

SUPPLEMENTARY MATERIAL

Table A1. Summary of the data from studies examining the effect of classroom air quality on performance of psychological tests and school tasks by school children																
Study	Year	Location	Season	Type	Population		Age of pupils	CO <sub>2</sub> averaging in original study (exposure metric)	Measured CO <sub>2</sub> concentration: range or levels (average concentration) (ppm)	Measurement of performance	Speed or reaction time			Accuracy		
					Schools	Pupils					Change in speed or reaction time per 100 ppm decrease in CO <sub>2</sub> conc.	Signif. (P)	Cohen's d	Change in accuracy per 100 ppm decrease in CO <sub>2</sub> conc.	Signif. (P)	Cohen's d
<i>Psychological tests</i>																
Myhrvold et al.	1996	Norway	Winter	Measurements before and after intervention	22 classrooms in 5 high schools	550	15-20	Mean concentration during school-day	600-3800 (2200)	Simple reaction time; Choice reaction time; Colour-word vigilance	0,1%	0,009				
Myhrvold and Olsen (1997)	1997	Norway	Winter	Measurements before and after intervention	35 classrooms in 8 high schools	600	16-19	Mean concentration during school-day	735-1515 (1125)	Simple reaction time; Choice reaction time Colour-word vigilance	0,66%	N/A				
Coley et al.	2007	England	Summer	Measurements with windows open and closed	1 classroom in 1 elementary school	18	10-11	Concentration at the onset of the test period	700- 2900 (1800)	Simple reaction time	0,31%	0,02	0,28			
										Digit vigilance	0,10%	0,08	0,20	0,05%	0,44	0,08
										Choice reaction time	0,23%	0,06	0,24	0,01%	0,75	0,04
										Picture presentation and recognition	0,37%	0,15	0,22	0,07%	0,02	0,32
Ribic	2008	Austria	N/A.	Measurements with windows open and closed	6 classrooms in 2 high schools	152	15-16	Concentration at the onset of the test period	870- 3300 (2085)	d2 test of attention	0,44%	0,001				
Ribic	2008	Austria	N/A	Measurements with windows open and closed	6 classrooms in 2 high schools	152	15-16	Concentration at the onset of the test period	870, 4300 (2585)	d2 test of attention	N/A	0,001				
Bakó-Biró et al.	2012	England	Autumn, winter, spring and early summer	Field intervention. Ventilation rates were changed	16 classrooms in 8 elementary schools	332	9-10	Mean concentration during the test period	950- 3000 (1975)	Simple reaction time	0,07%	0,33		0,05%	0,10	
										Choice reaction time	0,08%	0,05		0,02%	0,12	
										Colour-word vigilance	0,06%	0,06		0,05%	0,05	
										Addition reaction time	0,00%	0,25		-0,02%	0,16	
										Digit-span memory	0,15%	0,18		0,04%	0,47	
										Digit classification	-0,05%	0,25		-0,01%	0,46	
Digit-symbol matching	-0,23%	0,02	N/A	0,00%	0,44	N/A										

