This is the post print version of the article, which has been published in Indoor Air.
2017, 27(2), 329-337.
http://dx.doi.org/10.1111/ina.12303

The associations of indoor environment and psychosocial factors on subjective evaluation of indoor air quality among lower secondary school students – a multilevel analysis

Eerika Finell*

Ulla Haverinen-Shaughnessy

Asko Tolvanen

Seppo Laaksonen

Sakari Karvonen

Reijo Sund

Vesa Saaristo

Pauliina Luopa

Timo Ståhl

Tuula Putus

Juha Pekkanen

*Requests for reprints should be addressed to Eerika Finell, School of Social Sciences and Humanities, Linna, 33014 University of Tampere, Finland. E-mail: eerika.finell@uta.fi

Other affiliations:

Ulla Haverinen-Shaughnessy: Department of Health Protection, National Institute for Health and Welfare, P.O. Box 95, 70701 Kuopio, Finland

Asko Tolvanen: Methodology Centre for Human Sciences, P.O. Box 35, 40014 University of Jyväskylä, Finland

Seppo Laaksonen: Department of Social Research, P.O. Box 68, 00014 University of Helsinki, Finland

Sakari Karvonen: Department of Health and Social Care Systems, National Institute for Health and Welfare, P.O. Box 30, 00271 Helsinki, Finland

Reijo Sund: Centre for Research Methods, Department of Social Research, P.O. Box 18, 00014 University of Helsinki, Finland

Vesa Saaristo: Department of Welfare, National Institute for Health and Welfare, Biokatu 10, 33520 Tampere, Finland

Pauliina Luopa: Department of Welfare, National Institute for Health and Welfare, P.O. Box 30, 00271 Helsinki, Finland

Timo Ståhl: Department of Welfare, National Institute for Health and Welfare, Biokatu 10, 33520 Tampere, Finland

Tuula Putus: Department of Public Health, University of Turku, Lemminkäisenkatu 1, 20520 Turku, Finland

Juha Pekkanen: 1) Department of Public Health, P.O. Box 20, 00014 University of Helsinki, Finland, 2) Department of Health Protection, National Institute for Health and Welfare, Finland

Abstract

Subjective evaluation of indoor air quality (subjective IAQ) reflects both building related and psychosocial factors, but their associations have rarely been studied other than on the individual level in occupational settings and their interactions have not been assessed. We therefore studied whether schools' observed indoor air problems and psychosocial factors are associated with subjective IAQ, and their potential interactions. The analysis was done with a nationwide sample (N= 195 schools/ 26946 students) using multilevel modelling. Two datasets were merged: 1) survey data from students, including information on schools' psychosocial environment and subjective IAQ and 2) data from school principals, including information on observed indoor air problems. On the student level, school-related stress, poor teacher-student relationship, and whether the student did not easily receive help from school personnel were significantly associated with poor subjective IAQ. On the school level, observed indoor air problem (standardized beta = -.43) and poor teacher-student relationship (standardized beta = -.22) were significant predictors of poor subjective IAQ. In addition, school-related stress was associated with poor subjective IAQ, but only in schools without observed indoor air problem (standardized beta = -.44).

Keywords (6): indoor air quality, psychosocial environment, stress, multilevel analysis, upper secondary school, indoor air problems.

Practical implications: Although school's psychosocial environment influences subjective IAQ, it may have a stronger effect in buildings without observed indoor air problems than in buildings with such problems. In schools with observed indoor air problems subjective IAQ may, to a high degree, reflect this factual situation. These findings should be taken into account when questionnaires are used to assess IAQ.

Introduction

Subjective evaluation of indoor air quality (subjective IAQ) has been used in many studies when evaluating the quality of indoor environment (e.g., Dutton, 2014; Pereira et al., 2014) as well as in some follow-up studies, for example before and after mold remediation (Haverinen-Shaughnessy et al., 2004; Haverinen-Shaughnessy et al., 2008). Indoor environmental quality problems in schools are relatively common (e.g. Haverinen-Shaughnessy et al., 2012) and they have been associated with adverse health effects (e.g. Borras-Santos et al., 2013, Mendel et al., 2011). Therefore it is important to study whether students can reliably evaluate their indoor environment and how possible complaints should be interpreted.

Subjective IAQ seems to be sensitive to both building related and psychosocial factors. There is evidence that building factors influence how indoor air quality (IAQ) is perceived (Bakke et al., 2007; Nordström et al., 1999). For example, ventilation and thermal comfort has been associated with perception of IAQ (Norbäck and Nordström, 2008; Turunen et al., 2014, Wang et al., 2015). In addition, previous research shows that psychosocial factors such as work stress, job support, work satisfaction, and possibilities to control environmental conditions significantly predict individuals' complaints about indoor environmental quality (Brauer and Mikkelsen, 2010; Frontczak et al., 2011; Lahtinen et al., 2004; Smedje et al., 1997). This poses a serious challenge to occupational and school health services and those in charge of the building maintenance and repairs (e.g., Magnavita, 2015).

