

Evaluating Healthy Building Investments on the Workforce:

Evidence, Methods, and Application

Presented by: Juan Palacios (jpalacio@mit.edu)

Types of Outcomes

Impact
Outdoor
Environment

- Environmental studies show:
 - Outside air pollution effects on [Zivin and Neidell, 2013] :
 - Mortality
 - Human capital formation
 - Productivity
- Higher mortality rates at (extremely) high and low temperatures [Deschenes, 2014]
- We spend 90% of our time indoors. Buildings are key to avoid exposure to environmental hazards:
 - Sorting: moving away from the sources [Chay and Greenstone, 2005, Currie et al., 2015]
 - Spending more time indoors in highly polluted days [Zivin and Neidell, 2014]

Buildings
and
Adaptation

Healthy Building Headlines

BUSINESS The New York Times PLAY THE CROSSWORD

SQUARE FEET
How Healthy Is Your Office?



Harvard
Business
Review

Social Responsibility | What Makes an Office Building “Healthy”

SOCIAL RESPONSIBILITY

What Makes an Office Building “Healthy”

by Joseph G. Allen and John D. Macomber

April 29, 2020

Summary Save Share Comment 10 Print



Forbes

Billionaires Innovation Leadership Money Business Small Business Lifestyle List

1,421 views | Jun 8, 2020, 10:32pm EDT

Why COVID-19 Raises The Stakes For Healthy Buildings



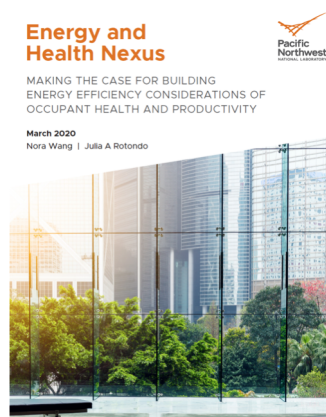
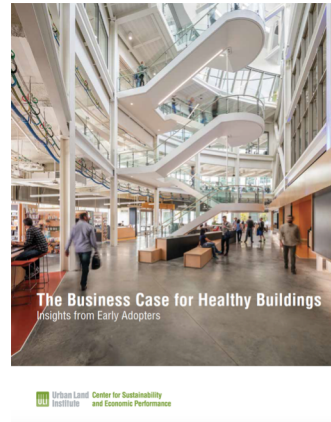
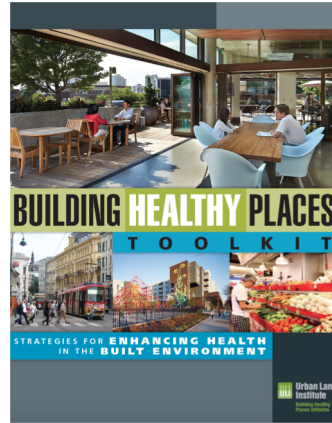
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- [1] New York Times
- [2] Harvard Business Review
- [3] Why COVID-19 Raises the Stakes for Healthy Buildings

Healthy Building Industry Reports



Types of Outcomes

Labs

- Relative to 600 ppm, at 1,000 ppm CO₂, moderate & statistically significant decrements occurred in 6 of 9 scales of decision-making performance. At 2,500ppm, large and statistically significant reductions occurred in 7 scales of decision-making performance (raw score ratios, 0.06-0.56), but performance on the focused activity scale increased.(Satish et al. 2012)
- On average, cognitive scores were 61% higher on the Green building day and 101% higher on the two Green+ building days than on the Conventional building day. The largest effects were seen for Crisis Response, Information Usage, and Strategy, all of which are indicators of higher-level cognitive function and decision making. (Allen et al. 2016)

Offices

- Increasing outdoor air supply, by approximately 2x, led to improved operator talk performance by between 7% to 9% at higher temperatures. Decreasing temperature from a marginally warm thermal sensation to a marginally cool thermal sensation at lower ventilation rate also improved operator talk performance by between 5% and 13%. (Tham & Willem, 2005)

Classrooms

- Due to the intervention the fresh air supply increased from 0.3-05 to 13-16 L/s per person that increased pupils' work rate by ~7% in addition (Bakó-Biró et al. 2007)
- Performance was significantly improved in 4 of 4 performance tests when the outdoor air supply rate was increased from an average of 1.7 to 6.6 l/s per person. CO₂ concentration was decreased from an average of approx. 1,500 ppm to 900 ppm due to the increased outdoor air supply rate.The performance improvements in the total sample,addition (6.3%), number comparison (4.8%), grammatical reasoning (3.2%), and reading & comprehension(7.4%), were all related to the number of correct answers made within the 10 min of each test. (Peterson et al. 2016)

