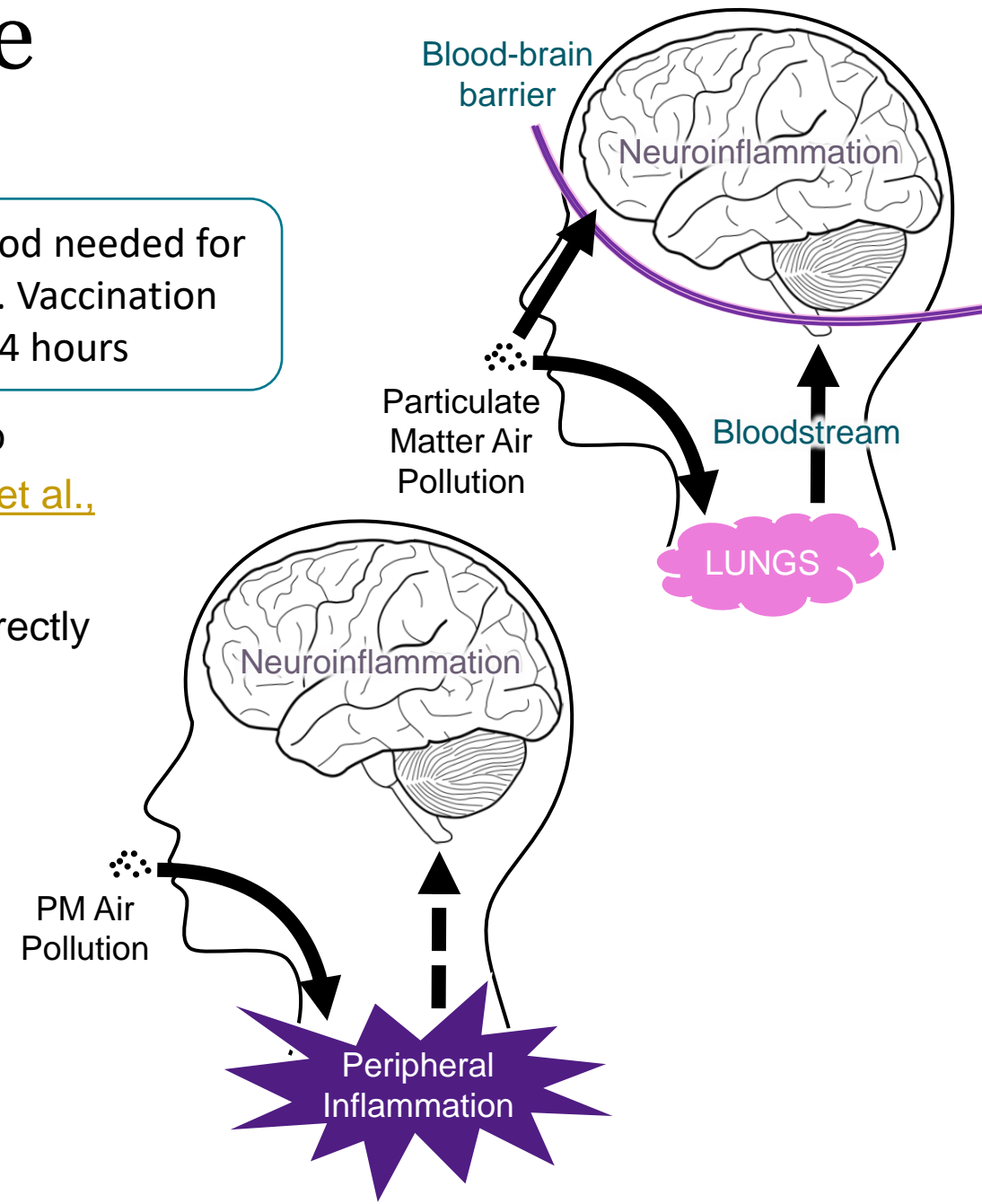
Evidence of a delay period needed for inflammation to occur. Vaccination studies suggest ~4 hours

- **Direct**

- Axonal transport from olfactory epithelium (roof of nose) to olfactory bulb in the brain ([Elder et al., 2006](#); [Oberdörster et al., 2004](#)). Particles interact with neurons in the brain.
- Or, for particles small enough to enter the blood stream directly through via the respiratory system.

- **Indirect**

- Impact of air pollution-induced systemic inflammation and transmission to the brain ([Seaton et al., 2020](#); [Shou et al., 2020](#)). Body-Brain Axis.



Acute Air Pollution Exposure reduces executive cognitive functioning after 4-hours

Dr Thomas Faherty
Professor Jane Raymond
Professor Gordon McFiggans (University of Manchester)
Professor Francis Pope



Article | [Open access](#) | Published: 06 February 2025

Acute particulate matter exposure diminishes executive cognitive functioning after four hours regardless of inhalation pathway

[Thomas Faherty](#), [Jane E. Raymond](#), [Gordon McFiggans](#) & [Francis D. Pope](#) 

[Nature Communications](#) **16**, Article number: 1339 (2025) | [Cite this article](#)

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<https://www.nature.com/articles/s41467-025-56508-3>



Air pollution from candles impairs brain function, study suggests

Researchers say particles from birthday cake candles and everyday cooking can reduce cognitive ability without good ventilation



Alarm as scientists demonstrate terrifying damage burning candles at home causes the body - negative effect on volunteers was dramatic

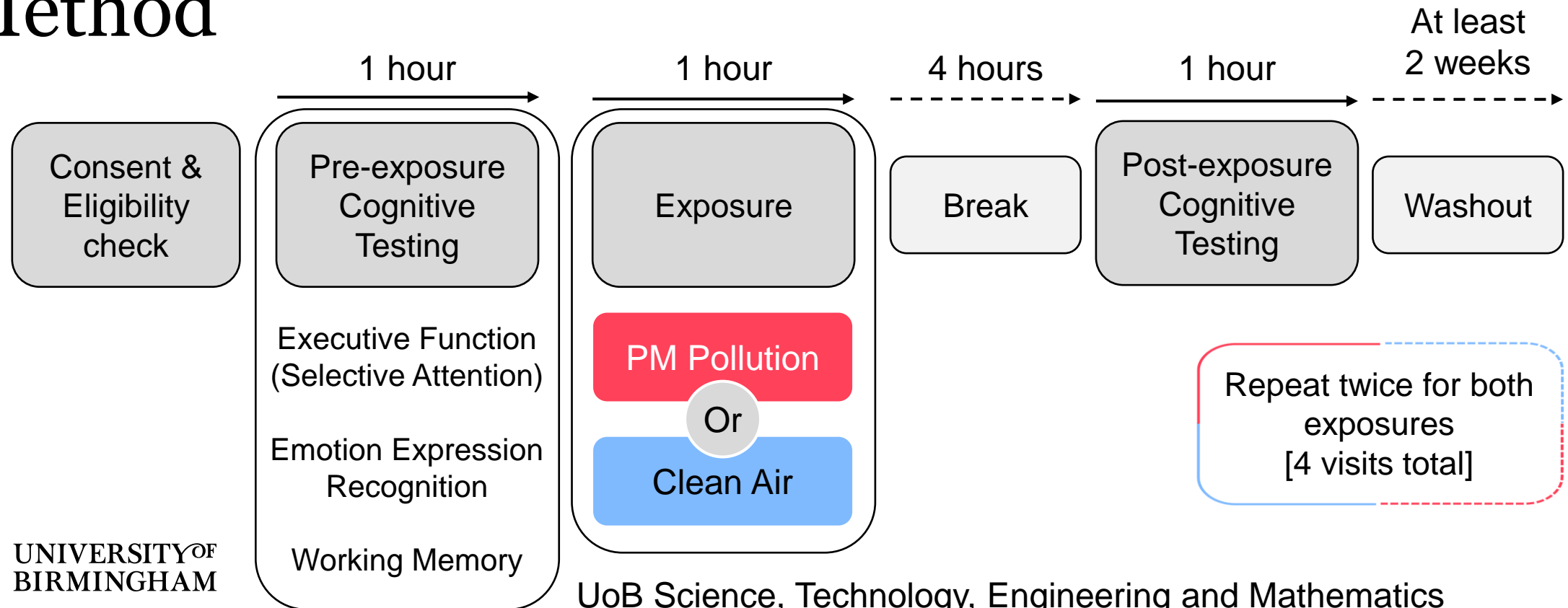
Objective

Identify if exposure to high PM concentrations negatively impacts cognitive functioning after 4-hours, comparative to clean air

