Acute particulate matter exposure diminishes executive cognitive functioning after 4 hours, regardless of inhalation pathway

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HIP
Hazard Identification
Platform

Background

- Well known that air pollution exposure is related to cardiovascular & respiratory illness (Landrigan et al., 2018)

    - Especially $PM_{2.5}$, which was estimated to be responsible for 14 million deaths in 2015 (Cohen et al., 2015).

- Chronic air pollution (AP) exposure is related to altered neuro*development* and neuro*degeneration*

    - Significant differences in volume of multiple brain areas between children raised in areas of high vs low ambient air pollution (Guxens et al., 2022).

    - Cognitive decline and dementia incidence consistently associated with exposure to air pollution (Delgado-Saborit et al., 2021).

- Evidence that cognitive function is temporarily reduced following **acute** high exposure episodes

    - **Global cognitive functioning** significantly lower after exposure to PM via candle burning (Shehab & Pope, 2019).

    - **Selective attention,** the ability to focus on task goals and avoid distraction, was significantly worse in those exposed to diesel exhaust compared to clean air 4-hours later (Faherty et al., 2021).

    - Children in schools with higher ambient $PM_{2.5}$ show less improvement on **attention** tasks compared to school with lower PM concentrations (Saenen et al., 2016).

    - 24-hours after high PM exposure, participants are more sensitive to negative-affective (fearful) than positive-affective (happy) stimuli i.e., changes in **socio-emotional processing** (Faherty (PhD thesis), 2022).

- Independence & interdependence of cognitive facets is necessary for completion of everyday tasks

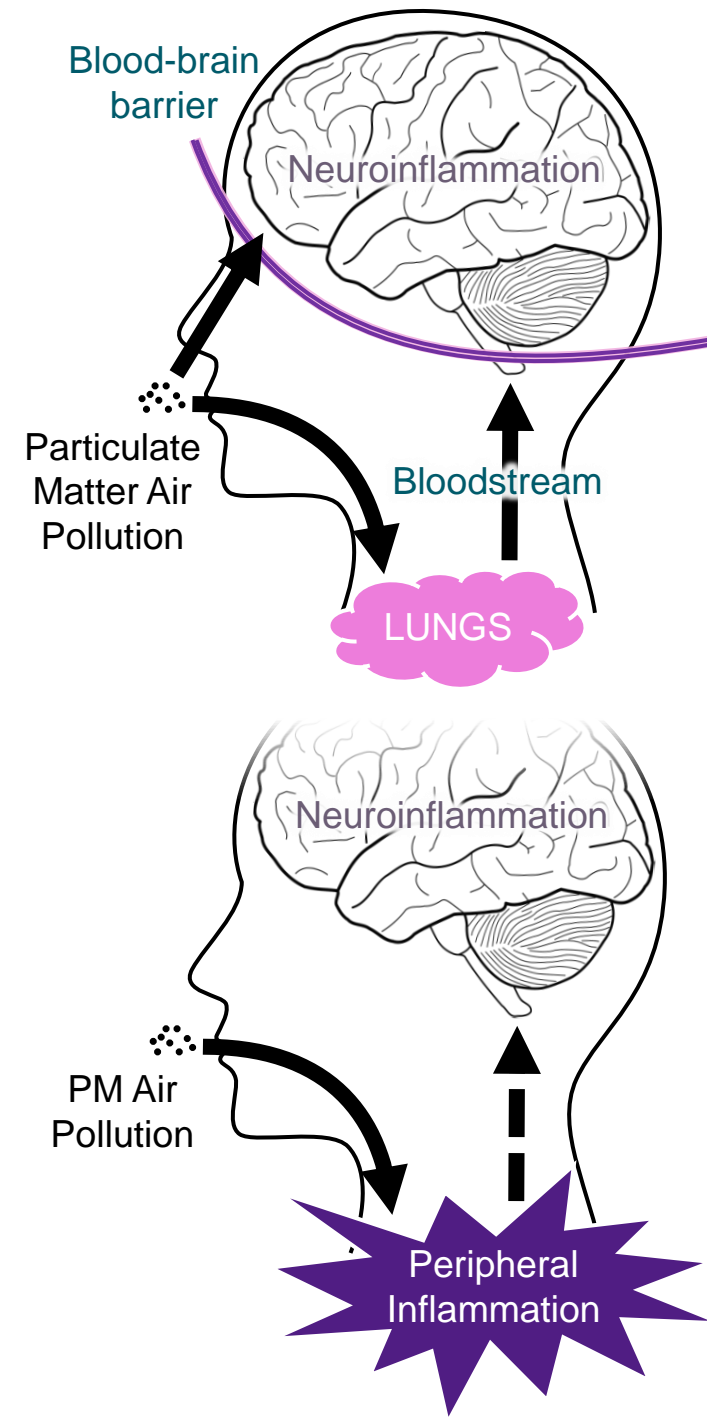UNIVERSITY OF BIRMINGHAM

Hypothesised Mechanistic Pathways

- **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.

  - Can also occur 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).

- Regardless of model, a time-lag is expected between inhalation and the manifestation of cognitive or behavioural effects resulting from an inflammatory response

- e.g., inflammation induced via vaccination (Bahador & Cross, 2007; Murray et al., 2011)

- In these studies, a transient decline in cognitive functioning becomes apparent several hours after the vaccination process (Balter et al., 2018; Balter et al., 2019)

Would we therefore expect differing cognitive effects, or severity of effects between inhalation methods?