Literature Dashboard

Literature Context

40

Peer-Reviewed Studies

3

Continents

10

Countries



Participant Representation

~6,150

Participants

60%

Students

9-45

Age Range

~24.1

Average Age



Study Characteristics

22.5%

Lab Studies

22.5%

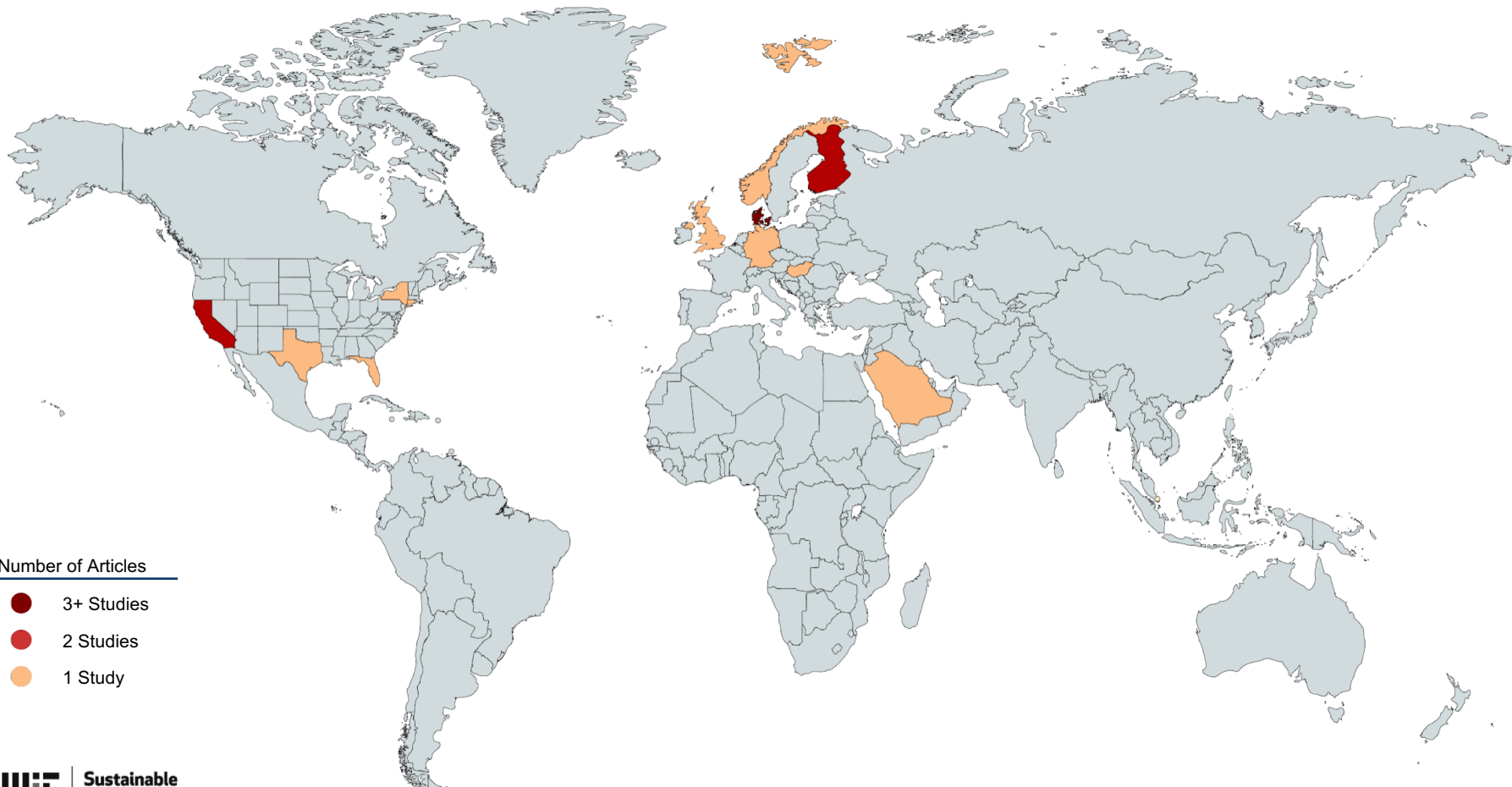
Classroom Studies

50%

Controlled Environment



Geographical Representation

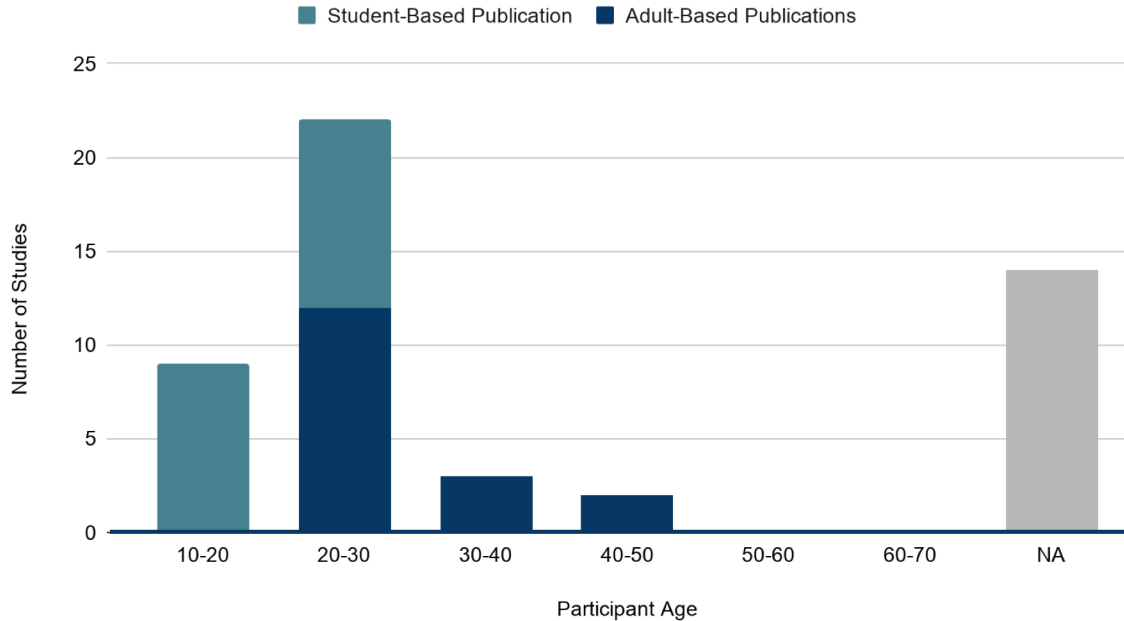


Number of Articles

- 3+ Studies
- 2 Studies
- 1 Study

Age Distribution and Counts

Count vs. Mean Participant Age in Collected Articles



Study Characteristics

~24.1

Average Age in Publications

9-70+

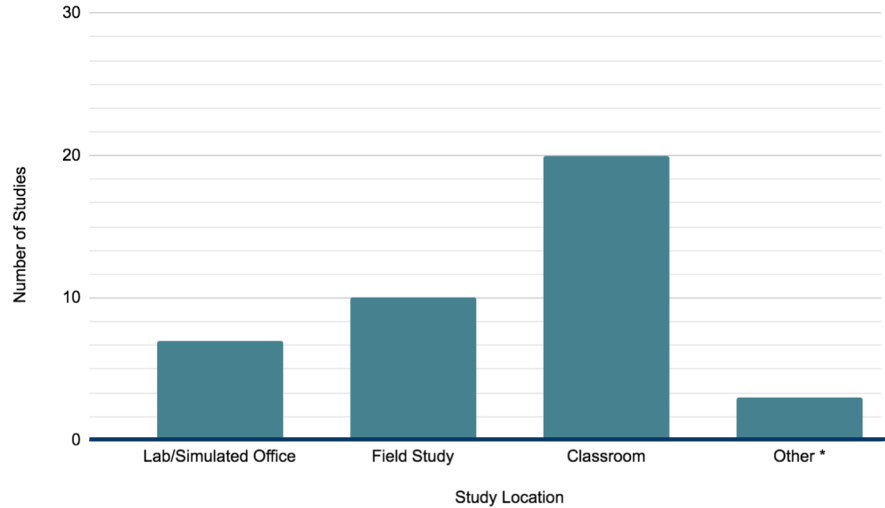
Age Distribution

17.8

Years Younger than US Average Age

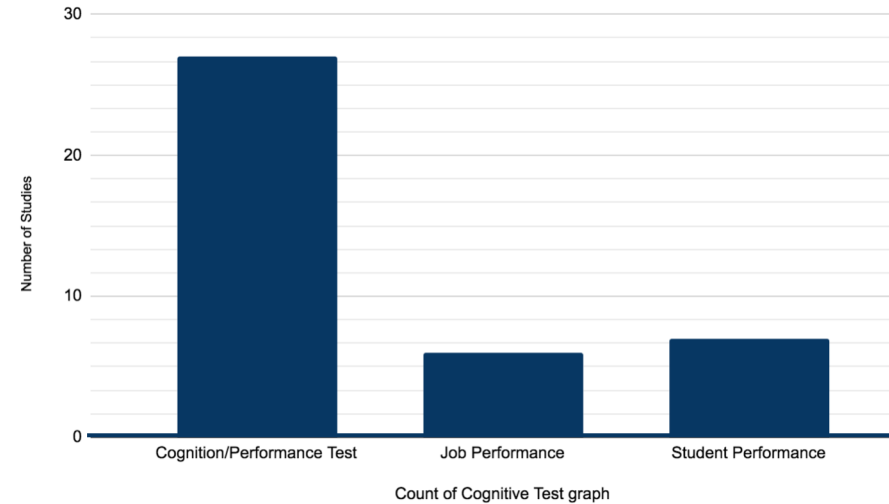
Setting and Tasks

Study Location in Collected Articles



*Submarine
Airplane
Simulated Space Chamber

Cognitive Evaluation Type



Study Evaluation

Remuneration

Remuneration

No Payment

22.5%

Participation Stipend

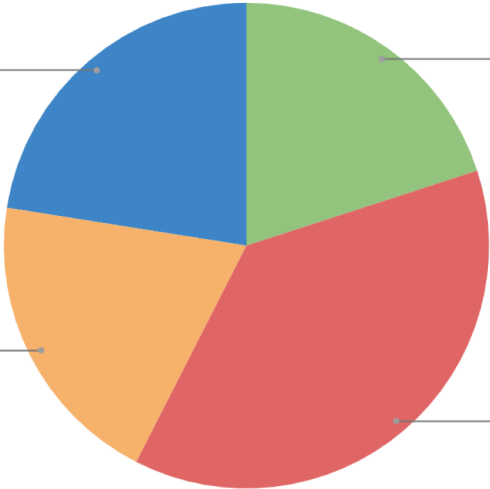
20.0%

Wages

20.0%

NA

37.5%