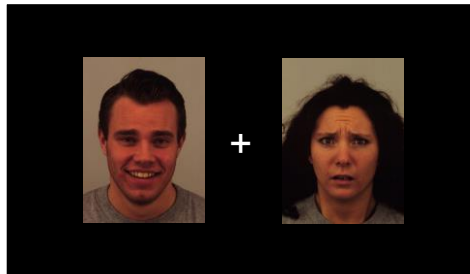
- *If yes:* Which cognitive functions are affected, or more affected, than others?



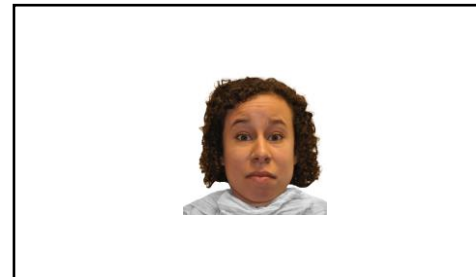
Method



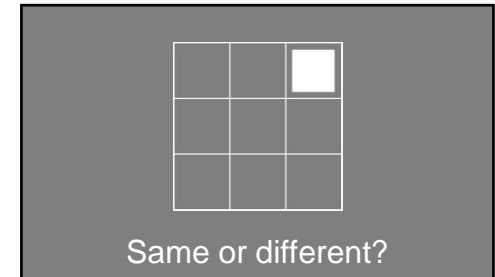
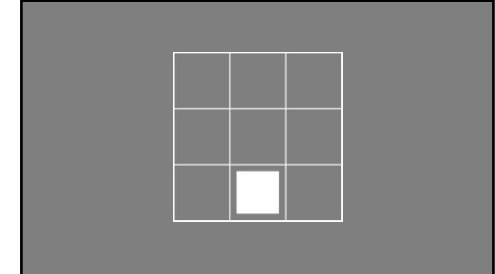
Cognitive Tasks



Executive Function
– Selective Attention



Socio-emotional Cognition
– Emotion Recognition



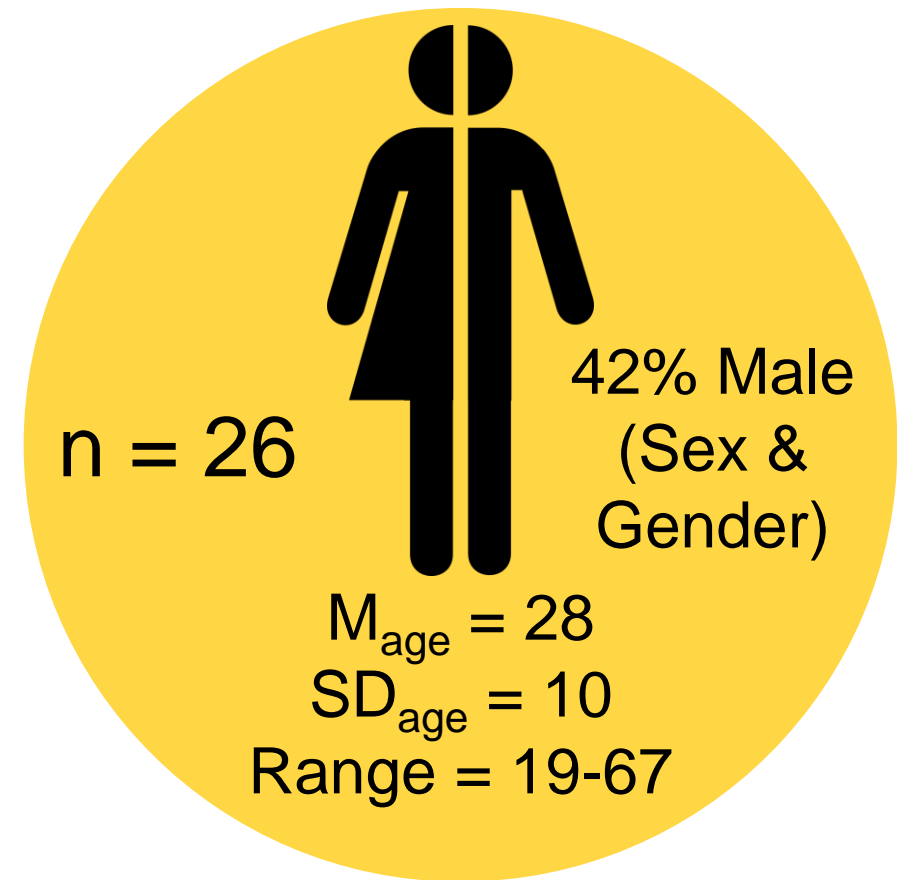
Working Memory



Participants

- Clinically healthy adults
 - No inflammatory disease
 - No respiratory disease
 - No neurological / psychiatric conditions
- Dataset from **26 participants**
- Condition blinding successful

| | | Actual Exposure | |
|-------------------|--------------|------------------|------------------|
| | | Clean Air | PM Pollution |
| Reported Exposure | Clean Air | 34 (2.29) | 27 (2.10) |
| | PM Pollution | 18 (2.13) | 25 (2.11) |