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Blood-brain barrier

Neuroinflammation

Particulate Matter Air Pollution

Bloodstream

LUNGS

Neuroinflammation

PM Air Pollution
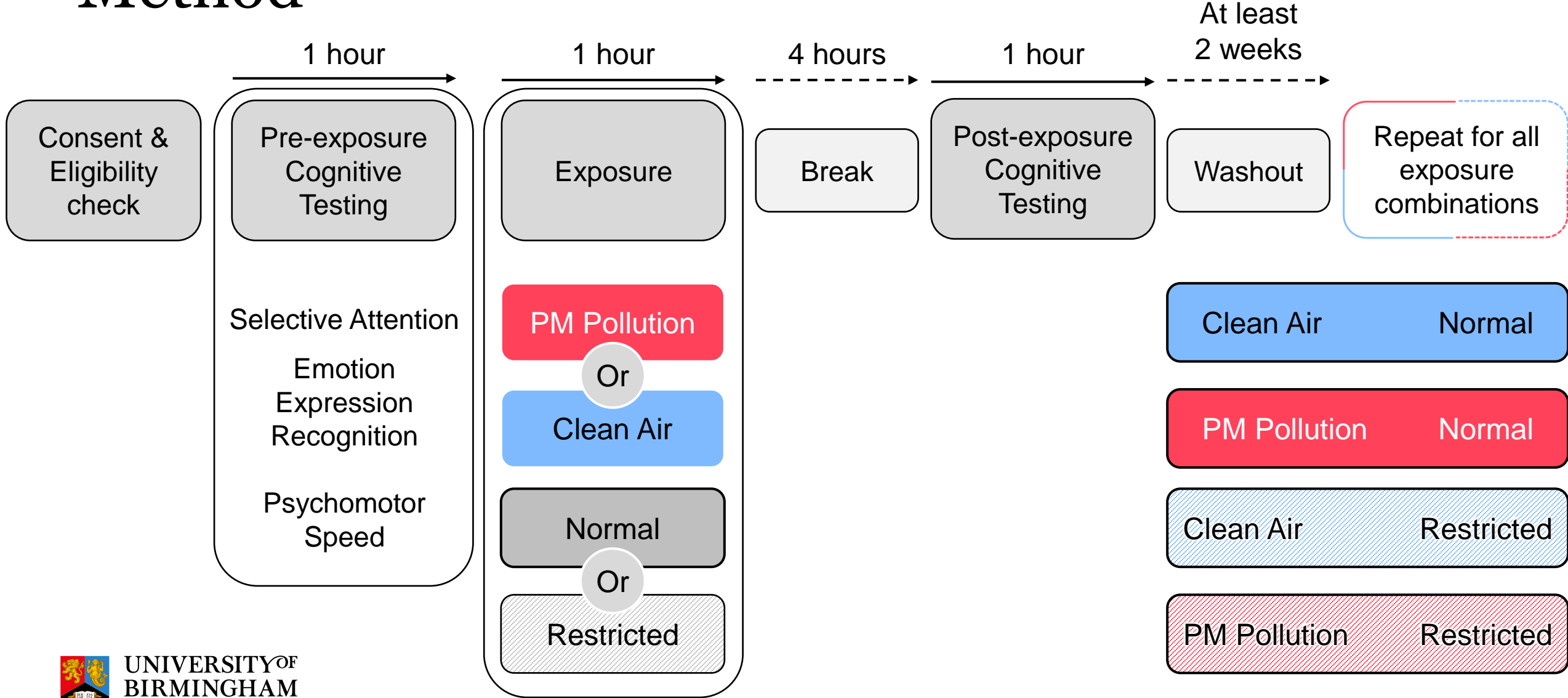
Peripheral Inflammation

Objectives

1. 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?

2. Identify if inhalation method mediates an effect of air quality on cognitive function
   - *If yes:* Does inhalation method mediate changes to all or only some cognitive functions?
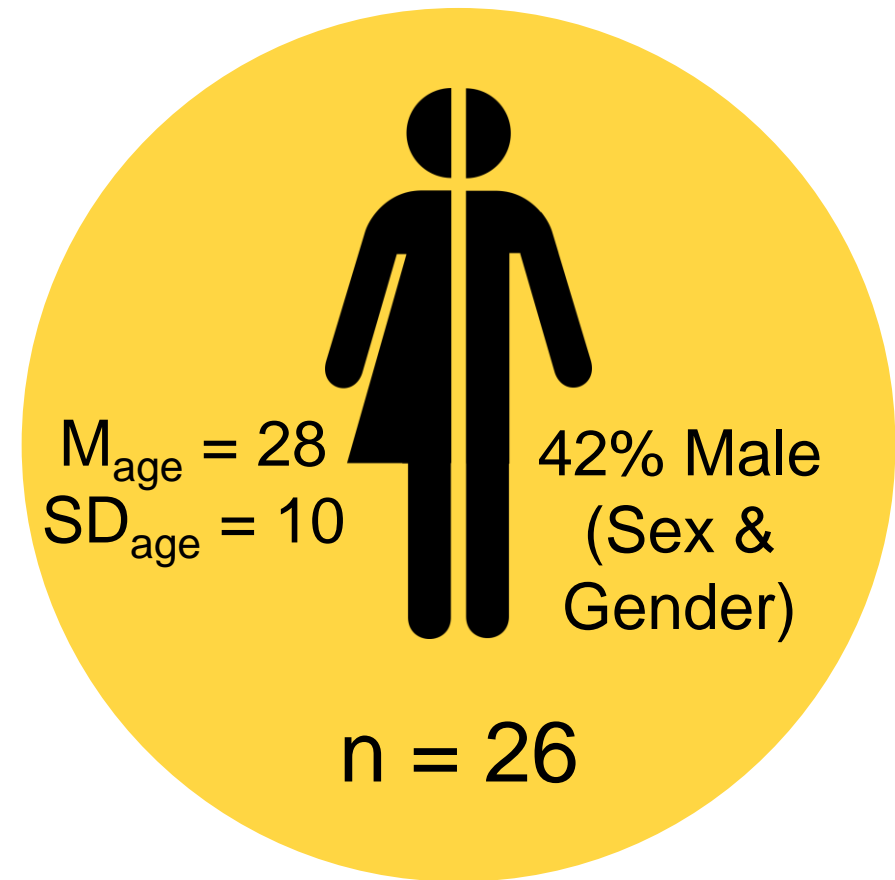

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Method

1 hour → 1 hour → 4 hours ⇢ 1 hour → At least 2 weeks ⇢

| Consent & Eligibility check | Pre-exposure Cognitive Testing | Exposure | Break | Post-exposure Cognitive Testing | Washout | Repeat for all exposure combinations |

Pre-exposure Cognitive Testing:
- Selective Attention
- Emotion Expression Recognition
- Psychomotor Speed

Exposure:
- PM Pollution
- Or
- Clean Air
- Normal
- Or
- Restricted

Exposure combinations:
- Clean Air — Normal
- PM Pollution — Normal
- Clean Air — Restricted
- PM Pollution — Restricted

University of Birmingham Science, Technology, Engineering and Mathematics ethics committee: ERN_21-1188A

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Participants

- Clinically healthy adults (≥18)
  - No inflammatory disease
  - No respiratory disease
  - No neurological / psychiatric conditions