*0% of studies gathered provided a performance-based compensations

Moving to Productivity

What is the impact of moving to a new healthy building? Evidence from 1,400 municipality workers



- Constructed in the 1980s
- No ventilation system



- Ventilation based on the principles of natural circulation
- Green wall

The Moving Experiment

Measurement design



Difference in Difference Strategy

$$Y_{it} = \mu_i + \tau_t + \delta Relocated * AfterMove_{it} + \beta X_{it} + \epsilon_{it} \quad (1)$$

- Y_{it} includes the set of outcome variables describing the perceived working conditions and health status of individual i at time t . We include the scales describing the perceived noise, temperature, light, and air quality in the workplace. Finally, we consider a dummy variable indicating whether the individual suffers from SBS.
- Relocated: Group of individuals moved to the new building. After Move: Survey takes place after the moving date. Our prime parameter of interest is δ , describing the average change in the outcomes (Y_{it}) after the move for the employees who relocated to the new building.
- The individual fixed effects (μ_i) should reduce bias resulting from differences between the movers and non-movers.
- In addition, we include time dummy variables τ_t for each survey wave, non-parametrically adjusting for possible shocks in the city or employer that coincide with the move (e.g., pollution reduction in the city).
- We include a set of individual time-varying controls, X_{it} . The set of controls includes the average working hours per week and the reported scales rating the *Office Layout*
- ϵ_{it} is the error term, which might be correlated within individuals. Therefore, we cluster standard errors at the individual level.

Stability of Results:

$$Y_{it} = \mu_i + \tau_t + \sum_{k=1}^K \delta_k Relocated * AfterMove_{it}^k + \beta X_{it} + \epsilon_{it} \quad (2)$$

Thus, $Relocated * AfterMove_{kit}$ is an indicator for being k time periods relative to the moving date. The reference category is $k = 0$; hence, the post-treatment effects are relative to the year immediately before the treated individuals were relocated to the new building.