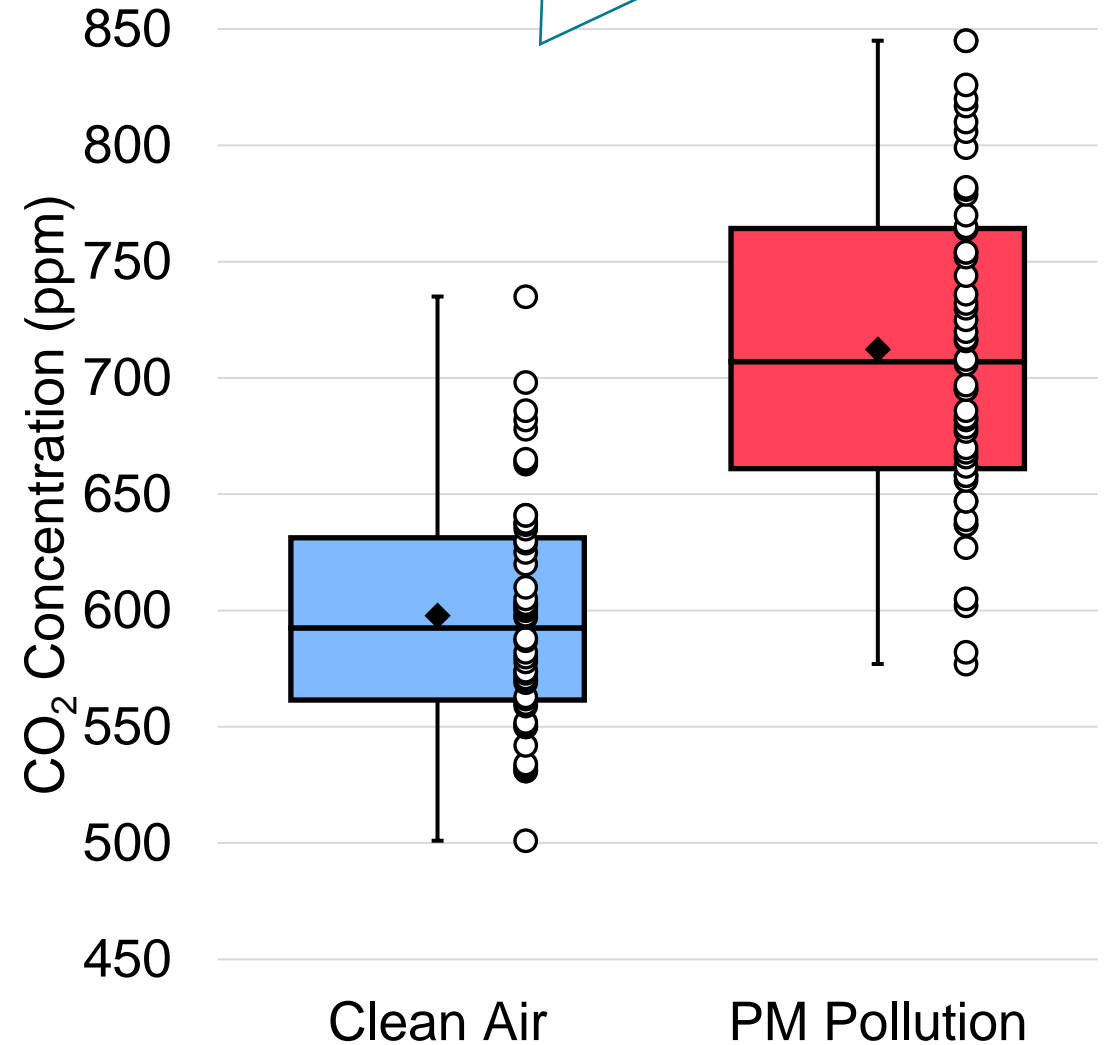
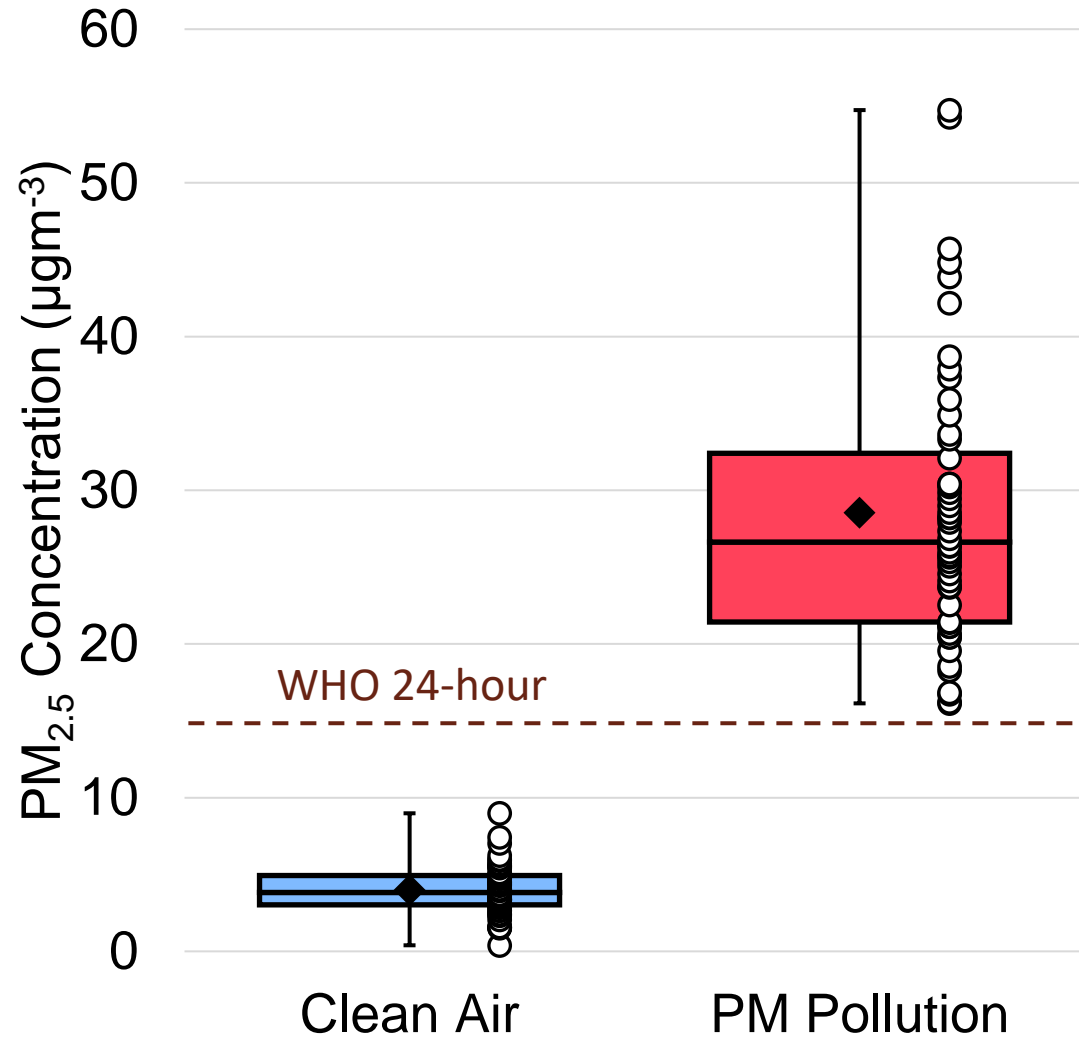


Air Quality

PM : TSI Optical Particle Sizer 3330

CO₂ : LI-COR LI-820 Gas analyzer

CO₂ concentrations in this range should not impact cognition (Especially with the 4-hour delay)



Selective Attention

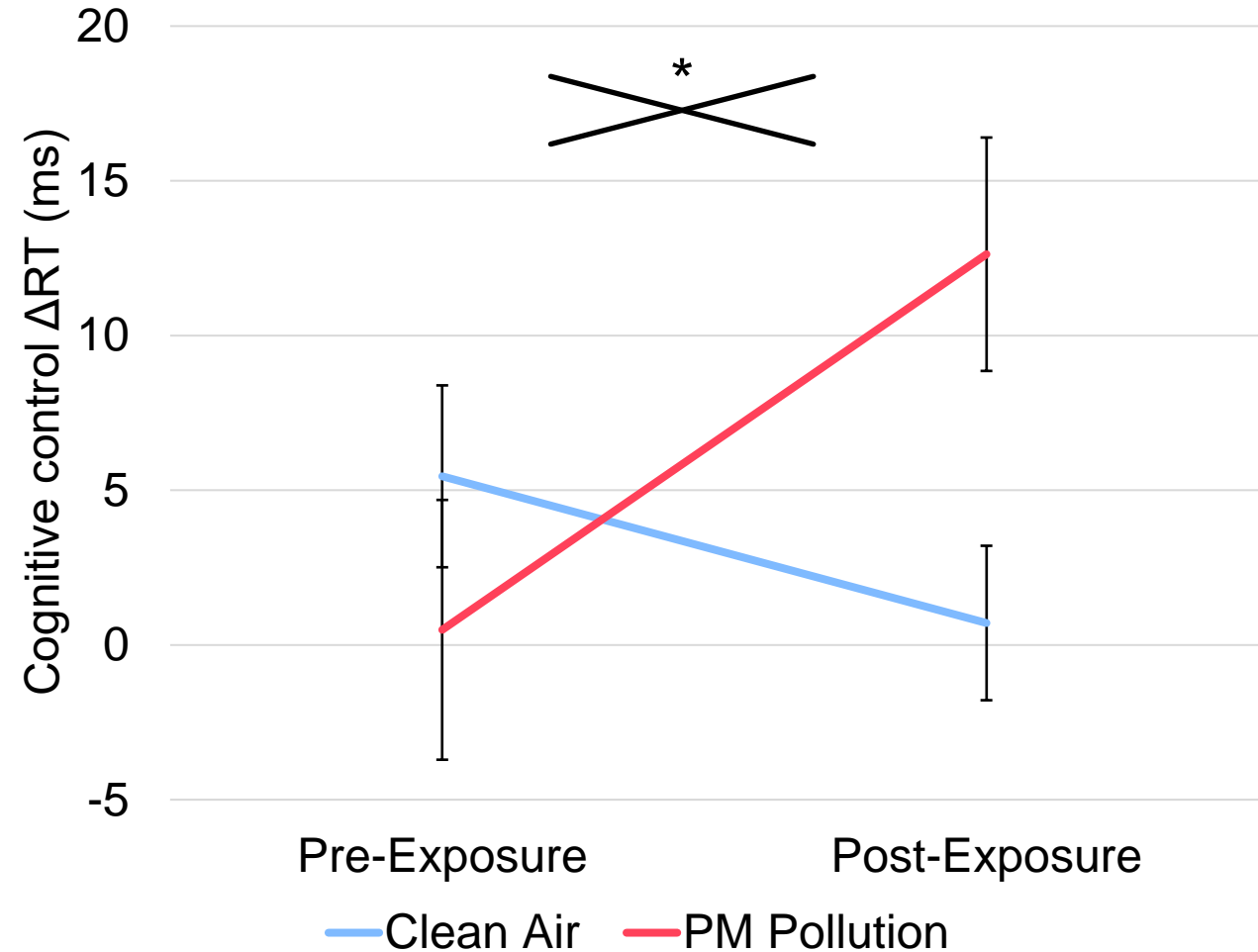
The brain's ability to focus on specific stimuli while ignoring others, and a decline in it can lead to difficulty filtering out distractions, reducing focus and performance in tasks.

