Traffic-related air pollution and attention in primary school children: short-term association

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eAppendix. Indoor pollutant levels in the classroom

We built predictive models for indoor air pollution in classrooms using linear mixed regression models. The dependent variable was repeat measures of indoor levels of the pollutant (two sampling campaigns). The independent variables were floor level (Ground or 1st; 2nd; and 3rd or higher), room orientation (classroom oriented towards: indoor area, outdoor playground, or directly onto the street), outdoor levels of the pollutant, seasonal and weather determinants such as temperature, relative humidity and rainfall.

We first performed a univariate analysis of all variables, including an evaluation of their normality. Second, we assessed the linearity of the relationship between indoor and outdoor levels of air pollutants and weather-related variables using generalized additive models. If there was evidence of a non-linear relationship, we tested for a curvilinear association based on the significance of the squared term of the independent variable. Third, we introduced the variables consecutively into the multivariate model in order of highest to lowest R^2, provided that they added more than 1% to the R2 and maintained the expected direction in the association. We then applied backward regression, retaining variables with a p-value of < 0.1.

Regression diagnostics tests included normality of residuals, homoscedasticity, and influential data points. We assessed model performance in the three ways. i) leave-one-out cross-validation (LOOCV), obtaining three measures of goodness-of-fit: the LOOCV R2 (pseudo R2, the square of the coefficient of correlation between the predicted and observed values of each air pollutant), LOOCV RMSE (the Root Mean Square Error: the standard deviation of the residuals), and LOOCV MAE (the Mean Absolute Error: the average of the absolute values of the residuals); ii) computing the Fraction Bias (FB), NMSE (the Normalized Mean Square Error) and FAC2 (the Factor of 2, defined as the ratios of model prediction to observed values that are ≥ 0.5 and ≤ 2). The model was considered acceptable if FAC2>0.5, |FB|<0.3, and NMSE<1.5; and iii) comparing predicted levels of the modeled pollutant to sampled levels at sites not included in the prediction model (only available for NO_2). Modeled levels of NO_2 had very good validity (correlation coef. = 0.94) against a subset (n=19) of NO_2 measurements conducted simultaneously in different classrooms of six schools. Finally, we then predicted levels of indoor pollution for all the classrooms using the parameter estimates derived from the regression model.

eTable 1. Short-term and long-term NO2 and EC relationship with children and daily characteristics.

	Short term exposure		Long term exposure	
	NO$_2$	EC	NO$_2$	EC
Spearman correlations				
Covariates				
Age	-0.05	-0.07	0.02	0.06
Home SES vulnerability index	-0.03	-0.03	0.25	0.32
Home air pollution (LUR)	-0.05	-0.04	0.34	0.26
Noise	0.07	0.02	0.41	0.38
Daily characteristics				
Temperature	0.07	0.06	-0.05	-0.08
Relative Humidity	0.14	0.39	-0.20	-0.20
Pollutant mean (sd) - µg/m^3				
Covariates				
Sex				
Girls	37.7 (18.3)	1.34 (0.84)	48.4 (13.3)	1.52 (0.72)
Boys	37.8 (18.3)	1.33 (0.83)	48.4 (13.0)	1.49 (0.69)
Maternal Education				
High	38.0 (18.2)	1.36 (0.82)	47.0 (13.4)	1.44 (0.69)
Medium-Low	37.4 (18.7)	1.31 (0.86)	50.3 (12.5)	1.61 (0.71)
Daily characteristics				
Season				
Warm	35.3 (19.8)	1.10 (0.70)	47.8 (13.9)	1.46 (0.70)
Cold	39.3 (17.3)	1.47 (0.88)	48.7 (12.6)	1.54 (0.71)
Period				
Year 1	37.6 (19.6)	1.29 (0.84)	47.8 (13.3)	1.47 (0.68)
Year 2	37.9 (16.6)	1.40 (0.83)	49.1 (12.9)	1.57 (0.73)
Day of the week				
Monday	31.7 (13.5)	0.99 (0.55)	53.1 (14.1)	1.87 (0.87)
Tuesday	34.5 (16.9)	1.13 (0.73)	49.9 (13.8)	1.68 (0.80)
Wednesday	40.9 (20.8)	1.62 (0.93)	50.9 (8.3)	1.50 (0.31)
Thursday	43.9 (19.9)	1.52 (0.89)	47.1 (11.8)	1.36 (0.63)
Friday	36.7 (16.9)	1.39 (0.84)	41.4 (13.5)	1.16 (0.55)
Hour of exam				
8h-11h	37.6 (18.4)	1.31 (0.84)	47.6 (13.8)	1.48 (0.73)
11h-13h	37.7 (19.4)	1.37 (0.87)	48.3 (12.1)	1.47 (0.66)
15h-17h	37.1 (15.8)	1.31 (0.78)	49.1 (12.9)	1.61 (0.71)

SES: socio-economic status based on the neighbourhood vulnerability index; LUR: Land Use Regression

eTable 2. Association (difference per interquartile range increase,) between daily variation (short-term) and indoor classroom levels (long-term) of traffic-related air pollution and daily cognitive function.