Subjective IAQ and psychosocial factors

Although there is some evidence that psychosocial factors predict subjective IAQ *on the individual level*, there is much less information on how these factors may predict it *on the organizational level*. Therefore, an important research question is whether psychosocial environment (shared by the whole group) influences individuals' subjective IAQ. Based on the "sick building syndrome (SBS)" literature, it has been suggested that individuals' complaints, to a high degree, are reflecting problems in the psychosocial work environment (Lahtinen et al., 2004). If this is the case, the organization's psychosocial environment should be an important predictor also on the organizational level. Nevertheless, the only study that has tested this hypothesis reported solely non-significant findings (Brauer and Mikkelsen, 2010). In addition, the study included only workplaces with no obvious IAQ problems.

Furthermore, there are not previous studies which has analyzed whether there is an interaction between building related and psychosocial factors. Frese and Zapf (1999) have proposed that individuals perceive strong contextual stressors (such as high room temperature) similarly: there is only a little disagreement between individuals in such issues. Therefore, it is possible that subjective IAQ in buildings with observed indoor air problems may be based more on the factual quality of the indoor air as compared to buildings where there are no observed indoor air problems (see Lahtinen et al., 2002). However, if the contextual stressor is mild or non-existing, other factors such as personal characteristics (e.g., sensitivity to stress) might influence more on the overall perception. In this case, other factors (such as work satisfaction) might influence subjective IAQ more than in the first case. However, to our knowledge this hypothesis has not been tested so far.

Present study

This study addresses the above issues in a school context among upper secondary school students. The first aim of this study is to analyze whether building related and psychosocial factors associate with subjective IAQ on the school level and psychosocial factors on the student level. Based on the literature (Bakke et al., 2005; Norbäck and Nordström, 2008; Lahtinen et al., 2004) we hypothesize that problems in building related and psychosocial factors deteriorate subjective IAQ on the school level and problems in psychosocial factors on the student level (H1). We analyze psychosocial factors from three perspectives: students' school-related stress, the support and aid received from school personnel (both teachers and other school personnel), and students' relationship with their classmates. The second aim is to test whether psychosocial factors associate with subjective IAQ differently in schools with observed problems in indoor air quality as compared to schools without such problems. We predict that observed IAQ problems modify the associations between psychosocial factors and subjective IAQ; psychosocial factors have a stronger influence on subjective IAQ in schools without an observed IAQ problem than in schools with such a problem (H2) (Frese and Zapf, 1999).

Material and methods

Data and participants

The data were obtained from two sources: a) School Health Promotion Study (SHP) 2013 and b) Benchmarking System of Health Promotion Capacity Building (BSHPCB) data collections from comprehensive schools in 2013.

SHP is a nationwide classroom survey, which has monitored the health and well-being of Finnish adolescents (14–18-years of age) since 1996. It is coordinated by the National Institute for Health and Welfare (THL), with the approval from THL's ethical committee. In 2013, the data were collected as a classroom survey during school lessons in April, and 90% of the comprehensive schools in Finland participated in it.

BSHPCB is a nationwide benchmarking tool for local governments and schools to manage, plan, and evaluate their own health promotion activities in the basic education. The data collection form is filled in by the school's principal together with a student welfare team. *BSHPCB* is run by THL and the Finnish National Board of Education (FNBE). The data were collected between October and December 2013, and 80% of the comprehensive schools in Finland participated in it.

This study focuses on the upper secondary school students in grades 8^{th} and 9^{th} (14 - 16 years old). We included schools into analyzes using two variables from *BSHPCB*. The first variable measured whether and when the most recent inspection of the health and safety of the school environment and the well-being of the school community was carried out. This inspection is required by Health Care Act 1326/2010 and it states that all schools in Finland have to be checked in every three years. This official triennial inspection is done in co-operation with school health service, representatives of the school (e.g. principal), representatives of health authority, occupational health care, and occupational health and safety and authorities responsible for construction and maintenance of school buildings. The inspection is large and it should include all possible factors (not only building related) which could influence the well-being of school community (Hietanen-Peltola and Korpilahti, 2015). Herewith, we explain the inspection focusing only on the building related factors.

During the inspection, following building related factors should be inspected: the condition of the building and HVAC systems, including possible problems related to dampness, ventilation, air tightness of the building envelope and pressure relations, the condition of building materials, how the building has been maintained and renovated, and whether microbiological contaminants has been found, among other issues. Before the initial inspection, responsible authorities should collect all the existing documents including results from possible questionnaires on IAQ and symptoms, IAQ measurements, and other building related reports. If it is considered necessary, additional information should be collected. The actual inspection starts by a meeting between the authorities. In this meeting, existing documents are presented and the building's possible risk factors are mapped. After the meeting, the authorities conduct a building walkthrough, focusing on areas where problems has been found or suspected. After the walkthrough, another meeting is held, in which follow-up actions are decided based on all information collected (Hietanen-Peltola and Korpilahti, 2015).