4-hours following clean air exposure, cognitive control ability significantly improved (ΔRT decreases) compared to after air pollution exposure, where cognitive control declines (ΔRT increases)

High PM exposure led to a comparative decline in selective attention ability.

Consistent with previous [currently unpublished] research at Manchester Aerosol Chamber Facility

* Interaction: $F(1, 25) = 6.556, p = 0.018$



Expression Recognition

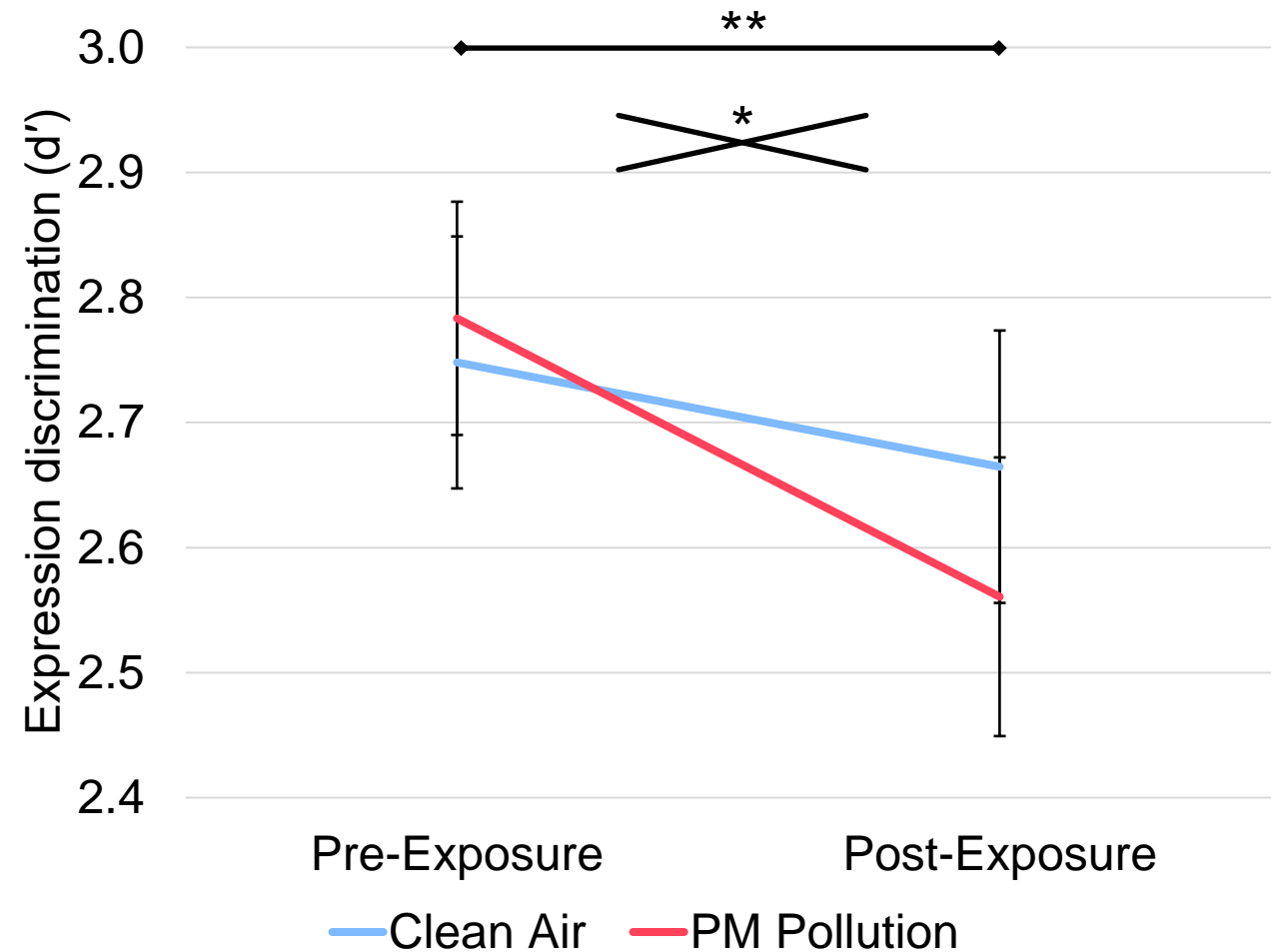
The ability to identify and interpret others' emotions based on facial expressions. Plays a key role in social interactions, and impairments in this ability can affect empathy, communication, and relationships.

4-hours following clean air exposure, ability to distinguish between emotions was lower (d' decreases) than before. However, this difference was more pronounced following air pollution exposure (larger d' decrease)

Difficulty with processing emotional stimuli following pollution exposure

This is consistent with literature suggesting mild inflammation following vaccination decreases emotion recognition after a delay period ([Balter et al., 2018](#))