- Dataset from **26 participants** analysed
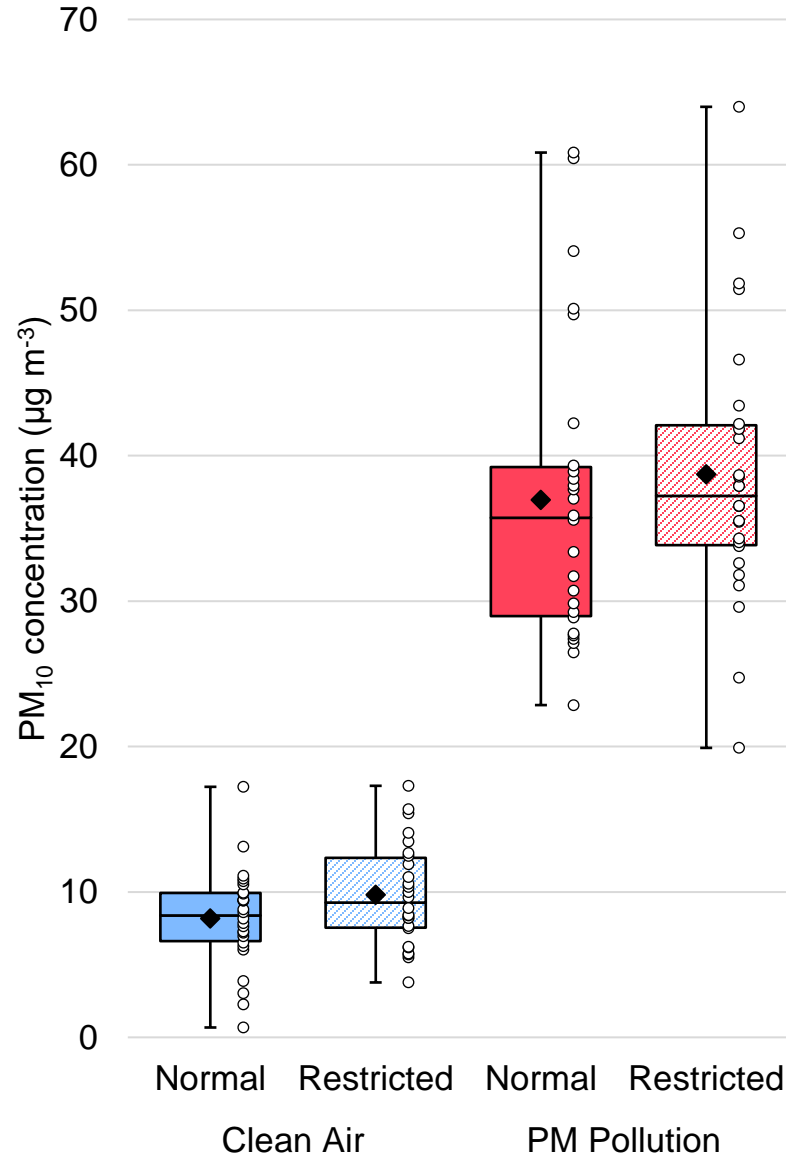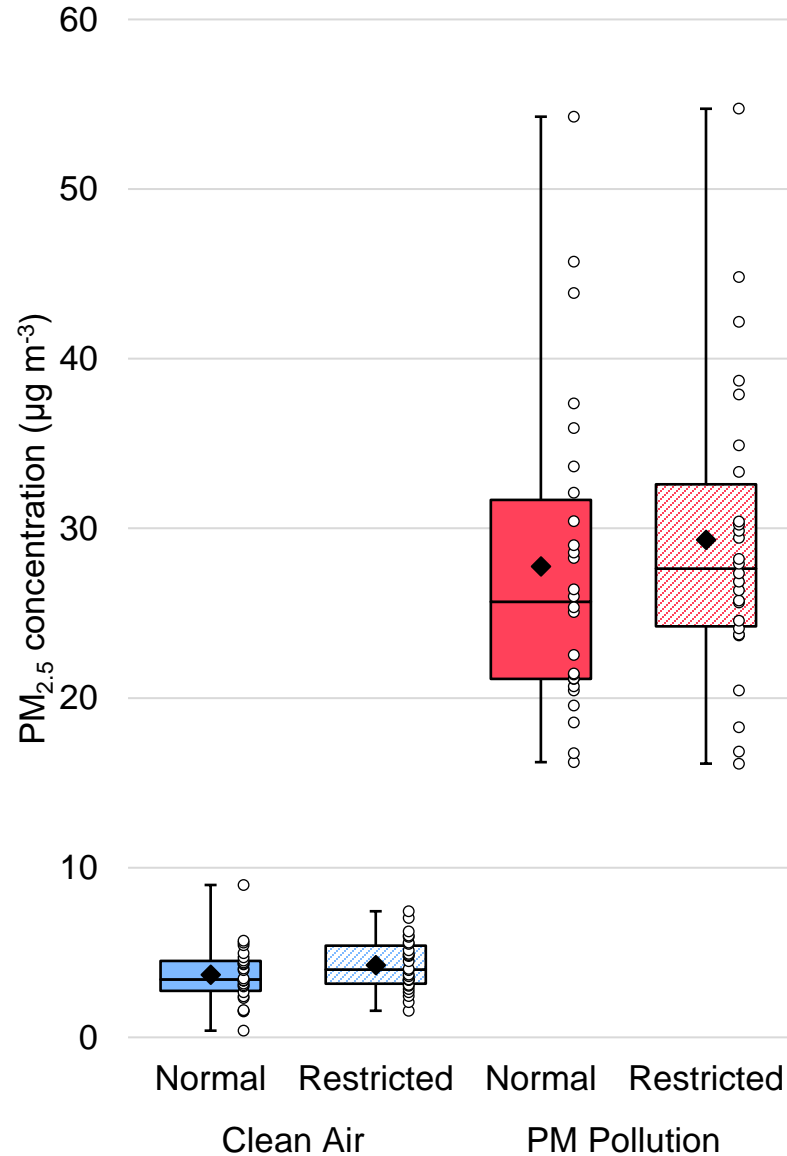
- Blinding successful

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

M_{age} = 28
SD_{age} = 10

42% Male (Sex & Gender)