For the analyses, we selected only schools in which the inspection was carried out in 2012 or 2013. The second variable measured whether or not there were biological exposures observed in the school (see Measures). We included into analyzes those schools where 1) biological exposures were identified during the check but the problems had not been remediated and 2) no indoor air problems were identified. Schools with less than 10 students were excluded from the analysis

(N=66, 0.2%). In addition, we excluded one school with 16 students, because it was considered to be on outlier based on its psychosocial status. Excluded from the analysis were also those respondents, who reported their age at least two years younger or three years older than the average age of their classmates (n= 64, 0.2%), as well as those who did not report their subjective IAQ (n= 219, 0.8%). The final data consist of 26946 students from 195 schools. About 63 per cent of the students were from schools without observed indoor air problems (16989 students from 127 schools).

Measures

Outcome variable

The dependent variable was *the subjective evaluation of indoor air quality (subjective IAQ).* The item "In your school, do the following conditions disturb your school work? Insufficient ventilation or bad indoor air") was measured on a 4-point scale (1= not at all, 2 = rather little, 3 = rather much, 4 = very much). The raw scores were transformed to a 0-100 scale, in order to make them more easily interpretable, after which the scale was reversed so that high numbers indicate good subjective IAQ and small numbers low subjective IAQ (i.e. 1=100, 2=66.6667, 3=33.3333, 4 = 0). The data source was SHP.

Predictors

Psychosocial factors were measured by four summed variables. The data source for all these variables was SHP and they were all included in both student and school levels in the models.

The perceived quality of teacher-student relationship was measured by four items: "Teachers encourage me to express my opinion in the classroom"; "Teachers are interested in how I am doing"; "Teachers treat us students fairly" and "The opinions of students are taken into consideration in the development of school work". The response scale was 1 = fully agree, 2 = agree 3 = disagree, 4 = fully disagree. We transformed raw scores to a 0-100 scale and then calculated a mean rating of the items. If the respondent had not answered to all items, the score was not calculated. These items have been used in many previous studies as indicators of teacher-student relationship (Karvonen et al., 2005; Konu et al., 2002; Virtanen et al., 2009). The reliability was reasonable (Cronbach alpha = .716).

The *class spirit*[1] was measured by three items: "The students in my class get along well, "The discipline in my classroom is good" and "The mood in our class is such that I dare to speak my opinion freely". The response scale was the same, and the raw scores were transformed, and the mean rating was calculated similarly as in the perceived quality of teacher-student relationship. These items have been used previously by Karvonen and his colleagues (2005) as an indicator of class spirit. The reliability was reasonable (Cronbach's alpha = .667).

The student's perception of the aid received from the school personnel was measured by four items asking: "If you wanted to visit your school nurse, physician, social personnel or psychologist, how easy would it be to get an appointment"? Each group of personnel was evaluated separately. The response scale was 1 = very easy, 2 = fairly easy, 3 = fairly difficult and 4 = very difficult. The raw scores were transformed and the mean rating was calculated as above (Cronbach's alpha = .781).

The school-related stress was measured by three items dealing with the emotions related to the school work: "Have you experienced the following feelings related to your schoolwork?" a) I feel overwhelmed by school work, b) It feels that there is no point in studying, c) I feel inadequate

[1] By the term class spirit we refer to the perceived peer relationships in the class (also referred to as peer classroom climate, e.g. Nelson and DeBacker, 2008).

at my studies. The response scale was 1 = hardly ever, 2 = a few times a month, 3 = a few days a week and 4 = almost daily. The raw scores were transformed and the mean rating was calculated as above (Cronbach's alpha = .752).

The item "Were the following issues evaluated in the most recent inspection: Exposure to biological agents (indoor air, mold, etc.)" measured whether biological exposures were found in school during the triennial assessment on the health and safety of school environment. The response options were 1 = no data available, 2 = not included in the inspection, 3 = inspected, no deficiencies detected, 4 = inspected, deficiencies detected but not yet corrected, 5 = inspected, deficiencies detected and corrected. In this study we focus only on the options 3 and 4 and they were recoded as follows: 0 = was checked, no problems were found and 1 = was checked, problems were found, no yet corrected. The resulting variable is referred to as 'observed indoor air problem'. The data source was BSHPCB.

Background variables

Gender and *age* were used only as student level background variables because of their very low intraclass correlations (ICC) [2] (see Supplementary material). The school's size (i.e. number of students) reported in BSHPCB was used as a school level background variable. The father's level of education was used as measure of social economic status (SES) on student and school levels. The original response options were 1 = comprehensive school or primary school, 2 = high school or vocational education institution, 3 = occupational studies in addition to high school or vocational education institution, 4 = university, university of applied sciences, or other higher education institution, 5 = no education. The item was dichotomized by pooling all other categories except for category 4, leading to (0) no university degree vs. (1) university degree (see Table 1).