** Time ME: $F(1, 25) = 8.167, p = 0.008$
* Interaction: $F(1, 25) = 5.552, p = 0.027$



Working Memory

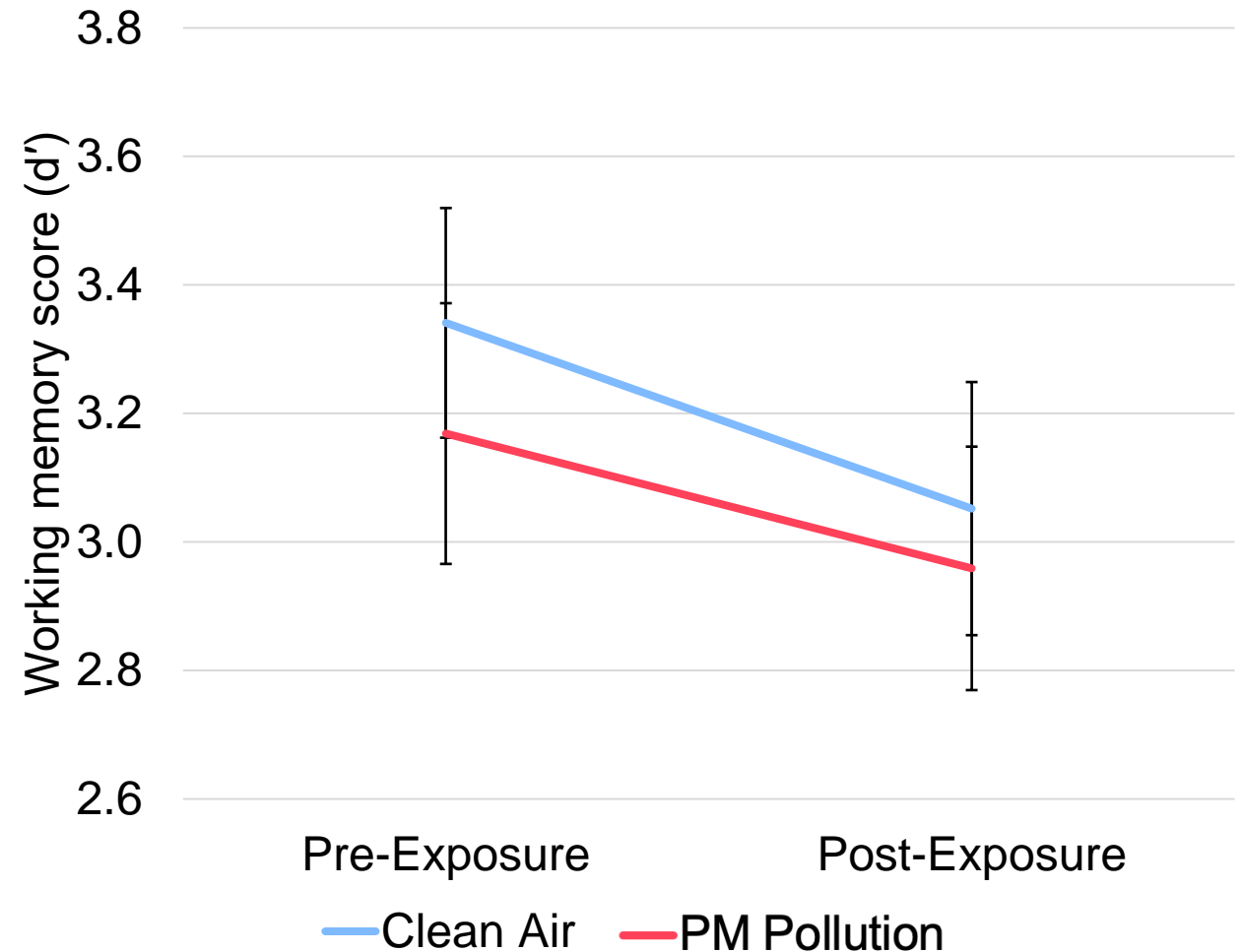
Ability to temporarily hold and manipulate information for tasks like problem-solving, learning, and reasoning. A decline in working memory can lead to difficulties in multitasking, retaining short-term information, and completing complex tasks.

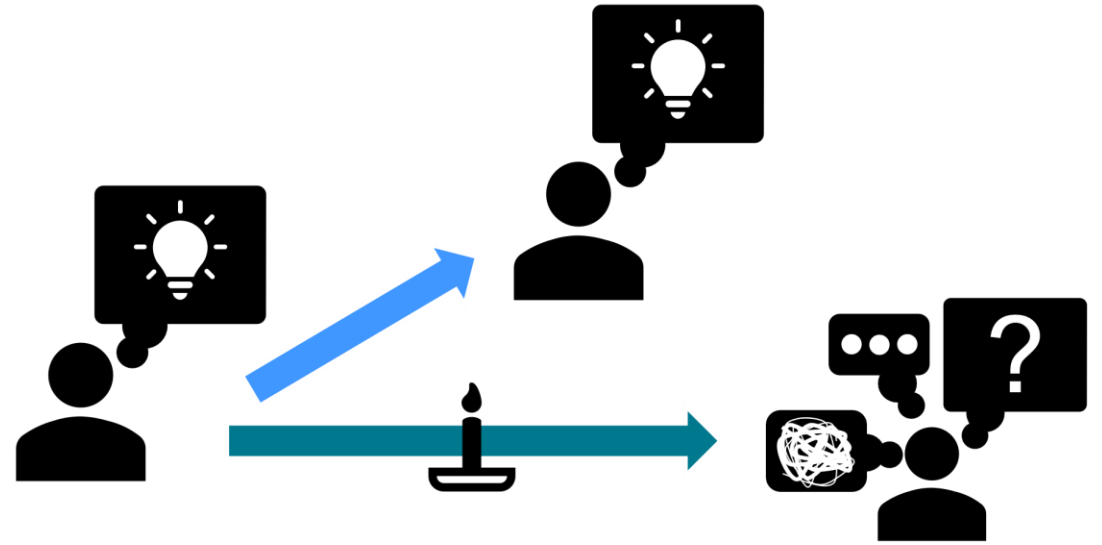
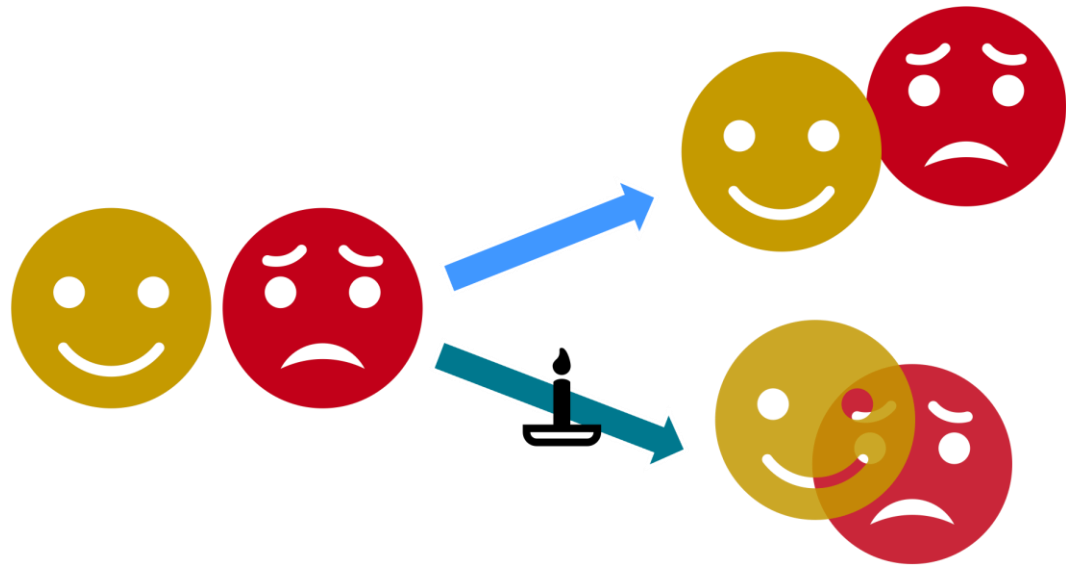
4-hours following both clean air and PM pollution exposure, working memory performance (d') decreases. However, this was not statistically significant.

No changes identified

Somewhat surprisingly, this is mostly consistent with literature. Working memory is robust to acute air pollution exposure – ([Saenen et al., 2016](#); [Bos et al., 2013](#)).