n = 26

$\chi^2(1, N = 104) = 1.943, p = 0.163$

Air Quality

PM : TSI Optical Particle Sizer 3330

CO_2 : LI-COR LI-820 Gas analyzer
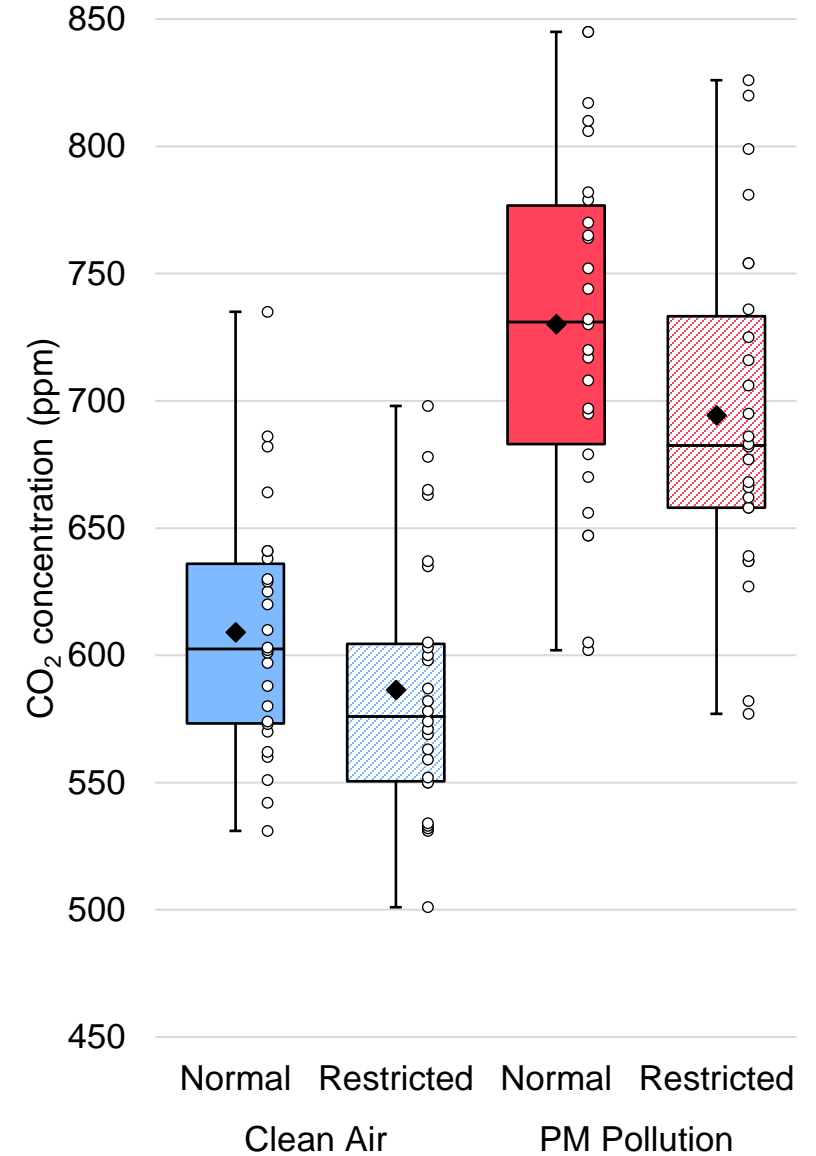
Selective Attention

The ability to remain task focused and avoid distraction

Two-face trial

One-face trial

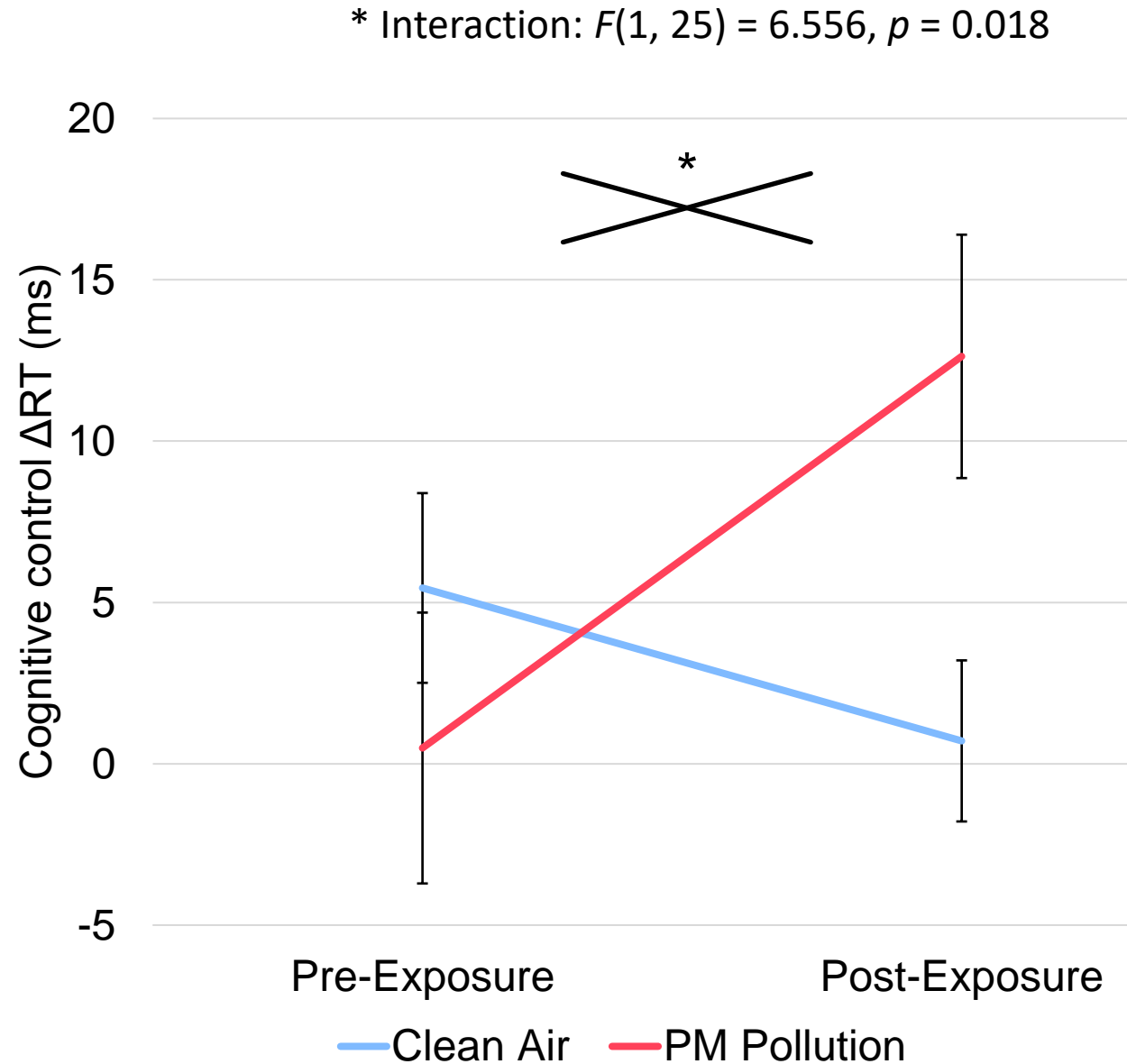Response (Gender presentation)