[2] Age: ICC = 0.003; gender: ICC = 0.005

Statistical analyzes

A two-level linear regression model (MLM) (Hox, 2010; Snijders and Bosker, 2012) was built and then analyzed using Mplus statistical software 7.0 (Muthén and Muthén, 1998-2012). Given that the data are hierarchical (school children nested within schools), multilevel analysis is used to assess both student and school level effects on student level outcome variable. Full information maximum likelihood estimation (FIML) with robust standard errors (MLR estimator in Mplus) was used as an estimation method. MLR is robust to moderate violations of assumptions such as non-normality (Hox et al., 2010; Savalei, 2010). Subjective IAQ is treated in the analysis as a continuous outcome variable. It is symmetrically distributed (see Table 1).

First we analyzed a null model in which only the outcome variable without any predictors was inserted in the model. The null model was used to estimate the variance between student and school levels and the intraclass correlation (ICC). ICC reports the proportion of the variance belonging to the school level. In addition we tested whether each predictor had a significant variation on the school level and calculated their ICCs. The equations and their interpretations are given in Supplementary material.

In order to test whether observed indoor air problem and psychosocial factors influenced subjective IAQ (H1) we estimated a random intercept model (Snijders and Bosker, 2012) (see Supplementary material). We used perceived quality of teacher-student relationship, students' perception of the aid received from the school personnel, class spirit, school-related stress and SES as student and school levels covariates. This means that each of these covariates was decomposed into two latent uncorrelated components by Mplus. The first component represents the deviation of students' answers from their school mean (i.e. student level). The second component represents the school mean (e.g. the cluster mean of school-related stress) and it reflects the deviation of each school mean from the grand mean (i.e. school level) (Asparouhov and Muthén, 2006; Muthén and Muthén, 1998 - 2012). Age and gender were included only on the student level because of their low ICCs. School size and observed indoor air problem were included only on the school level. All continuous predictors were centered by their grand means. If the estimate is significant, both unstandardized and standardized estimates are reported. The standardized estimates are provided by Mplus. They mean that if the predictor increases by one standard deviation then the outcome variable increases by the standardized estimate. Standardization helps to compare the effects of the estimates. R^2 was used as an indicator of explained variance. Mplus provides separate R^2 for both student and school levels (Muthén, 1998 - 2004). The linearity of the associations was checked.

Next, we tested whether observed indoor air problem modifies the associations between psychosocial factors and subjective IAQ (H2). This was tested by a random intercept model using multigroup MLM (Asparouhov & Muthén, 2012). Two models were built: 1) schools with observed indoor air problem and 2) schools without observed indoor air problem. In both of these models, all other predictors were identical to the model explained above. Because multigroup MLM was used, these models were tested simultaneously. We used Wald-test in order to assess whether the estimates of different models were significantly differed from each other.

Missing values

Number of missing values varied between variables. Gender, subjective IAQ, and observed indoor air problem had the lowest percentages of missing values (0%) and SES had the highest (11%). Values were assumed to be missing at random (MAR) (Little, 1988; Rubin, 1976). FIML is a recommended method for handling missing data because it uses all available data for estimation and produces unbiased parameter estimators (Enders and Bandalos, 2001; see also Baraldi and Enders, 2010; Eekhout et al., 2012).

Results

There were no differences between schools with and without observed indoor air problem in the distribution of gender **(**see **Table 1).** Although the average size of schools without observed indoor air problem was smaller than the size of schools with observed indoor air problem, the difference was not significant. The means and standard deviations of the psychosocial factors and outcome variable are presented in **Table 2.**

Table 1: Descriptives of student and school level background and outcome variables by indoor environment context.

	Schools without indoor air problems (N= 127 schools)			Schools with indoor air problems (N = 68 schools)			
	Mean or % (SD)	Min – Max	N	Mean or % (SD)	Min – Max	N	p-value
Gender (female %)	49		8379	50		4971	.344
Age (years)	15 (0.6)	13.50 – 18.16	16502	15 (0.6)	13.50 – 18.08	9668	.655
SES (university level education of father %)	31		4690	31		2708	.562
School size (students per school)	333 (187.5)	67 – 936	125[b]	377 (187.5)	53 – 933	68	.118
Subjective indoor air quality (%)[a]			16989			9957	.000
Not at all	17			9			
Rather little	39			32			
Quite much	31			35			
Very much	13			24			

[a] Item is: In your school, do the following conditions disturb your school work? Insufficient ventilation or bad indoor air.
[b] Missing information from two schools.

Table 2: Descriptive statistics for subjective IAQ and psychosocial factors in the full data.

	Mean	Sd	Min – Max	N
Subjective indoor air quality	49.19	31.16	0 – 100	26946
Class spirit	38.35	19.93	0 – 100	26477
Teacher-student relationship	47.56	17.18	0 – 100	26310
School-related stress	27.77	24.66	0 – 100	26380
Aid received from school personnel	36.95	20.53	0 – 100	25131

The correlations between subjective IAQ and all the main predictors reported in **Table 3** were negative and varied between -0.09 and -0.25 on the student level and -0.13 and -0.50 on the school level.

Table 3: Correlation coefficients [d] of the main predictors and subjective IAQ on the student and school levels.