Time ME: $F(1, 25) = 2.996, p = 0.096$





- Unanswered questions
 - Particulate Matter composition not reflective of multiple common pollutants (indoor & outdoor)
 - No *guarantee* of mechanism without more invasive measures i.e., blood markers
 - No closer to answering queries of whether WHO limits are reasonable

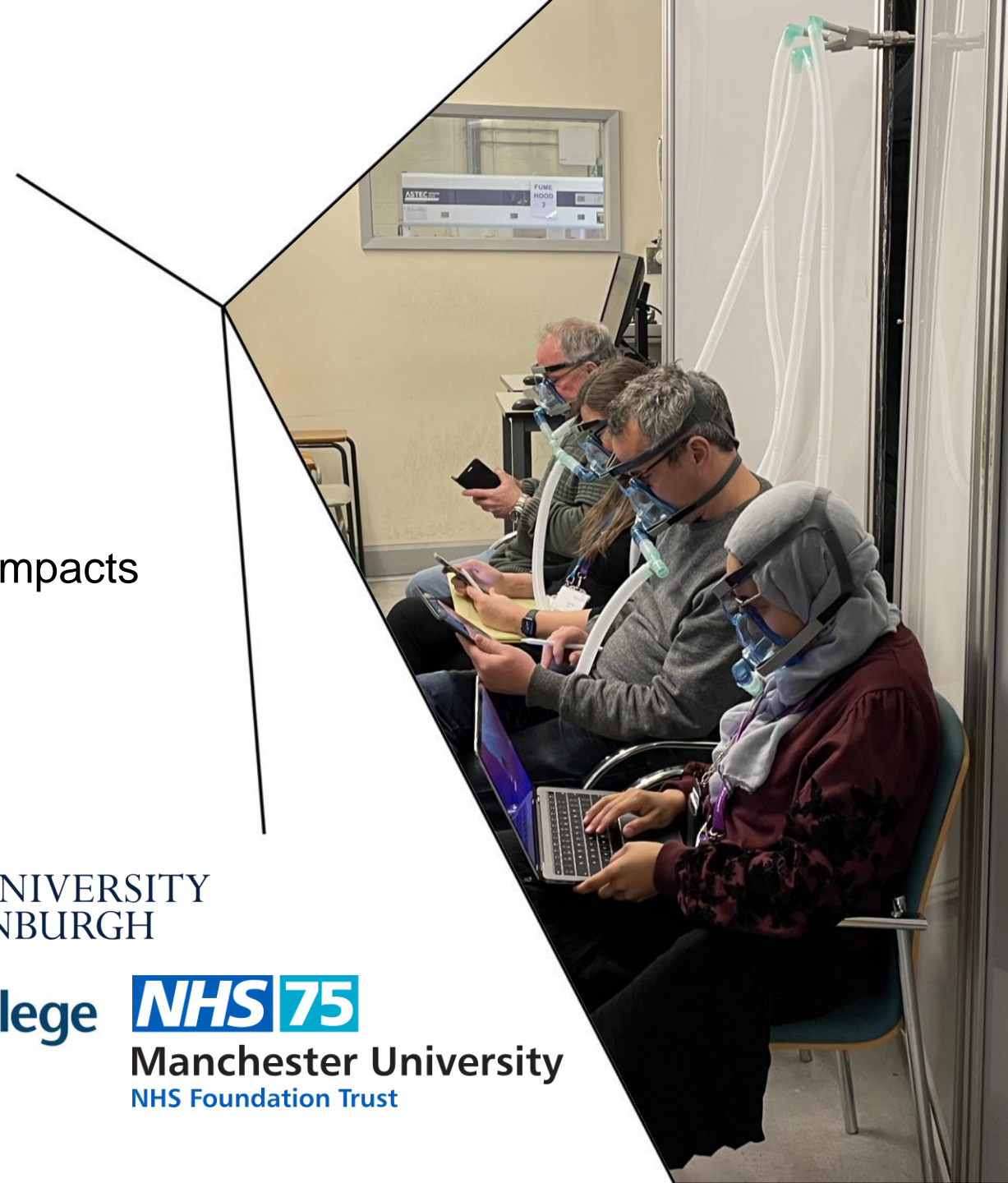




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HIPTox

Hazard Identification Platform to Assess the Health Impacts from Indoor and Outdoor Air Pollutant Exposures, through Mechanistic Toxicology: *Human exposures*



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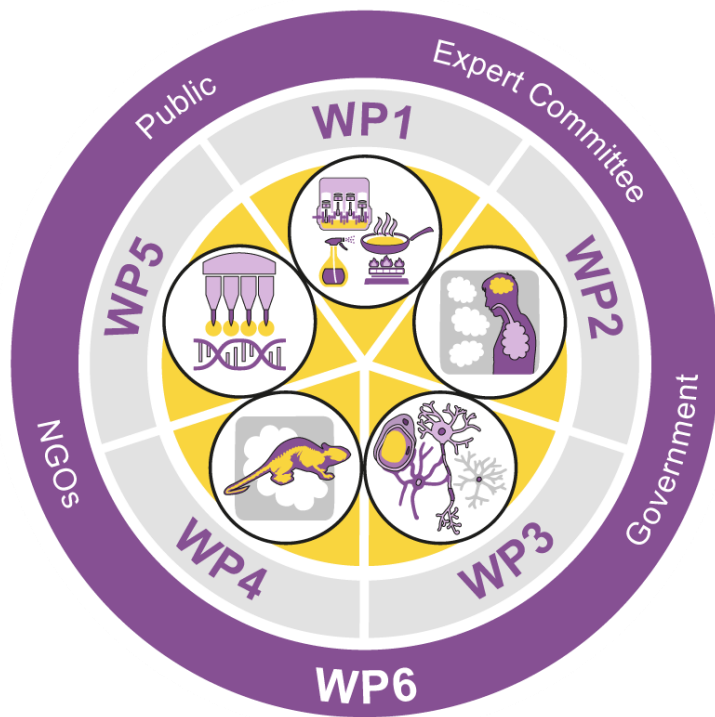


The University of Manchester

Imperial College
London



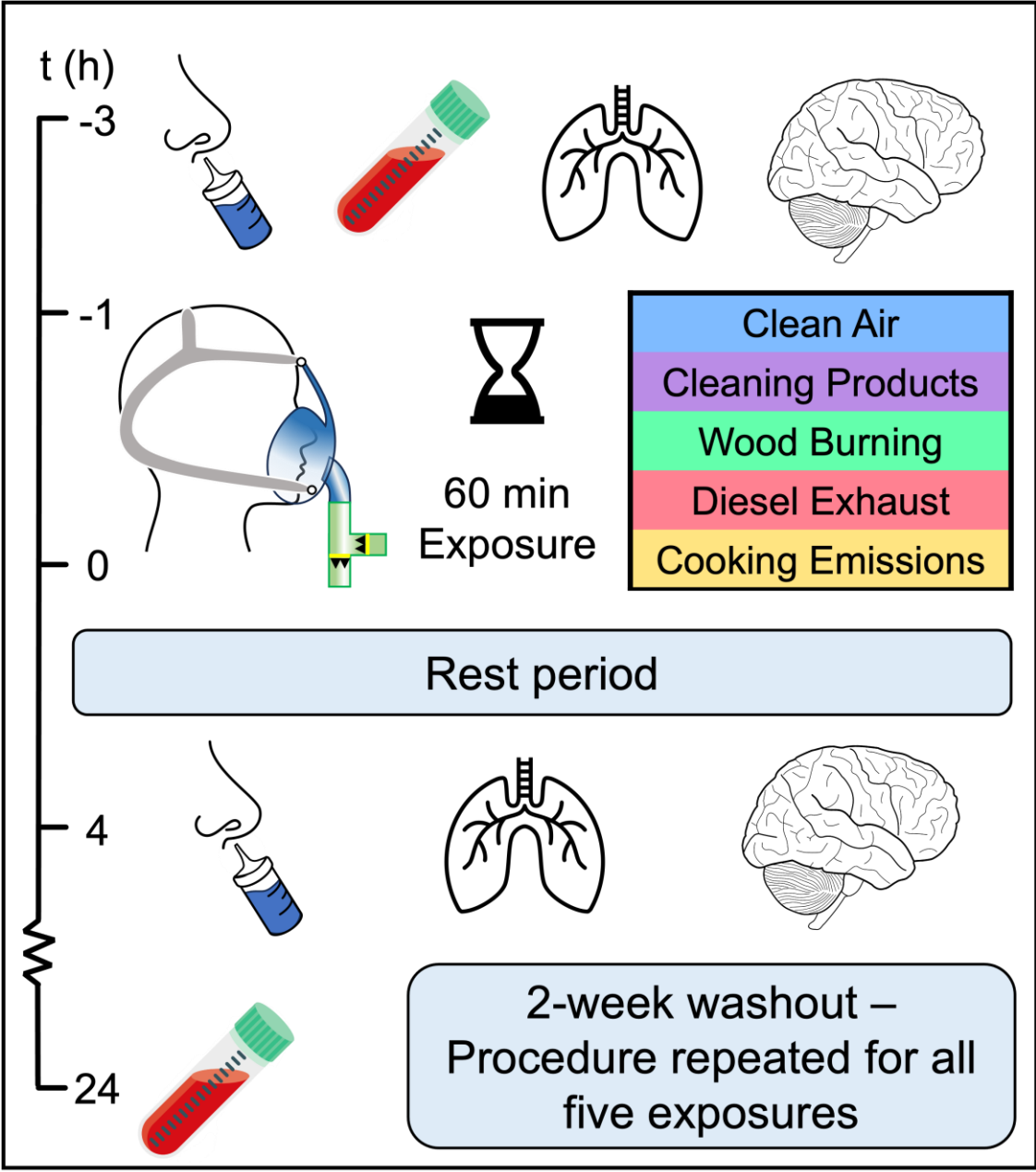
Manchester University
NHS Foundation Trust