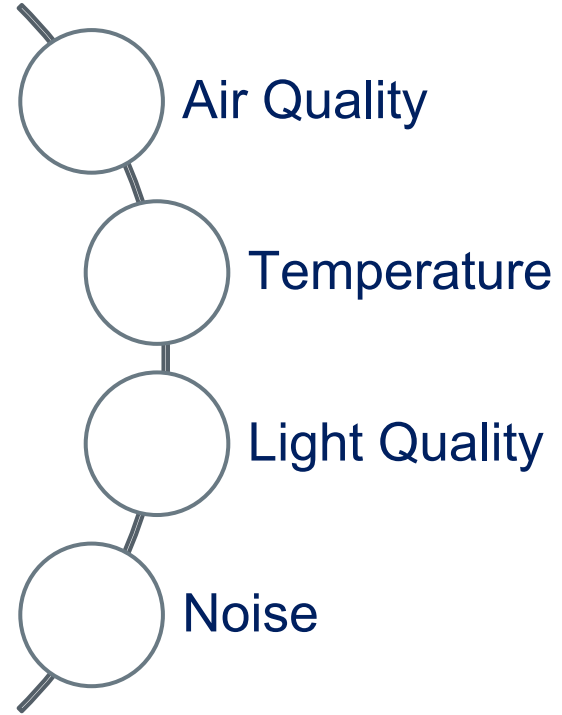
Measuring Perceived Working Conditions

The scales

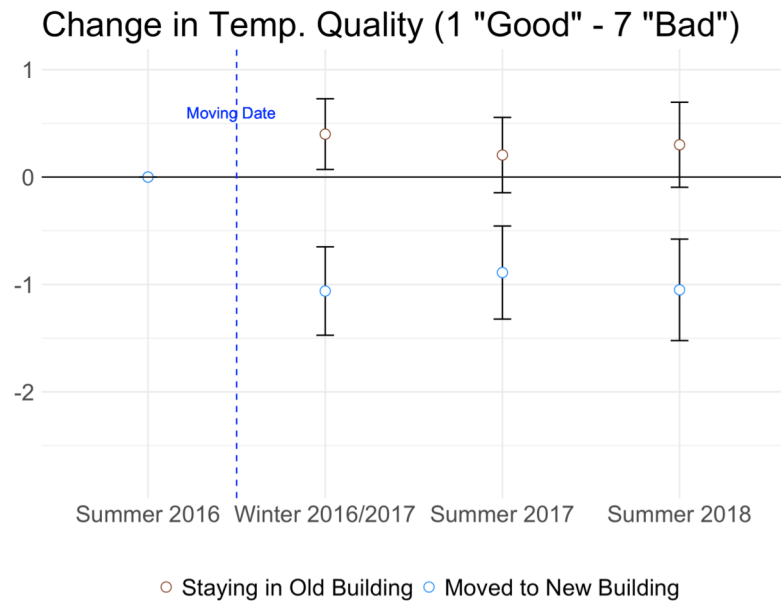
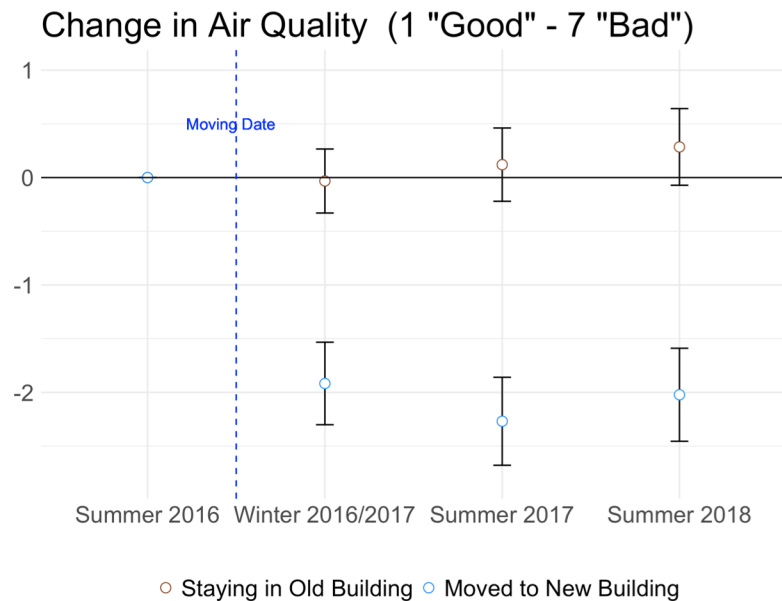
”Hoe tevreden bent u over de luchtkwaliteit op uw werkplek (bv. muffe lucht, zuiverheid, geuren)?”



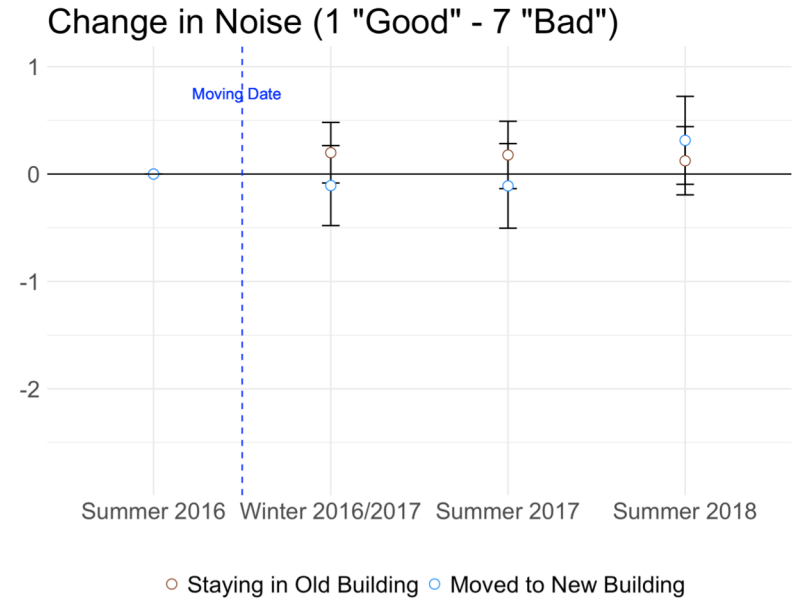
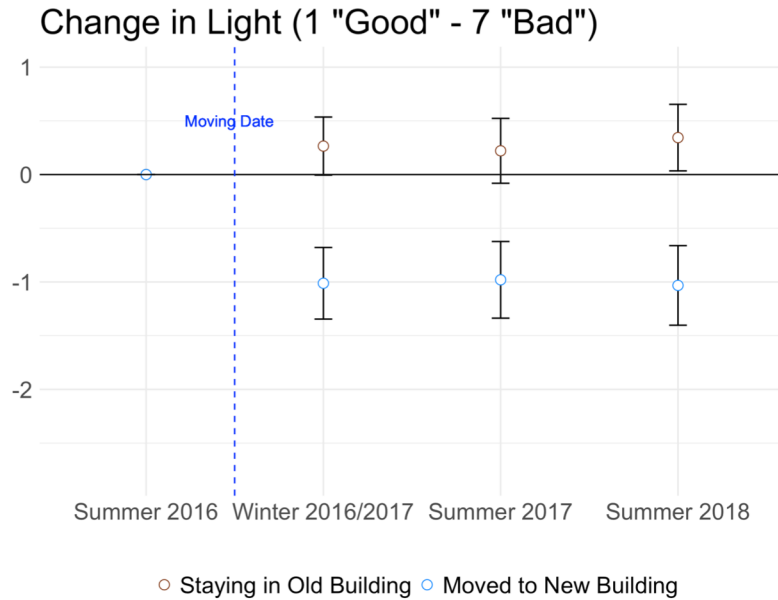
“In zijn algemeenheid: ondersteunt of hindert de luchtkwaliteit op uw werkplek uw werkzaamheden?”