	Student level (N= 26946 students)				School level (N= 195 schools)				
	1	2	3	4	1	2	3	4	5
1. Subjective indoor air quality [a]	1	-	-	-	1	-	-	-	-
2. Class spirit [b]	-0.09***	1	-	-	-0.13	1	-	-	-
3. Teacher-student relationship [b]	-0.24***	0.24***	1	-	-0.35***	0.36***	1	-	-
4. School-related stress [b]	-0.25***	0.17***	0.37***	1	-0.30***	0.33***	0.37***	1	-
5. Aid received from school personnel [b]	-0.18***	0.17***	0.29***	0.23***	-0.22**	-0.06	0.24***	0.20*	1
6. Observed indoor air problem[c]					-0.50***	0.17*	0.22**	0.22**	0.04

*** p<0.001, ** p<0.01, * p<0.05.
[a] Scale 0 – 100. The high value indicates good subjective indoor air quality.
[b] Scale 0 – 100. The high value indicates problems in psychosocial factors.
[c] Scale 0 – 1. 1= Observed indoor air problem.
[d] The correlations were estimated using FIML with robust standard errors.

Based on *the null model* (Hox, 2010) (see Supplementary material), there was a statistically significant variability in subjective IAQ within (σ^2_{W} = 881.29, $p < 0.001$) and between schools (σ^2_{B} = 96.83, $p < 0.001$). ICC was 0.099, which means that 9.9% of variability occurred between schools. It is higher than the socioeconomic difference between schools (ICC = 0.082)[3].

[3] The ICCs of the variables inserted in both level: perceived quality of teacher-student relationship (ICC = 0.035); students' perception of the aid received form the school personnel (ICC = 0.086); class spirit (ICC = 0.037); school-related stress (ICC = 0.016).

Next, in order to study the associations between subjective IAQ and both building related and psychosocial factors (H1), we built a *random intercept model* (see **Table 4: Model 1**). On the *student level,* one unit worsening of the teacher-student relationship and less aid received from the school personnel deteriorated students' subjective IAQ by 0.27 units (standardized β = -0.16) and 0.14 units (standardized β = -0.09), respectively. In addition, one unit increase in school-related stress deteriorated subjective IAQ by 0.20 units (standardized β = -0.17). Finally, girls reported significantly lower subjective IAQ than boys (-3.14 units: standardized β = -0.05) although the effect was very small. The model explained 10% of the variance on the student level. (R^2 = 0.101). *On the school level,* only teacher-student relationship and observed indoor air problem remained significant after all the variables were included in the model. One unit increase on how negatively students (on the average) perceived their school's teacher-student relationships deteriorated respondent's subjective IAQ by 0.68 units (standardized β = -0.22). The difference between schools with observed indoor air problem and without observed indoor air problem in subjective IAQ was 8.84 units (standardized β = -0.43). After the background variables were inserted into the null model, between school variance decreased from 96.83 to 95.73 (R^2= 0.007). Respectively, after inserting psychological factors into this model, this variance decreased from 95.73 to 78.08 (R^2 change = 0.179). Finally, inserting observed indoor air problem decreased variance from 78.08 to 61.17 (R^2 change = 0.165). In total, the model explained 35% of the between school variance (R^2 = 0.351).

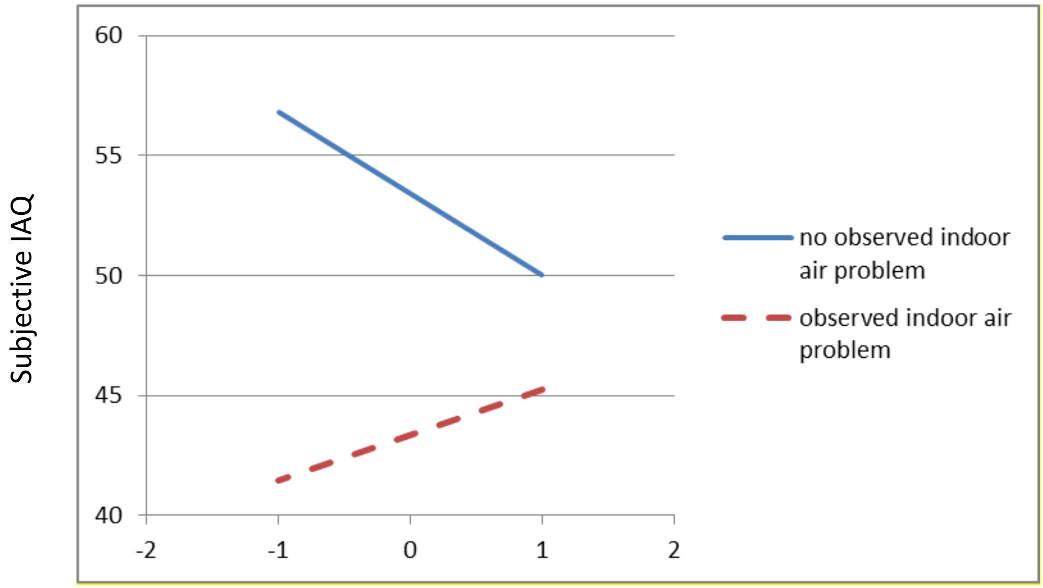
Next, we analyzed whether observed indoor air problem modifies the association between psychosocial factors and subjective IAQ (H2) using multigroup MLM and Wald-test**.** In **Table 4, Models 2a** and **2b** report unstandardized coefficients for both indoor environment contexts: no observed indoor air problem (Model 2a) and observed indoor air problem (Model 2b). One significant interaction between observed indoor air problem and psychosocial factors was found on the school level: the overall school-related stress was significantly associated with subjective IAQ only in schools where there was no observed indoor air problems. In these schools, one unit increase in the average level of school-related stress deteriorated subjective IAQ significantly by 1.14 units (standardized β = -0.44). In schools with observed indoor air problem the association was reverse but not significant (0.64 units; standardized β= 0.20) (see Figure 1)[4]. In addition, there was one significant student level interaction. Older students reported worse subjective IAQ than younger students in schools with observed indoor air problem. In schools without such exposure the association was reversed. However, the associations between variables were not significant and the effects were very small (Model 2a: standardized β= 0.01; Model 2b: standardized β= -0.02). Both models explained 10% of the variance on the student level (Model 2a: R^2 = 0.101; Model 2b: R^2 = 0.103,). On the school level, the proportion of explained variance was 31% (R^2 = 0.308)) for Model 2a, whereas it was only 17% (R^2 = 0.171,) for Model 2b (see Table 4: Models 2a and 2b).