WP2

Human exposures
Data collected

- WP1 – Repeatable generation of common representative outdoor and indoor pollutants & chemical and physical characterization of their emissions
- WP3 – Develop and test a realistic *in vitro* blood-brain barrier (BBB) model and conduct exposures to pollutants
- WP4 – Conduct controlled *in vivo* inhalation exposures of transgenic murine models to surrogate and realistic pollutants
- WP5 – Conduct extensive targeted and untargeted analyses of biomarkers of systemic oxidative stress, neuroinflammation and neuronal injury in blood samples collected in WP2



Cognitive Inequality?

EFFECTS OF AIR POLLUTION



Up to
900 DEATHS



per year linked to man-made air pollution

LINKED TO

Heart disease
Diabetes
Asthma
Obesity
Cancer
Dementia



LINKED TO

Still births
Infant deaths
Low birth weight
Organ damage
Premature deaths



CHILDREN IN
HIGH
POLLUTION
AREAS

x4



more likely to have reduced lung function when they become adults



61% OF JOURNEYS TO WORK ARE BY CAR OR VAN

Exposed to **21%** higher levels of pollution



Affects the
VULNERABLE & DEPRIVED areas most



BUS & TAXI DRIVERS

are exposed to

3x



more pollution than anyone else

#BrumBreathes

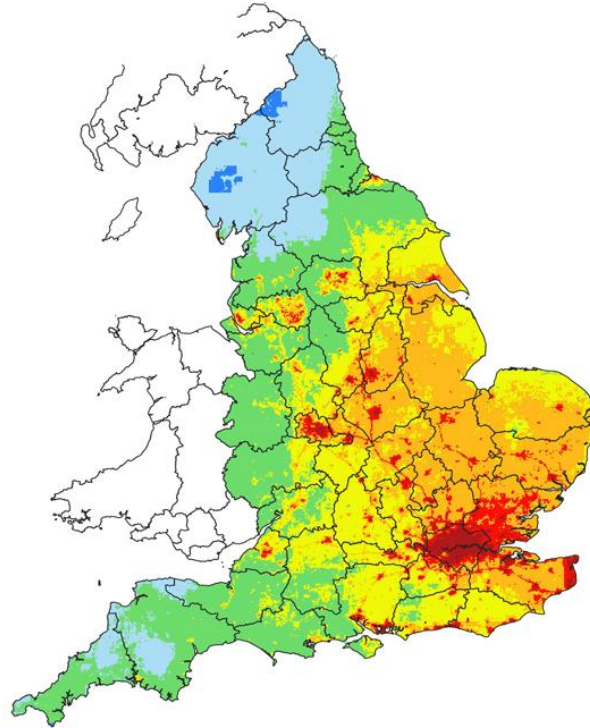
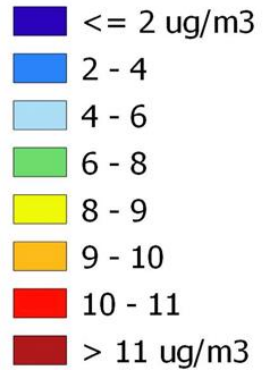
Numbers have been rounded. Evidence provided by Public Health Birmingham, May 2017: birminghampublichealth.co.uk

Physical inequalities pretty well established, for example this infographic from BrumBreathes

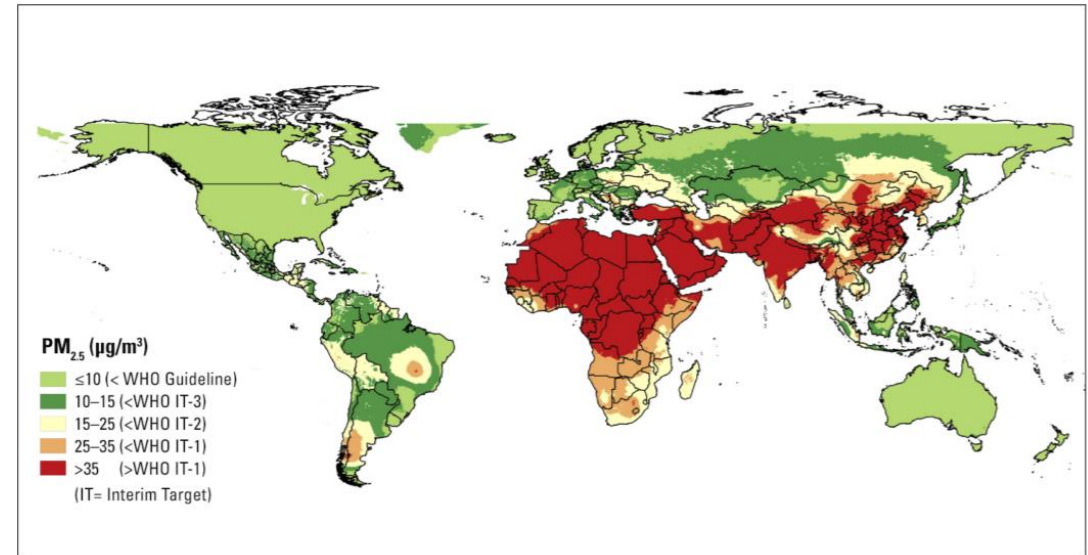
Regional and Global Inequalities?

PM2.5 Conc.