	Short-term (Lag 1)[a]	Long-term[b]	Short-term adjusted for long-term[c]	
			Short-term	Long-term
NO_2				
Superior WM (three-back numbers, d');	-1.24 (-4.25 , 1.76)	-2.81 (-8.19 , 2.56)	-0.28 (-3.24 , 2.67)	-3.89 (-9.22 , 1.44)
WM (two-back words, d');	-1.55 (-5.38 , 2.28)	-6.52* (-11.87 , -1.17)	0.62 (-2.99 , 4.23)	-6.92* (-12.28 , -1.56)
Superior WM (three-back words, d');	0.93 (-2.16 , 4.02)	-2.20 (-7.35 , 2.95)	1.97 (-1.00 , 4.94)	-2.45 (-7.72 , 2.82)
EC				
Superior WM (three-back numbers, d');	-0.54 (-3.57 , 2.49)	-3.07 (-7.90 , 1.77)	-0.20 (-3.17 , 2.77)	-5.60* (-10.78 , -0.42)
WM (two-back words, d');	1.92 (-1.87 , 5.71)	-2.25 (-7.57 , 3.06)	2.43 (-1.21 , 6.07)	-3.58 (-9.40 , 2.24)
Superior WM (three-back words, d');	1.36 (-1.71 , 4.44)	0.02 (-4.63 , 4.67)	1.84 (-1.14 , 4.82)	-1.25 (-6.32 , 3.81)

WM: Working Memory; d': detectability; EC: Elemental Carbon; NO_2: Nitrogen Dioxide

[a] Lag 1 = exposure of the day before of the attention test, model adjusted (cubic spline) for temperature and relative humidity on the current day, season (cold, warm), day of the week and period (year 1 or 2), hour of exam.

[b] Adjusted for child's age, sex, maternal education, socioeconomic status of the neighborhood of residence, and home air pollution.

[c] Adjusted for [a] and [b] above.

* $p < 0.05$

eTable 3. Sensitivity analyses of the association (difference per interquartile range increase,) between daily variation (acute effects) of traffic-related air pollution and daily cognitive function.

	Unadjusted	Fixed effects per individual[a]	Temporal trend pre-adjustment[b]
Inattention			
Mean HRT, ms;			
NO_2	24.52* (21.36 , 27.69)	5.30* (2.62 , 7.98)	10.43* (6.14 , 14.71)
EC	23.68* (20.52 , 26.85)	10.20* (7.15 , 13.25)	6.26* (2.24 , 10.28)
HRT-SE, ms;			
NO_2	8.02* (6.16 , 9.88)	2.33* (0.61 , 4.05)	3.14* (0.66 , 5.62)
EC	6.43* (4.56 , 8.30)	2.85* (0.88 , 4.83)	1.24 (-1.10 , 3.58)
Number of Omissions;			
NO_2	14%* (10%, 18%)	5%* (1%, 8%)	7%* (2%, 13%)
EC	7%* (4%, 11%)	4%* (0%, 8%)	2% (-4%, 7%)
Number of Commissions;			
NO_2	8%* (3%, 13%)	1% (-1%, 4%)	10%* (0%, 22%)
EC	2% (-2%, 7%)	3%* (0%, 6%)	7% (-3%, 18%)
Working memory			
Two-back numbers, d'x100;			
NO_2	-3.67* (-6.94 , -0.39)	-1.62 (-4.84 , 1.61)	-0.06 (-4.26 , 4.14)
EC	-3.30 (-6.61 , 0.01)	0.08 (-3.58 , 3.74)	0.54 (-3.58 , 4.65)

HRT: Hit Reaction Time; SE: Standar error; ms: milliseconds; RR: Rate ratio; d': detectability; EC: Elemental Carbon; NO_2: Nitrogen Dioxide

[a] Adjusted for temperature on the current day (linear and quadratic term), relative humidity on the current day, season (cold, warm), day of the week and period (year 1 or 2), hour of exam, and fixed-effect for subject.

[b] Pre-adjusted exposures were used as explained elsewhere (26). GAM models for the air pollutant as a function of day of the week, season, and smooth terms for time (7 df/year), temperature (3 df) and relative humidity (3df for NO2 and 1 df for BC) were fitted . Residuals were adjusted for period (year 1 or 2), hour of exam.

*$p < 0.05$

eTable 4. Stratified analyses[a] of the association (difference per interquartile range increase) between daily variation (short-term) of traffic-related air pollution and daily cognitive function.