Changes in EQ Perception

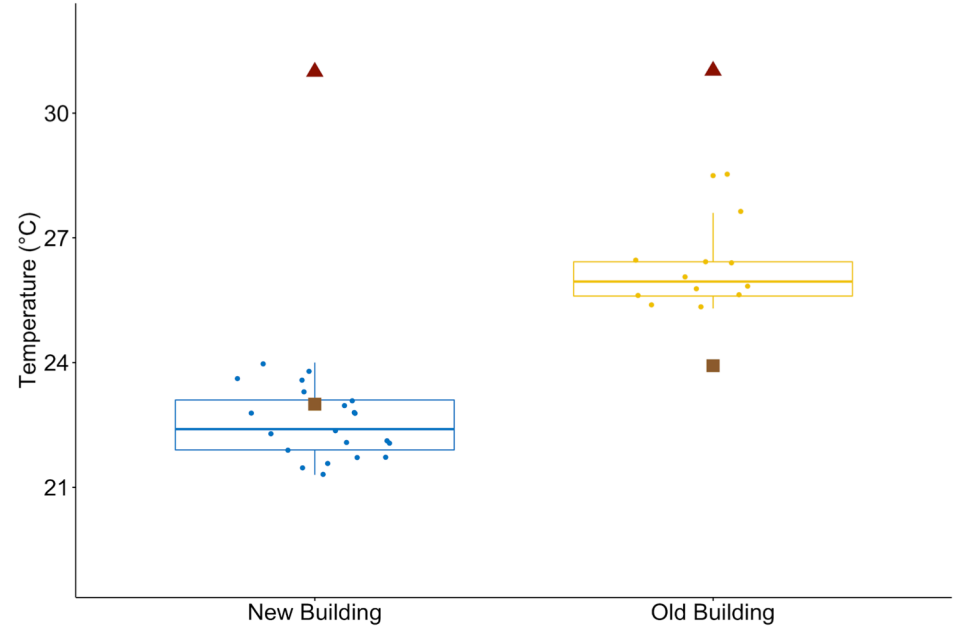
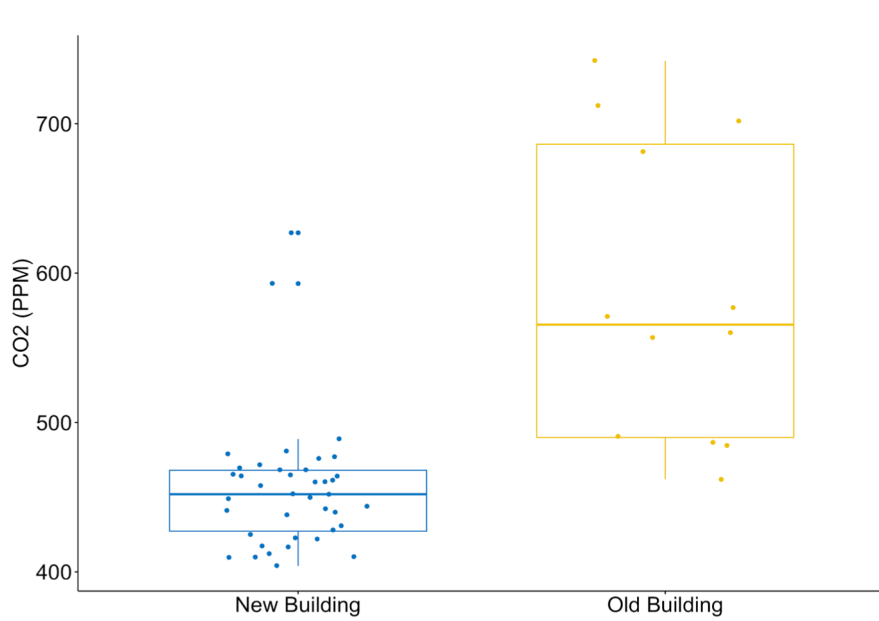