____

Table 4 here

____

[4] The univariate association had the same pattern: no observed biological exposure (standardized β= -0.53); observed biological exposure (standardized β = 0.16).



[a] No observed indoor air problem: p = 0.004; observed indoor air problem: p = 0.229.

Figure 1: Subjective indoor air quality on school-related stress in schools with and without observed indoor air problem. School-related stress reported by +/- 1 SD (N=26946).

Discussion

We found that students' psychosocial factors were associated with their perception of subjective IAQ. Furthermore, we found that both IAQ problems and school's psychosocial environment were associated with it. On the school level, school-related stress deteriorated subjective IAQ only in schools without observed IAQ problems, but not in schools with such problems. Our results provide evidence that the influence of psychological environment on subjective IAQ can be complicated, also depending on whether there are actual IAQ problems or not.

This study contributes to the earlier literature by showing that subjective stress influences subjective IAQ also among school students. Although this association has been reported previously for adults (Frontczak and Wargocki, 2011), this is the first study that has tested the hypothesis among school students to our knowledge. It was also found that the teacher-student relationship, and aid received from the school personnel associated with subjective IAQ on the student level. These findings support the previous literature showing that psychosocial factors influence subjective IAQ (Brauer and Mikkelsen, 2010; Lahtinen et al., 2004). In addition, it clarifies the picture by showing that especially the relationship with authorities can be reflected to the perceived environment. That is, the more negative the relationship with authorities is found to be, the more negatively indoor environment is also perceived. There was no association between class spirit and subjective IAQ. Although it is possible that the attribution process among adults in an occupational context and children in a school context differs, this study suggests that it may be important to report social support received by coworkers (peers) and superiors separately, which have not usually been done in the previous indoor air studies (Bakke et al., 2007; Marmot et al., 2006).

It was also found that school's psychosocial environment only partly associated with subjective IAQ. In other words, only one school level psychosocial variable was significantly related to subjective IAQ after all variables were included in the model. Thus, our study partially replicated the findings reported by Brauer and Mikkelsen (2010) indicating that psychosocial factors may have only limited effect on subjective IAQ on the organizational level. Instead, we found a significant association between observed indoor air problem and subjective IAQ. Students from schools with observed indoor air problems reported poor subjective IAQ more frequently than students from schools without such problems. Being that observed indoor air problem was the most important single predictor on the school level it connotes that building related factors have significant effects on subjective IAQ.

Finally, our study offers some evidence on that psychosocial factors associate with subjective IAQ in a different way in buildings where there are problems in indoor environment than in buildings without such problems. Although being highly relevant, this idea has not been tested before in indoor air studies. Specifically, our results support this hypothesis by showing that school level stress predicted subjective IAQ differently in schools with and without observed indoor air problem. In schools without indoor air problems, the school-level stress predicted subjective IAQ significantly, whereas in schools with indoor air problems such association was non-significant and it was even reverse. Although more research is needed, this finding may reflect the differences against these two backgrounds. In schools with indoor air problems, subjective IAQ might reflect more the factual situation and group norms associated to it than in schools without indoor air problems. Hence, in the latter case subjective IAQ might reflect more problems in psychosocial environment, partly because additional information is not available on which the evaluation can be based. The results indicate a need to study these different situations simultaneously. It would also be interesting to study whether raising awareness about good IAQ (when no problems exist) could make the perception of subjective IAQ more reliable.