	By sex		By Maternal Education		By ADHD	
	Boys (n=1,343)	Girls (n=1,344)	High (n=1,575)	Low-Middle (n=1,112)	No (n=2,382)	Yes (n=274)
Mean HRT, ms;						
NO$_2$	16.78* (12.08 , 21.47)	14.01* (8.84 , 19.19)	13.13* (8.76 , 17.50)	17.61* (11.81 , 23.42)	14.48* (10.74 , 18.23)	22.02* (10.48 , 33.57)
EC	10.13* (5.66 , 14.59)	9.65* (4.89 , 14.41)	10.05* (6.01 , 14.09)	8.74* (3.18 , 14.29)	8.87* (5.38 , 12.36)	20.18* (8.98 , 31.38)
HRT-SE, ms;						
NO$_2$	5.60* (2.48 , 8.71)	4.38* (1.16 , 7.61)	3.98* (1.18 , 6.78)	5.71* (2.04 , 9.38)	4.44* (2.05 , 6.84)	10.90* (3.35 , 18.45)
EC	1.81 (-1.17 , 4.80)	3.05* (0.02 , 6.08)	2.52 (-0.09 , 5.14)	2.28 (-1.29 , 5.86)	1.83 (-0.43 , 4.09)	8.15* (0.79 , 15.52)
Number of Omissions;						
NO$_2$	8% * (2%, 15%)	7% * (1%, 13%)	5% (-1%, 11%)	10% * (3%, 17%)	7% * (2%, 12%)	1%8* (6%, 33%)
EC	5% (0%, 11%)	1% (-4%, 7%)	4% (-1%, 9%)	3% (-3%, 9%)	3% (-2%, 7%)	8% (-4%, 21%)
Number of Comissions;						
NO$_2$	13% * (5%, 22%)	17% * (8%, 27%)	27% * (19%, 37%)	4% (-4%, 13%)	15% * (8%, 22%)	28% * (10%, 49%)
EC	13% (-4%, 11%)	16% * (8%, 25%)	12% * (5%, 20%)	4% (-4%, 13%)	6% * (1%, 12%)	5% (-12%, 24%)
Two-back numbers. d';						
NO$_2$	-1.47 (-6.78 , 3.83)	-1.43 (-6.76 , 3.89)	-2.99 (-7.93 , 1.94)	-0.59 (-6.30 , 5.11)	-0.26 (-4.31 , 3.78)	-10.02 (-21.84 , 1.79)
EC	0.37 (-4.89 , 5.63)	0.76 (-4.44 , 5.97)	0.23 (-4.50 , 4.97)	-0.24 (-6.07 , 5.60)	1.89 (-2.10 , 5.89)	-11.82* (-23.39 , -0.26)

[a] Adjusted (cubic spline) for temperature and relative humidity on the current day, season (cold, warm), day of the week and period (year 1 or 2), hour of exam.

*$p < 0.05$

eTable 5. Stratified analyses[a] of the association (differenced per interquartile range increase) between daily variation (short-term) of traffic-related air pollution and daily cognitive function.

	By season		By noise	
	Cold (N=2,647)	**Warm** (N=2,616)	**Low** (N=1,336)	**High** (N=1,351)
Mean HRT, ms;				
NO_2	10.71* (5.39 , 16.02)	10.62* (3.61 , 17.63)	13.10* (7.49 , 18.70)	16.47* (11.23 , 21.71)
EC	0.55 (-4.64 , 5.75)	17.22* (10.09 , 24.36)	14.20* (8.55 , 19.84)	5.88* (1.16 , 10.60)
HRT-SE, ms;				
NO_2	2.12 (-1.43 , 5.66)	1.92 (-2.82 , 6.67)	6.41* (2.99 , 9.83)	4.49* (1.12 , 7.87)
EC	0.11 (-3.31 , 3.53)	3.24 (-1.67 , 8.15)	3.89* (0.43 , 7.35)	0.65 (-2.42 , 3.72)
Number of Omissions;				
NO_2	7%* (1%, 4%)	-7% (-15%, 1%)	11%* (4%, 18%)	5% (-1%, 12%)
EC	0% (-6%, 6%)	2% (-7%, 12%)	9%* (2%, 17%)	-2% (-8%, 4%)
Number of Commissions;				
NO_2	7% (-1%, 15%)	15%* (5%, 26%)	23%* (13%, 34%)	17%* (8%, 27%)
EC	-3% (-11%, 5%)	32%* (21%, 45%)	28%* (18%, 39%)	-3% (-10%, 5%)
Two-back numbers, d',				
NO_2	0.60 (-4.93 , 6.13)	0.80 (-6.69 , 8.28)	-2.20 (-7.82 , 3.43)	-1.39 (-7.08 , 4.30)
EC	4.11 (-1.28 , 9.49)	2.34 (-5.42 , 10.10)	-3.10 (-8.95 , 2.76)	2.99 (-2.40 , 8.39)

[a] Adjusted for (cubic spline) for temperature and relative humidity on the current day, season (cold, warm), day of the week and period (year 1 or 2), hour of exam.