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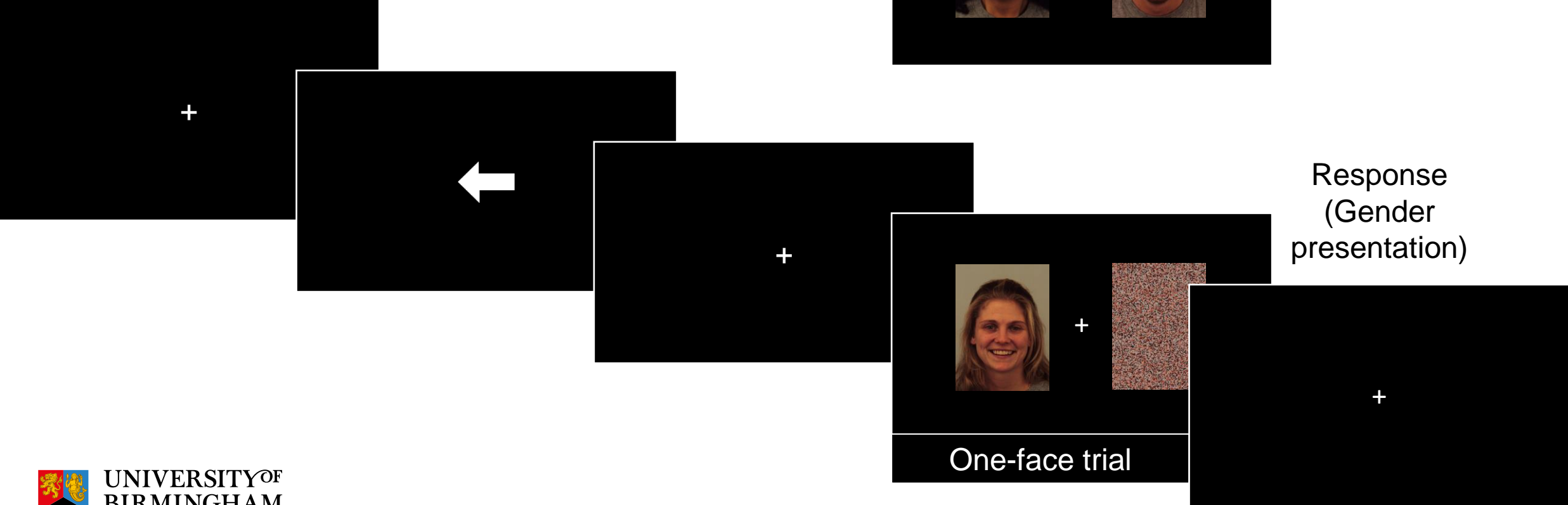
Selective Attention

* 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)

T-tests show significant difference in PM Pollution between pre- and post-exposure (but not pre- and post- clean air)

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

Consistent with previous [unpublished] research at Manchester Aerosol Chamber Facility – Faherty et al., (2021)

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

Cognitive control ΔRT (ms) vs Pre-Exposure / Post-Exposure. Clean Air (blue), PM Pollution (red).

Selective Attention

No three-way interaction identified

Inhalation method does not mediate decline in selective attention ability following pollution exposure
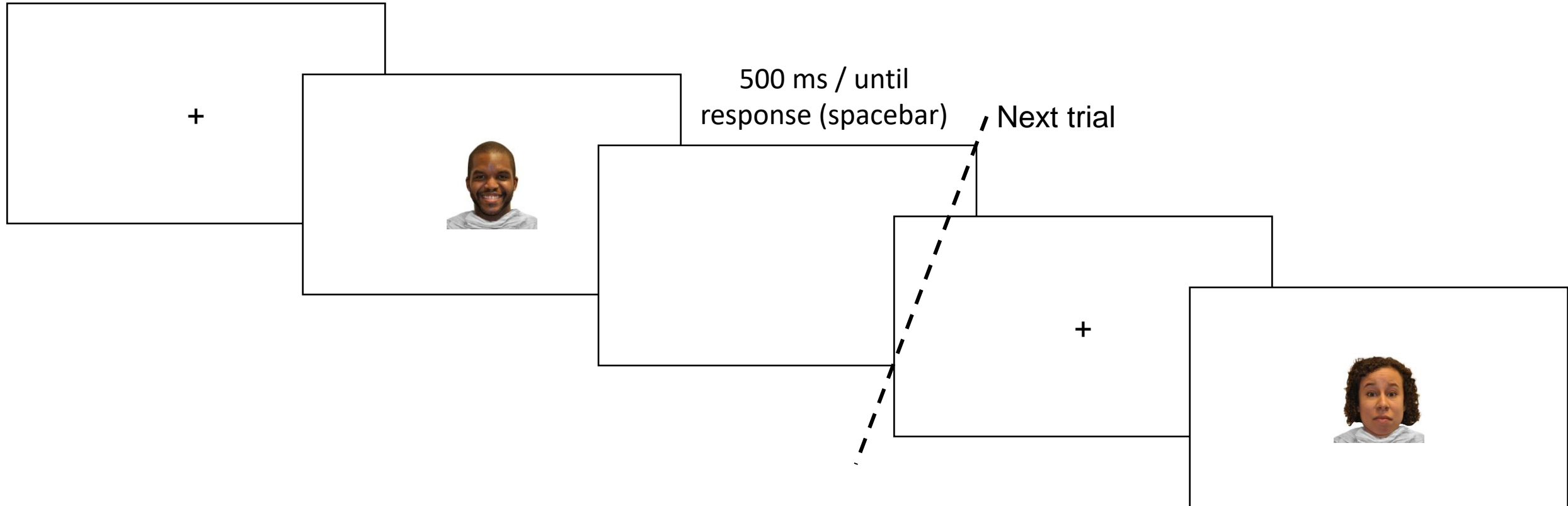
Possible trends:

Clean Air groups behave similarly

Greater change of PM Pollution higher under normal vs restricted inhalation

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Expression Recognition

500 ms / until
response (spacebar)