From the practical point of view these results are important especially for occupational and school health service personnel, health protection authorities, and other actors who utilize questionnaires to collect information about IAQ. Such questionnaires could be improved by including questions on psychosocial factors. In addition, when questionnaires are used to evaluate IAQ problems in schools, the results should preferably be compared with a reference school without problems.

The study has several strengths enhancing the validity of our findings. The sample size is large and representative. Furthermore, we used multilevel analysis which has many advantages. For example, various problems related to aggregation and disaggregation of the data can be avoided. Using aggregated data leads to loss of statistical power whereas using disaggregated data, as commonly done in indoor air studies, leads to significant findings that might be spurious

(Hox, 2010). So far, only a few indoor air studies using multilevel modelling have been published (Brauer and Mikkelsen, 2010; Haverinen-Shaughnessy et al., 2012; Haverinen-Shaughnessy and Shaughnessy, 2015; Marmot et al., 2006). None of them has tested psychosocial and building related factors or their interactions simultaneously on the organization level. Thus, to our knowledge this is the first study which analyzes effects of both factors on subjective IAQ utilizing advanced statistical methods.

Our study has of course its limitations. The study is cross-sectional and it used questionnaire data. In addition, we had no physical or health measures, and we had only one IAQ parameter measured on a 4-point scale (which was however symmetrical).

To conclude, the results indicate that both building related and psychosocial factors influence the subjective evaluation of school’s indoor air quality. In addition, this study offers some school level evidence on that subjective IAQ in schools with indoor air problems may be more based on building related factors (i.e. the factual situation), whereas in schools without such problems it may reflect more psychosocial problems in school environment.

Supplementary Material

The null model

The null model tests the proportion of variation in variables occurring between schools. The equations are presented below:

Level 1 (Students): $Y_{ij} = \beta_{oj} + e_{ij}$ (1.1)

Level 2 (Schools): $\beta_{oj} = \Upsilon_{00} + u_{0j}$ (1.2)

In the equation 1.1 student's subjective IAQ score *i* in school *j* (Y_{ij}) was modelled as a function of mean subjective IAQ for school *j* (β_{oj}) and a residual term (e_{ij}). The latter term reflects student specific difference around the mean of school *j*. The mean subjective IAQ score for school *j* (β_{oj}) reflects a grand mean of subjective IAQ (Υ_{00}) and school specific difference from the grand mean (u_{0j}) (see equation 1.2). The residual terms e_{ij} and u_{0j} are assumed to be normally distributed. This model gives an estimate for intraclass correlation *ICC* (1.3) so that σ^2_B is the variance of the school level residuals u_{0j} and σ^2_W is the variance of student level residuals e_{ij} (Hox, 2002; Snijder and Bosker, 2012).

$$ICC = \sigma^2_B / (\sigma^2_B + \sigma^2_W) \quad (1.3)$$

The random intercept model

In the random intercept model the intercepts of each school *j* are allowed to vary across schools (Hox, 2002). The equations of Model 1 (see Table 3: Model 1) are presented below:

Model 1:

Level 1 (Students): (2.1)

$$Y_{ij} = \beta_{oj} + \beta_{1j} \text{(Class spirit)} + \beta_{2j} \text{(Teacher-student relationship)} + \beta_{3j} \text{(Aid received from the school personnel)} + \beta_{4j} \text{(School-related stress)} + \beta_{5j} \text{(SES)} + \beta_{6j} \text{(age)} + \beta_{7j} \text{(gender)} + e_{ij}$$

level 2 (School): (2.2)

$$\beta_{oj} = \Upsilon_{00} + \Upsilon_{01} \text{(Class spirit)} + \Upsilon_{02} \text{(Teacher-student relationship)} + \Upsilon_{03} \text{(Aid received from the school personnel)} + \Upsilon_{04} \text{(School-related stress)} + \Upsilon_{05} \text{(SES)} + \Upsilon_{06} \text{(school size)} + \Upsilon_{07} \text{(Observed indoor air problems)} + u_{0j}$$

The parameters β_{1j-7j} stand for the constant slopes of the student level variables estimated in the model (equation 2.1). In turn, e_{ij} is the residual term in student level (equation 2.1). Coefficient Υ_{00} is the fixed intercept, which reflects the general mean. Coefficients Υ_{01} - Υ_{07} are school level slopes and u_{0j} reflects the part that cannot be predicted by school level variables (equation 2.2) (Hox, 2002; Snijders and Bosker, 2012). The teacher-student relationship, students' perception of the aid received from the school personnel, class spirit, school-related stress and SES were decomposed into two latent uncorrelated components in the analysis (Asparouhov and Muthén, 2006; Muthén and Muthén, 1998 - 2012).

References

Asparouhov, T. and Muthén, B. (2006). Constructing covariates in multilevel regression. *Mplus. Web Notes,* **11**. www.statmodel.com.

Asparouhov, T. and Muthén, B. (2012). Multiple group multilevel analysis. *Mplus. Web Notes*, **16**. www.statmodel.com.