* $p < 0.05$

eFigure 1 Association (difference per interquartile range increase, IQR) between ambient daily levels (short-term by lag period) and indoor classroom levels (long-term) of NO2 and inattention: (A) number of comissions and B) mean HRT).

A

Number of Commissions

B

Mean HRT, ms

NO_2
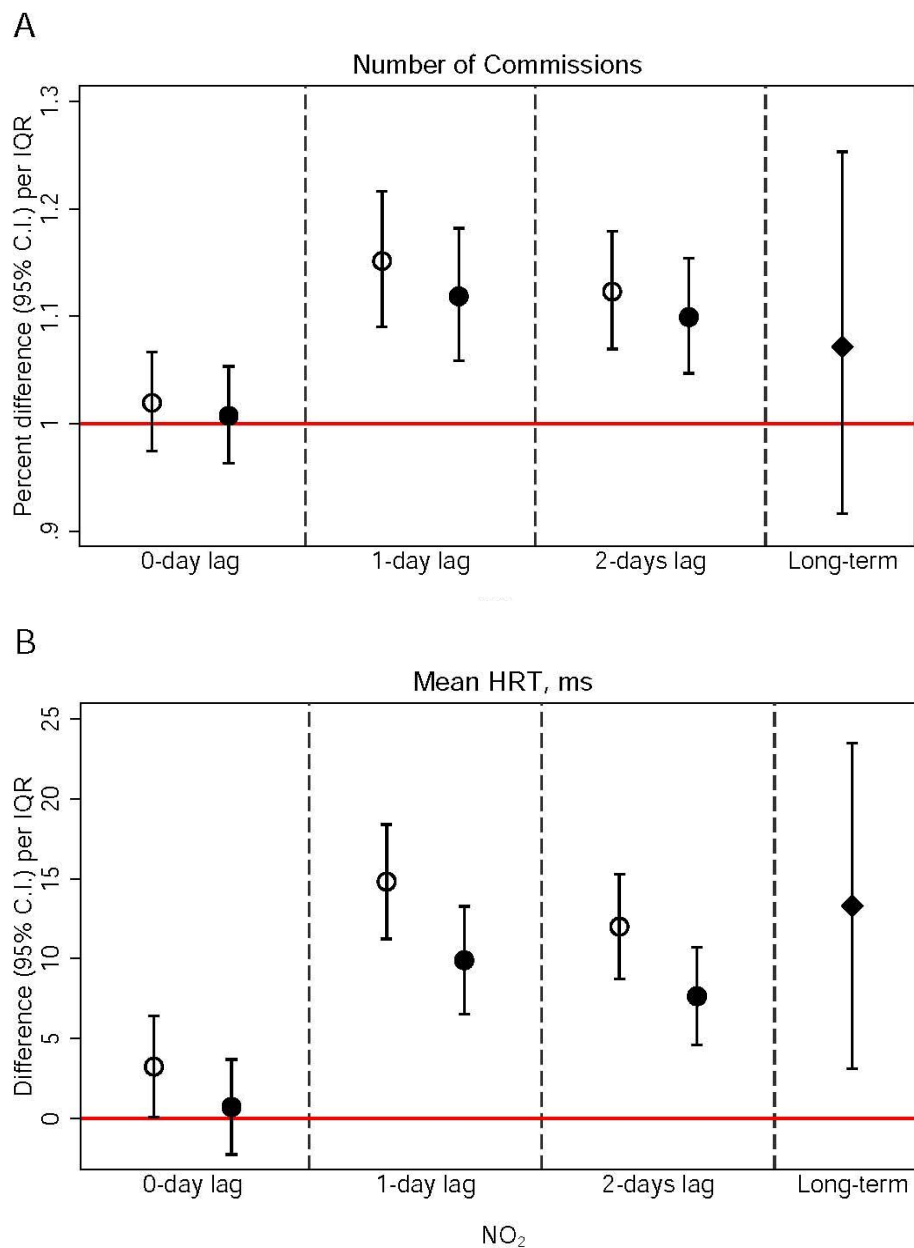
Legend: Lag 0: same day exposure, Lag 1: day before exposure, Lag 2: two days before exposure .

○ Models were adjusted (cubic spline) for the temperature and relative humidity on the current day, season (cold, warm), day of the week, period (year 1 or 2), and the hour of the exam. Subject nested in classroom, and classroom nested in school.

● Adjusted as for the above, plus child's age, sex, maternal educational level, socioeconomic status of the neighborhood of residence, home air pollution and indoor air pollution in the classroom.

◆ Indoor estimate from the 1-day lag model.