Next trial
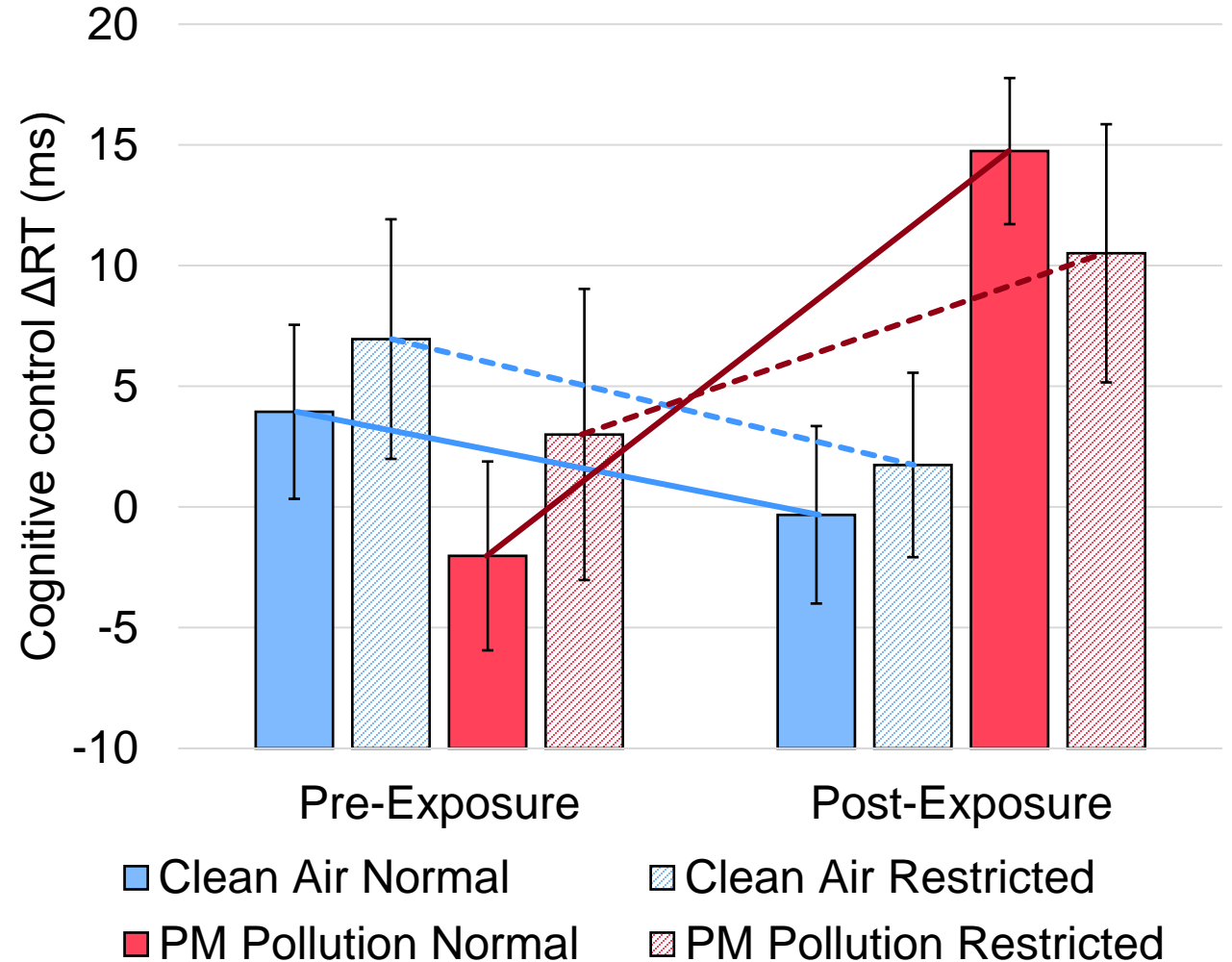
Expression Recognition

*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)

T-tests show significant difference in PM Pollution between pre- and post-exposure (but not pre- and post- clean air)

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)