Changes in IEQ Perception

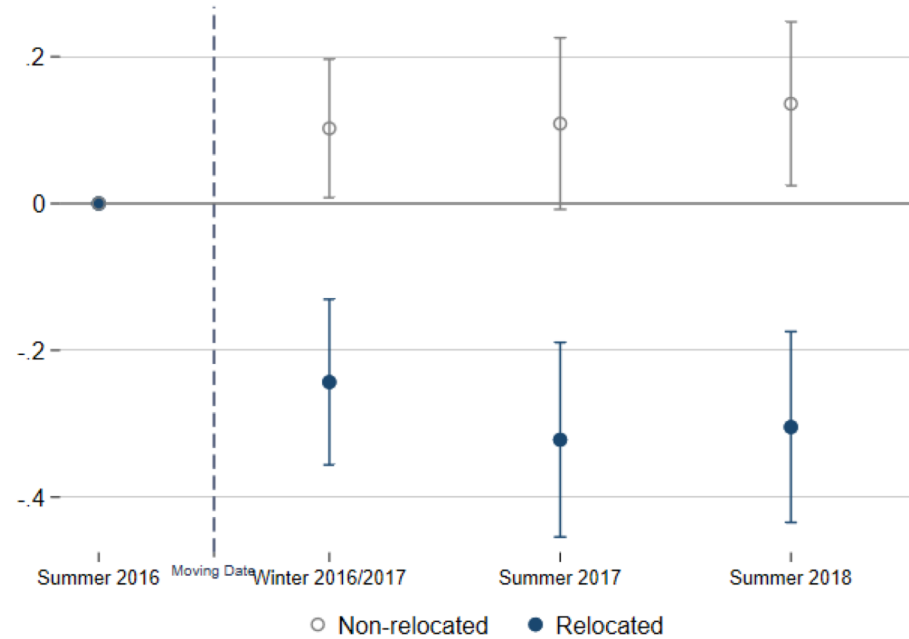


Sensor Data

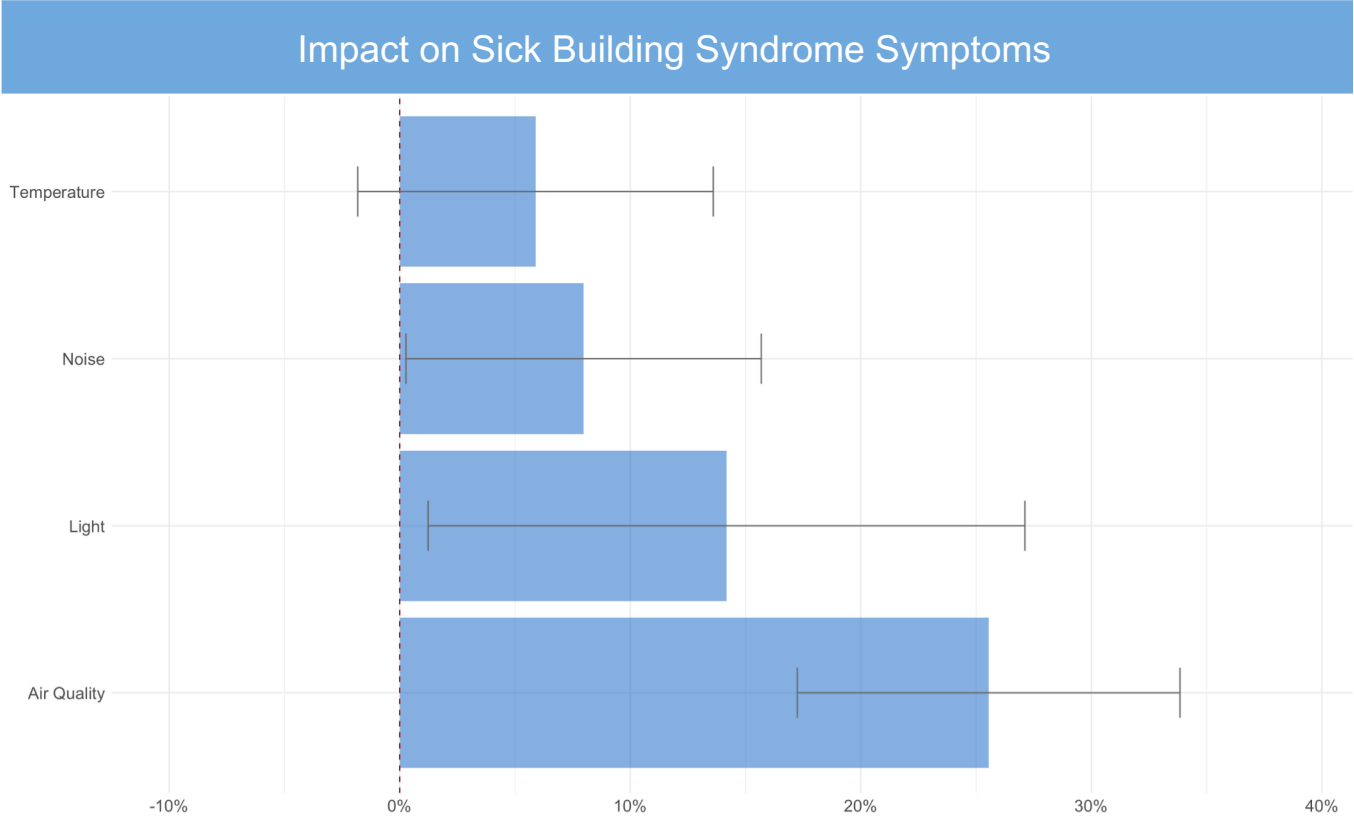
Data From Measurement Campaigns



Sick Building Syndrome



Impact on Worker Health



Associated drop in proportion reporting sick building syndrome associated with scales.