Total_PMf_B2018



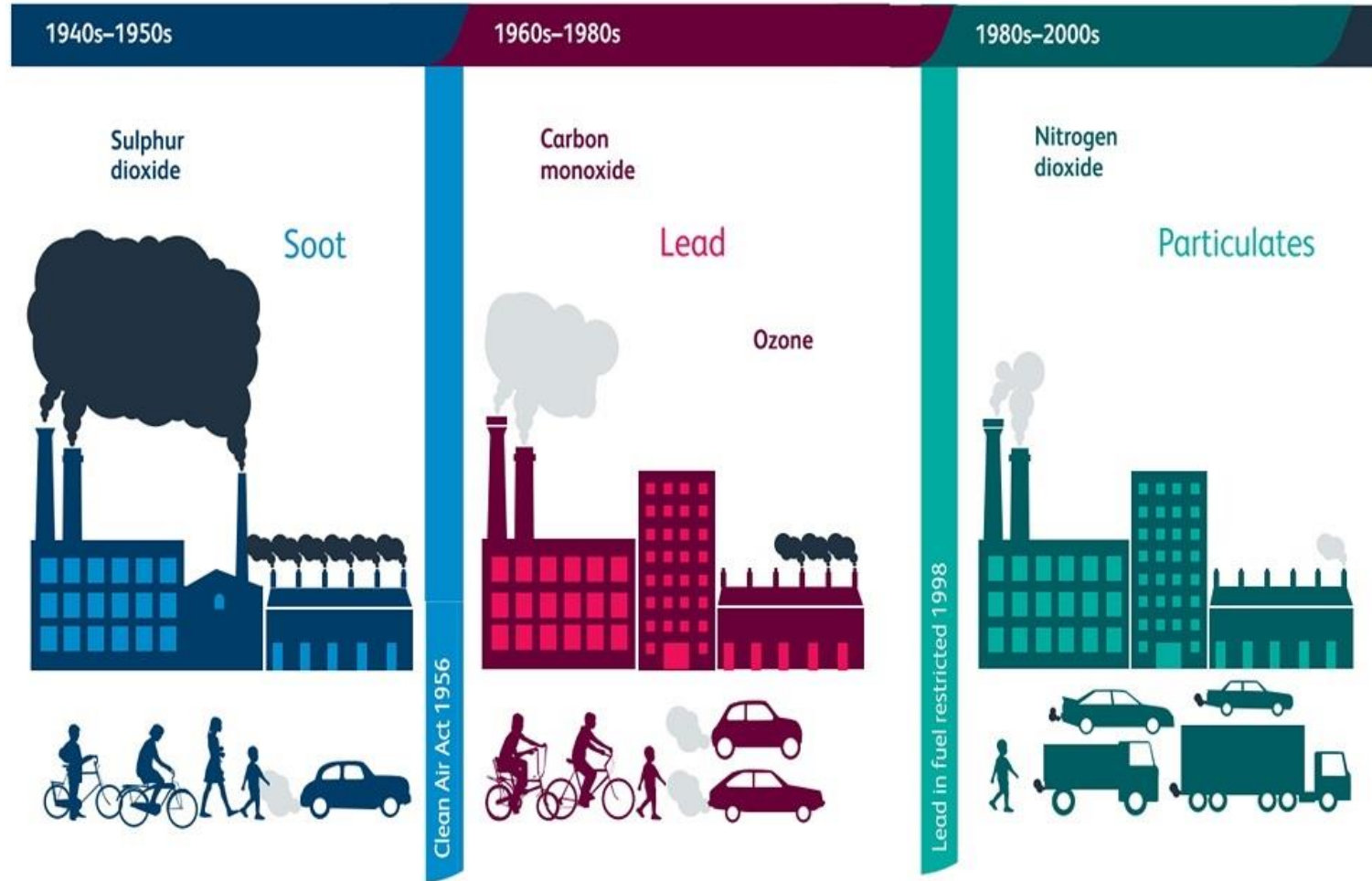
Modelled PM2.5 concentrations across England in 2018



Annual average PM2.5 concentrations in 2017 relative to the WHO Air Quality Guideline. State of Global Air 2019

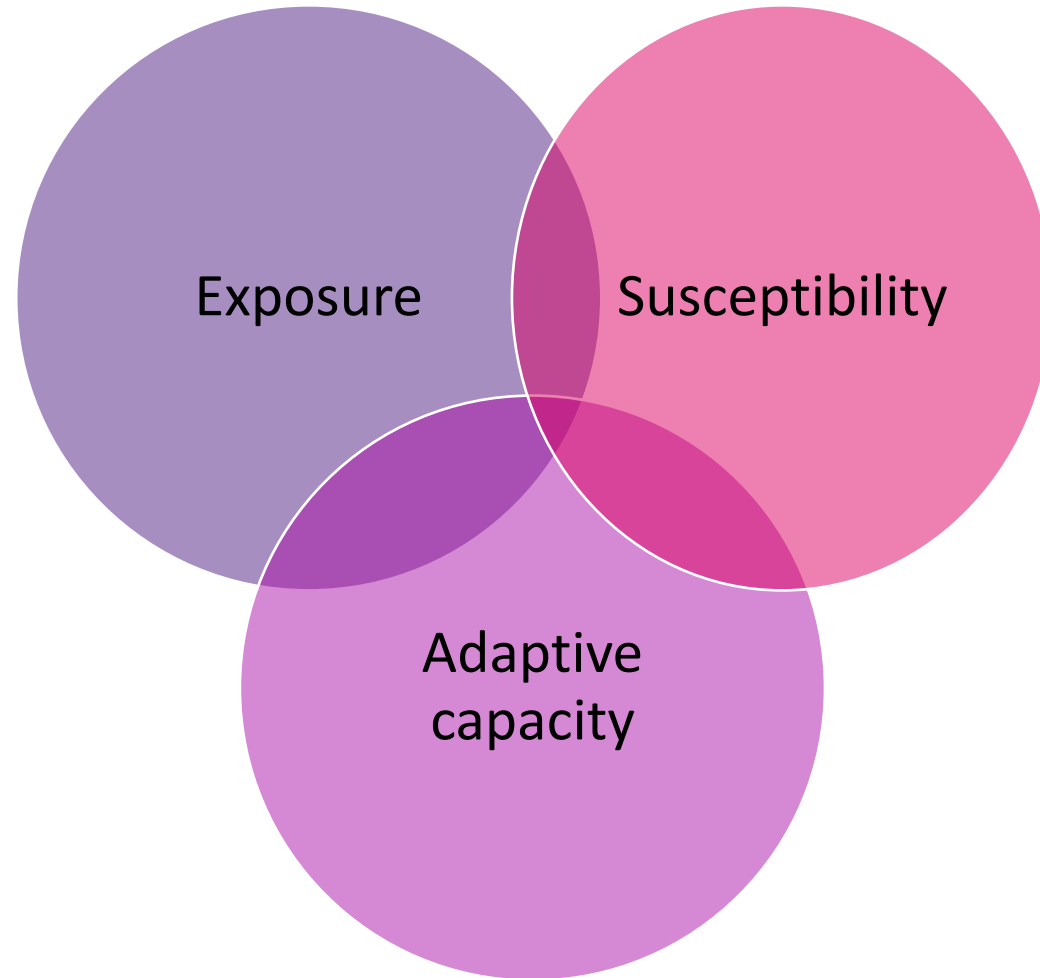


Changes in the sources and strengths of air pollution



Who is vulnerable?

Three dimensions of vulnerability:



Clean the air and boost the world's IQ?

- Mitigating air pollution should not just be about protecting physical health but preserving and enhancing human cognitive capabilities.
 - Improved air quality will likely improve educational outcomes
 - Improved air quality will likely improve workplace productivity
- In an increasingly sophisticated world where small advantages make a big difference, improving air quality could have significant effects on competitive advantage.



Cost of Air Pollution

Research by the Clean Air Fund reveals clean air could deliver a £1.6 billion annual boost to the UK economy.

It could deliver 3 million additional working days lost to staff absences and prevent almost 17,000 premature deaths among workers each year.

The findings provide a new incentive for national and local governments to put clean air at the heart of their green recovery plans.

This cost estimate does not include an estimate cost of air pollution mediated cognitive dysfunction.



Areas for future research

- Studies should focus on:
 - Exposure-response relationships for different pollutants
 - Standardizing methodologies on both:
 - Experimental air quality manipulation
 - Cognitive testing approaches
 - Expand research beyond healthy adult populations.
- Raising Awareness
 - Educating communities, schools, and healthcare providers about the impact of air pollution on brain health can drive societal change and support efforts to mitigate its effects.



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Thank you for your attention

With thanks to

All participant volunteers

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All researchers and staff involved with the HIPTox project



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