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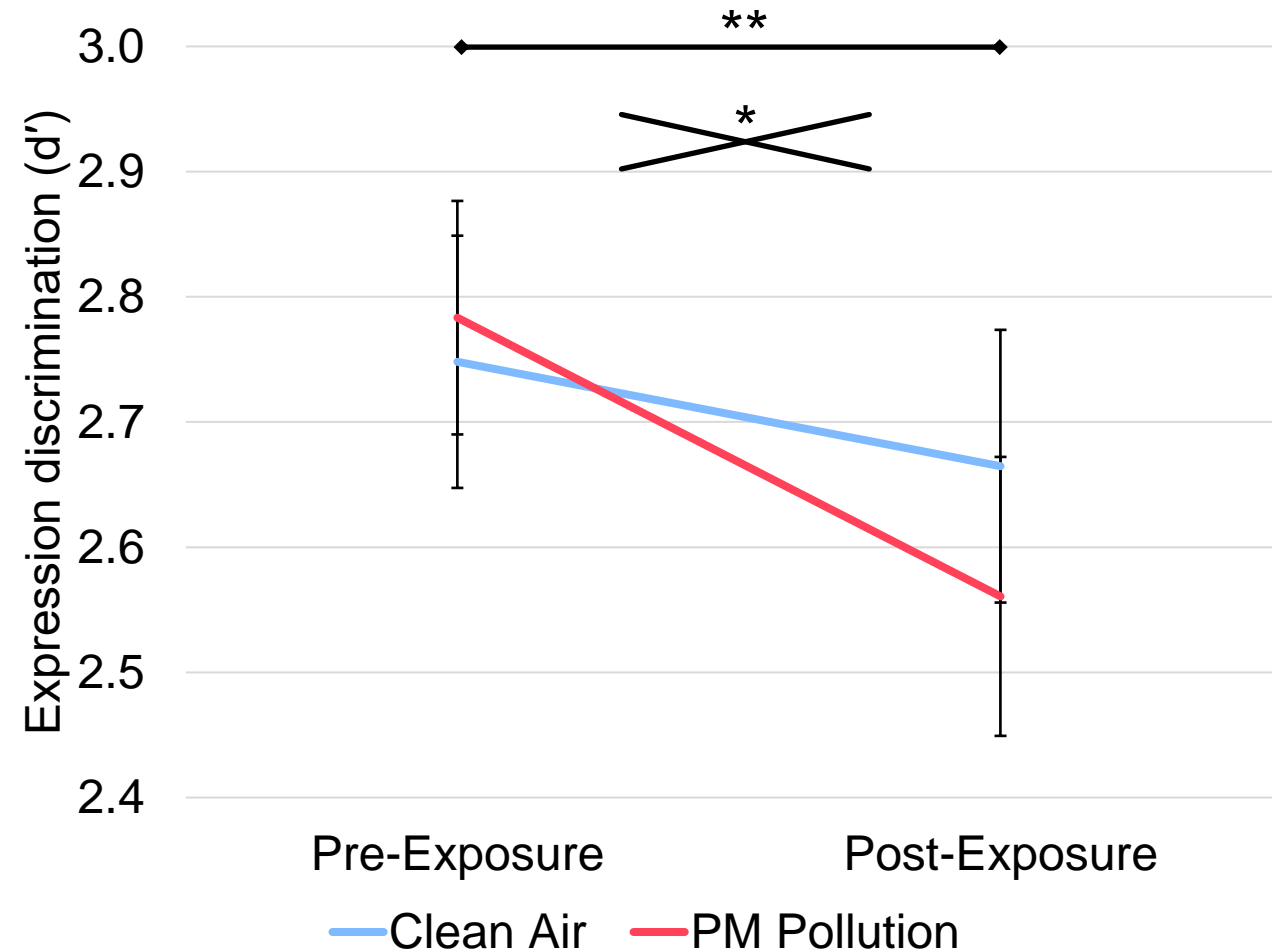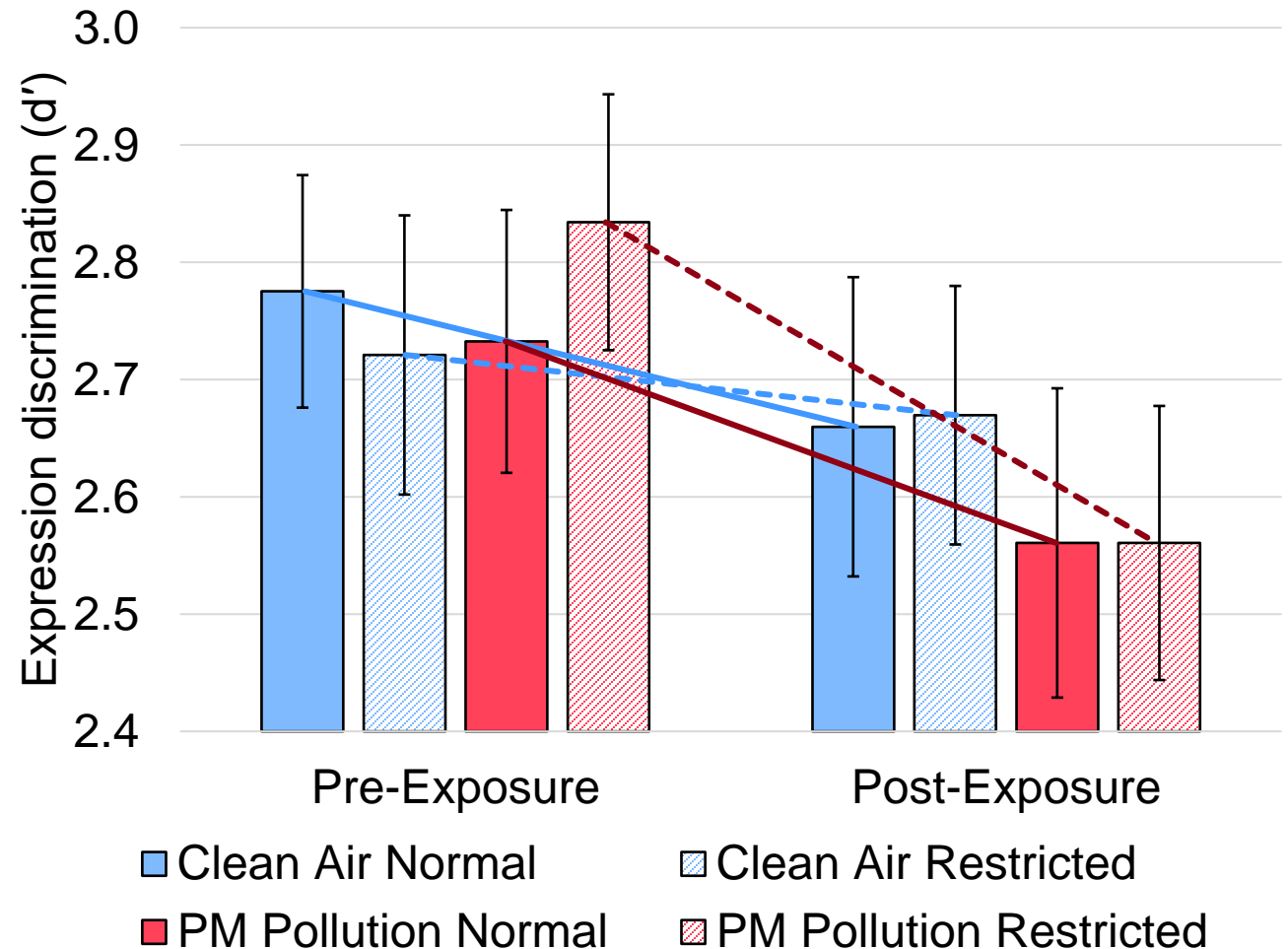
Expression Recognition

No three-way interaction identified

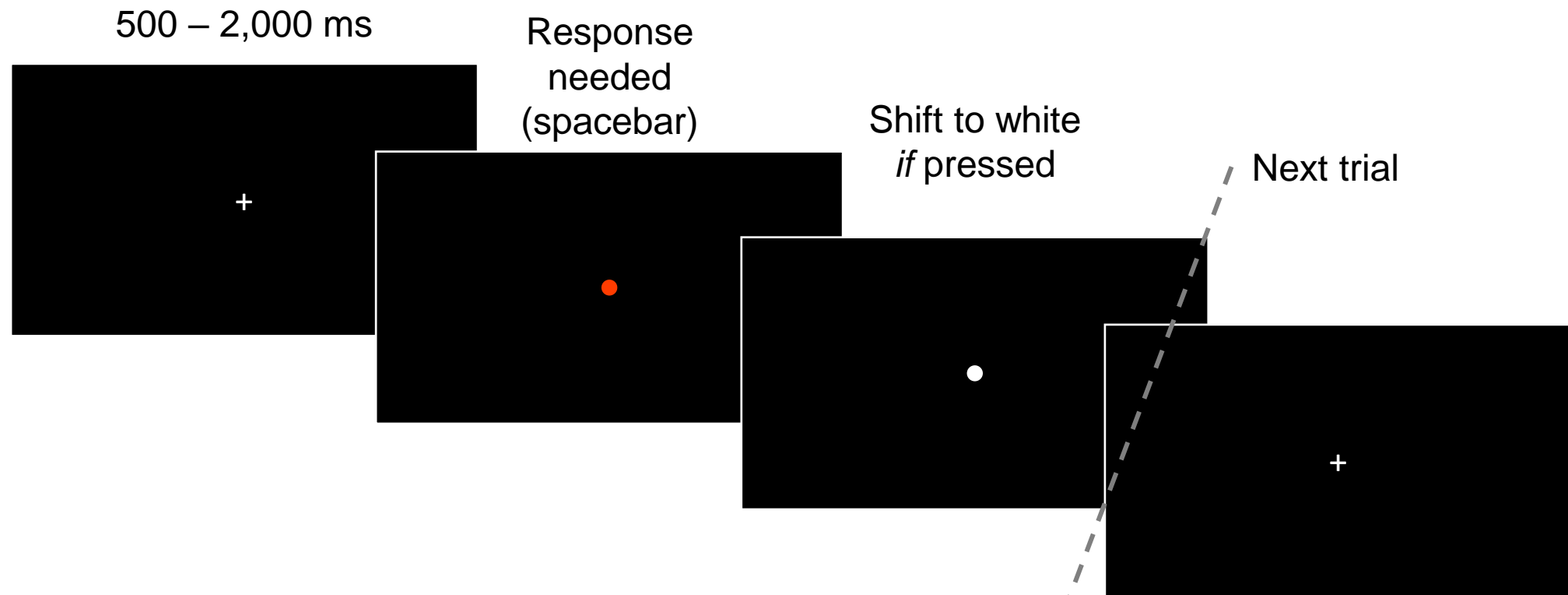**Inhalation method does not mediate difficulty with processing emotional stimuli following pollution exposure**