Estimates based on fixed effects regression

Sick Building Syndrome

		(1) Full Sample	(2) Men	(3) Women	(4) Age Below 31	(5) Age 30-50	(6) Age Above 50
<i>Health Indicator</i>							
Sick Building Syndrome	Dummy (1 = Yes)	-0.216*** (0.056)	-0.277*** (0.075)	-0.223** (0.078)	-0.355 (0.223)	-0.216* (0.085)	-0.255** (0.078)
Wave-Fixed Effects		YES	YES	YES	YES	YES	YES
Individual-Fixed Effects		YES	YES	YES	YES	YES	YES
Controls		YES	YES	YES	YES	YES	YES

Robust standard error clustered at the individual level.

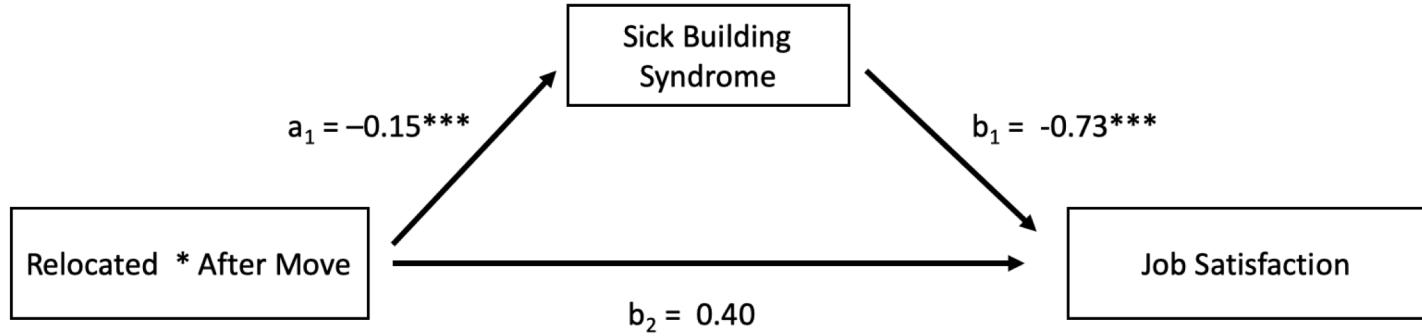
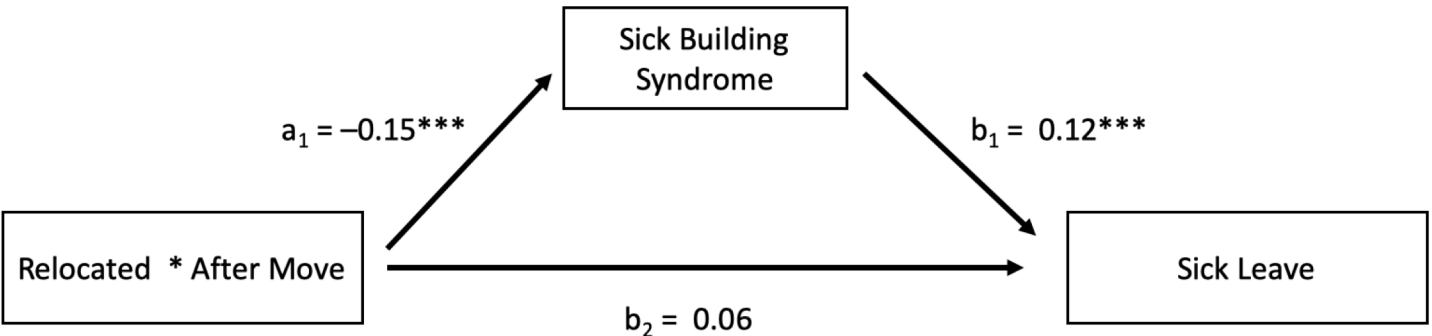
* p<0.1,

** p<0.05,

*** p<0.01.

Mediation Analysis

Impact on sick building syndrome symptoms



Discussion

- There is a shortage of field studies estimating the benefits of healthy buildings on real workforce.
- This study investigates the impact of the indoor environmental conditions in the workplace on the health and job satisfaction of employees, as core factors of productivity.
- We exploit a natural experiment, based on the relocation of 70% of the workforce of a municipality in the south of the Netherlands.
- We observe a 42% reduction in the prevalence of SBS symptoms.
- Results from a mediation analysis:
 - Job satisfaction increased by 1.2%
 - Drop in the prevalence of sick leave by 2%

Thank you.

Juan Palacios
(jpalacio@mit.edu)