										Picture memory	-0,03%	0,25	N/A	0,35%	0,02	N/A
										Word recognition	0,57%	0,001	N/A.	0,02%	0,27	N/A
<i>School tasks</i>																
Bakó-Biró et al.	2007	England	N/A	Field intervention. Ventilation rates were changed	2 classrooms in 1 elementary school	40	9-10	Mean concentration during the test period	650-1850 (1250)	Addition	0,17%			0,25%		
										Subtraction	-0,22%			0,50%		
										Reading and comprehension	N/A	NS		N/A	NS	
Wargocki and Wyon	2007	Denmark	Late summer (August, September)	Field intervention. Ventilation rates were changed	2 classrooms in 1 elementary school	44	10-12	Weekly average (when pupils were present)	775- 1000 (888)	Subtraction	8,29%	0,01	0,31	2,09%	0,06	0,19
										Multiplication	9,69%	0,01	0,10	3,37%	0,05	0,25
										Number comparison	4,66%	0,04	0,32	-0,63%	0,75	0,27
										Addition	6,85%	0,001	0,76	0,82%	0,23	0,15
										Logical reasoning	-0,62%	0,49	0,04	0,84%	0,47	0,09
										Acoustic proof-reading				0,69%	0,96	0,07
										Reading and comprehension	-0,30%	0,78	0,02	0,49%	0,58	0,06
Proof-reading				0,91%	N/A	0,09										
Wargocki and Wyon	2007	Denmark	Winter (January)	Field intervention. Ventilation rates were changed	2 classrooms in 1 elementary school	44	10-12	Weekly average (when pupils were present)	925- 1280 (1102)	Subtraction	6,80%	0,01	0,51	-0,50%	0,20	0,17
										Multiplication	2,20%	0,002	0,19	0,47%	0,32	0,07
										Number comparison	1,53%	0,62	0,12	0,04%	0,53	0,02
										Logical reasoning	6,58%	0,003	0,51	-0,04%	0,63	0,01
										Acoustic proof-reading				-0,22%	0,56	0,07
										Reading and comprehension	10,79%	0,001	0,74	-0,04%	0,91	0,01
Wargocki and Wyon	2007	Denmark	Late summer (August)	Field intervention. Ventilation rates were changed	2 classrooms in 1 elementary school	48	10-12	Weekly average (when pupils were present)	900- 1125 (1012)	Subtraction	4,14%	0,19	0,31	-0,08%	0,66	0,02
										Addition	1,41%	0,24	0,11	0,13%	0,66	0,06
										Logical reasoning	-1,29%	0,57	0,10	-1,26%	0,29	0,14
										Acoustic proof-reading				0,20%	0,71	0,03
										Reading and comprehension	3,47%	0,01	0,22	1,33%	0,24	0,18
de Gids et al.	2007	Nederland	Spring	Field intervention. Ventilation rates were changed	Elementary school	47	10-11	N.A.	620- 2125 (1373)	Neuro-psychological tasks						
Petersen et al.	2015	Denmark	Autumn (September-October)	Field intervention. Ventilation rates were changed	4 classrooms in 2 elementary schools	40	10-12	Weekly average (when pupils were present)	880- 1510 (1195)	Addition	0,84%	0,01		0,16%	0,26	
										Number comparison	0,62%	0,03		0,12%	0,87	
										Grammatical reasoning	-0,35%	0,04		1,02%	0,29	
										Reading and comprehension	0,50%	0,01		0,50%	0,24	

**Table A2. Summary of the data from studies examining the effect of classroom air quality on standard tests and rating schemes used to examine progress in learning**