Possible trends:

Clean Air groups behave similarly

Greater change of PM Pollution higher under restricted vs normal inhalation?
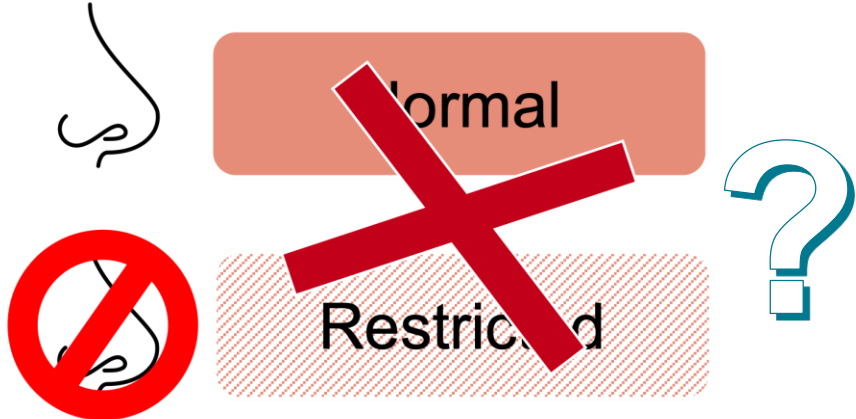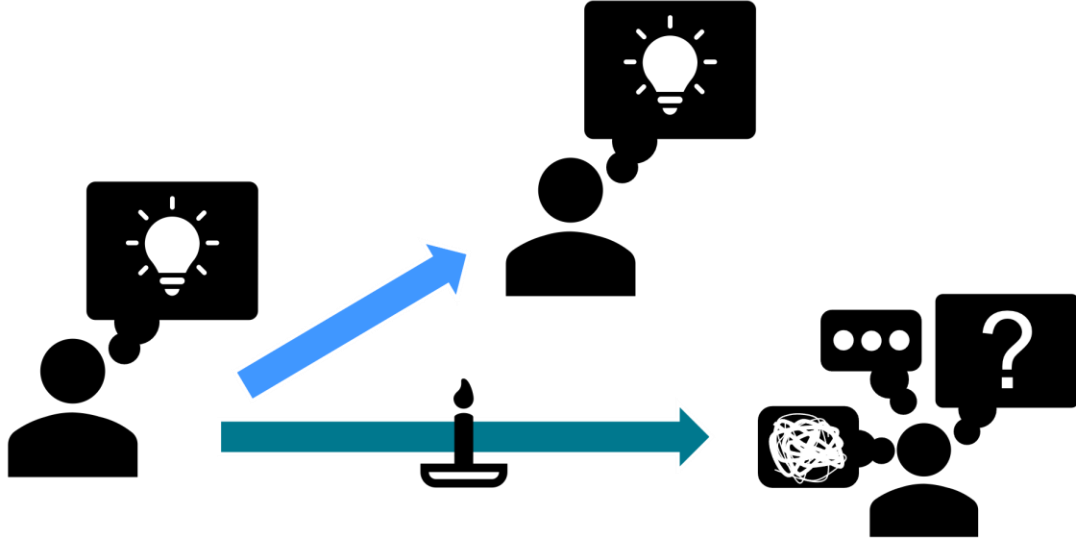

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# Psychomotor Speed

500 – 2,000 ms

Response needed (spacebar)

Shift to white *if* pressed

Next trial

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Psychomotor Speed

Psychomotor Speed (RT)	Normal Inhalation		Restricted Inhalation	
	Clean Air	PM Pollution	Clean Air	PM Pollution
Pre-Exposure	**321**	**317**	**318**	**315**
	(29)	(29)	(26)	(27)
Post-Exposure	**319**	**320**	**315**	**313**
	(29)	(35)	(27)	(22)
Change	-2 ms	+3 ms	-3 ms	-2 ms

Clean Air Conditions get slightly quicker; mixed results for PM Pollution

But - No significant Main Effects or Interactions identified

As expected! We can be confident that the declines in selective attention and emotion expression recognition are not due to a global decline in cognitive speed, but instead are attributable to the more complex cognitive functions outlined

Summary
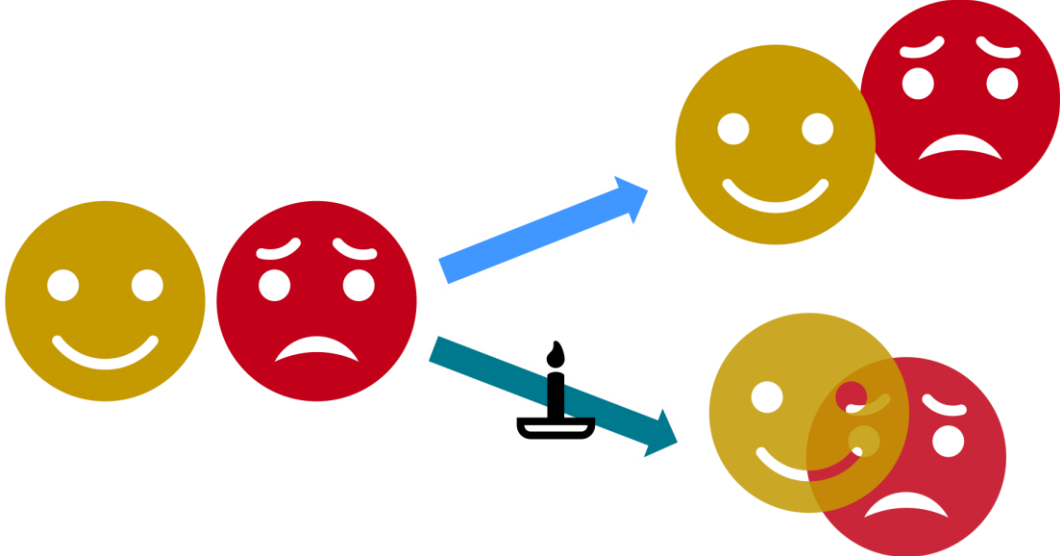
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Thank you for your attention

With thanks to

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