Study	Year	Location	Season	Type	Population		Age of pupils	Range of ventilation rates (L/s per person)	Peak CO2 concentration back calculated from ventilation rates reported (measured CO2 concentration) (ppm)	Measurement of performance	Effect
					Schools	Pupils					
Shaughnessy et al.	2006	USA (Midwest)	Winter and spring	Cross-sectional	54 classrooms in 54 elementary schools	N/A	10	0.9-11.74	765-5200 (2982)	Standard math and reading test scores	Percentage of students scoring satisfactorily and above on math test (passing the test) increased significantly (P<0.10) with increasing ventilation; no effect on reading test scores
Haverinen-Shaughnessy et al.	2011	USA (Midwest)	Winter and spring	Cross sectional	104 classrooms in 104 elementary schools	5178	10	0.9-7.1	1000- 5200 (3100)	Standard math and reading test scores	2.9% higher number of students scoring satisfactorily and above on math test (passing the test) for each 1 L/s per person increase in ventilation rate; the effect was significant (P=0.033) 2.7% higher number of students scoring satisfactorily and above on reading test (passing the test) for each 1 L/s per person increase in ventilation rate; effect not significant (NS)
Gaihre et al.	2014	Scotland	Late spring (May, June)	Cross-sectional	60 classrooms in 30 elementary schools	N/A	6-7, 10-11	N/A	590-2115 (1352)	Reading, writing and numeracy	No significant effect
Haverinen-Shaughnessy et al.	2015	USA (Southwest)	Winter and spring (January to April)	Cross-sectional	140 classrooms in 70 elementary schools	3019	10	<2-11.3	1000- 5200 (3100)	Standard math, reading and science test scores	0.5% increase in scores on math for each 1 L/s per person increase in ventilation rate; the effect was significant (P=0.006). 6.7 points increase in mathematics (P=0.006), 4.3 points increase in reading (P=0.078) and 4.6 points increase in science (P=0.074) for each 1 L/s per person increase in ventilation rate; score>2400 points (commended performance); average score on mathematics 2286 points
Mendell et al.	2015	USA (California, 3 climate zones)	All seasons	Longitudinal 2-year long cross-sectional study in 3 school districts	150 classrooms in 27 elementary schools	5000	8-10	1.4-19.4	965-1950 (1458)	Standard math and English-arts test scores	0.6% increase in performance of English-arts at ventilation rate <7L/s per person and 0.15% increase at ventilation rate >7 L/s per person for each 1 L/s per person increase in ventilation rate; the effect was significant (P=0.01) For English-arts 0.6 point increase per 10% higher ventilation (P=0.01) and for math 0.5 point per 10% increase in ventilation (P=0.23); average score 379 points (above basic of 350)
Toftum et al.	2015	Denmark	Fall/Winter	Cross-sectional with retrospective data on test performance	820 classrooms in 389 elementary schools	N/A	8-16	N/A	400- 4000 (2300)	Danish national test scheme: language fluency, competency in math, knowledge of English, knowledge in science arts (physics/chemistry, geography and biology)	No significant association between measured CO2 and the scores on national test scheme; there was a significant effect of type of ventilation pupils scoring higher in classrooms with mechanical ventilation compared to natural ventilation

<b>Table A3. Summary of CO<sub>2</sub> generation rates (L/s) reported in the studies examining the effect of indoor air quality on learning outcomes</b>			
<b>Study</b>	<b>Year</b>	<b>CO<sub>2</sub> generation rates (L/s per person)</b>	
		<b>Teachers</b>	<b>Children</b>
Myrvold	1996	N.A. <sup>1</sup>	
Myrvold	1997	0.0052	
Shaughnessy, R. J.	2006	N.A. <sup>2</sup>	
Coley et al.	2007	0.0038	
Bakó-Biró et al.	2007	N.A. <sup>1</sup>	
Wargocki and Wyon (T)	2007	0.0049 (±0.0004) <sup>3</sup>	
Wargocki and Wyon (V1E)		0.0054 (±0.0004) <sup>4</sup>	
Wargocki and Wyon (V2E)	2007	0.0052 (±0.0004) <sup>4</sup>	
Ribic	2007	N.A. <sup>1</sup>	
Haverinen-Shaughnessy et al.	2011	0.0052	0.0043
Bakó-Biró et al.	2012	0.0034 (±0.0002) <sup>5</sup>	
Gaihre et al.	2014	N.A. <sup>1</sup>	
Haverinen-Shaughnessy and Shaughnessy	2015	0.0052	0.0043
Mendell et al.	2015		0.0043
Petersen et al.	2015	0.0057	0.0040
<b>Mean teachers and children separate (SD)</b>		<b>0.0054 (±0.0003)</b>	<b>0.0042 (±0.0002)</b>
<b>Mean teachers and children together (SD)</b>		<b>0.0047 (±0.0007)</b>	
<sup>1</sup> CO <sub>2</sub> measurements were reported but no equivalency to ventilation rates was given <sup>2</sup> Ventilation rates were reported but no equivalency to CO <sub>2</sub> concentration was given <sup>3</sup> Average production of CO <sub>2</sub> 10 to 11-year-old children + teacher <sup>4</sup> Average production of CO <sub>2</sub> 12-year-old children + teacher <sup>5</sup> The carbon dioxide production per person was estimated, considering the children and adults present in the classroom. Body parameters of children: A <sub>DuBois</sub> = 1.15 ± 0.05m <sup>2</sup> at normal activity levels of 1.2 met.			