Bakke, J.V., Moen, B.E., Wieslander, G. and Norbäck, D. (2007). Gender and the physical and psychosocial work environments are related to indoor air symptoms. *J. Occup. Environ. Med.*, **49**, 641-650.

Baraldi, A.N. and Enders, C.K. (2010). An introduction to modern missing data analyses. *J. School. Psychol.,* **48**, 5-37.

Brauer, C., and Mikkelsen, S. (2010). The influence of individual and contextual psychosocial work factors on the perception of the indoor environment at work: a multilevel analysis. *Int. Arch. Occ. Env. Hea.*, **83**, 639-651.

Borràs-Santos A., Jacobs J.H., Täubel M., Haverinen-Shaughnessy U., Krop E.J., Huttunen K., Hirvonen M.R., Pekkanen J., Heederik D.J., Zock J.P., and Hyvärinen A. (2013). Dampness and mould in schools and respiratory symptoms in children: the HITEA study. *Occup Environ Med*, **70**, 681-687.

Dutton, S. M., Chan, W.R.,Mendell, M.J., Barrios, M., Parthasarathy, S., Sidheswaran, M., Sullivan, D.P., Eliseeva, K., and Fisk., W.J (2014). *Evaluation of the indoor air quality procedure for use in* *retail buildings.* Berkeley, CA: Lawrence Berkeley National Laboratory. Access method: http://escholarship.org/uc/item/9v05h2r3 (accessed 10 January 2016).

Eekhout, I., de Boer, R. M., Twisk, J. W. R., de Vet, H. C. W., and Heymans, M. W. (2012). Missing data: a systematic review of how they are reported and handled. *Epidemiology*, **23**, 729–732.

Enders, C. K., and Bandalos, D. L. (2001). The relative performance of full information maximum likelihood estimation for missing data in structural equation models. *Structural Equation Modeling*, **8**, 430-457.

Frese, M., and Zapf, D. (1999). On the importance of the objective environment in stress and attribution theory. Counterpoint to Perrewé and Zellars. *J. Organ. Behav.*, **20**, 761-765.

Frontczak, M., and Wargocki, P. (2011). Literature survey on how different factors influence human comfort in indoor environments. *Build. Environ*., **46**, 922-937.

Haverinen-Shaughnessy U., Borras-Santos A., Turunen M., Zock J.-P., Jacobs J., Krop E.J.M., Casas L.,Shaughnessy R., Täubel M., Heederik D., Hyvärinen A., Pekkanen J., Nevalainen A., and the HITEA study group.(2012). Occurrence of moisture problems in schools in three countries from different climatic regions of Europe based on questionnaires and building inspections - the HITEA study. *Indoor Air,* **22***,* 457–466.

Haverinen-Shaughnessy, U., Hyvärinen, A., Putus, T., and Nevalainen, A. (2008). Monitoring success of remediation: seven case studies of moisture and mold damaged buildings. *Sci. Total Environ.*, **399**, 19-27.

Haverinen-Shaughnessy, U., Pekkanen, J., Nevalainen, A., Moschandreas, D., and Husman, T. (2004). Estimating effects of moisture damage repairs on students' health—a long-term intervention study. *J. Expo. Anal. Env. Epid.,* **14**, S58-S64.

Haverinen-Shaughnessy, U., and Shaughnessy, R. J. (2015). Effects of classroom ventilation rate and temperature on students' test scores. *PloS one*, **10**, e.0136165.

Haverinen-Shaughnessy U, Turunen M, Metsämuuronen J, Palonen J, Putus T, Kurnitski J, Shaughnessy R. (2012). Health and Academic Performance of Sixth Grade Students and Indoor Environmental Quality in Finnish Elementary Schools. *British Journal of Educational Research*, **2**, 42-58.

Hietanen-Peltola, M., and Korpilahti, U. (Eds.) (2015). Terveellinen, turvallinen ja hyvinvoiva oppilaitos. Opas ympäristön ja yhteisön monialaiseen tarkastamiseen [A healthy, safe and well-being school. A guide to the multidisciplinary inspection of the environment and the community]. Helsinki:THL.

Hox, J. J (2010). *Multilevel analysis. Techniques and applications*. Second Edition. New York, Routledge.

Hox, J. J., Maas, C. J. M., and Brinkhuis, M. J. S. (2010). The effect of estimation method and sample size in multilevel structural equation modelling. *Statistica Neerlandica*, **64**, 157-170.

Karvonen, S., Vikat, A., and Rimpelä, M. (2005). The role of school context in the increase in young people's health complaints in Finland. *J. Adolescence*, **28**, 1-16.

Konu, A. I., Lintonen, T. P., and Rimpelä, M. K. (2002). Factors associated with schoolchildren's general subjective well-being. *Health Educ. Res.,* **17**, 155 -165.

Lahtinen, M., Huuhtanen, P., Kähkönen, E and Reijula, K. (2002). Psychosocial dimensions of solving an indoor air problem. *Indoor Air*, **12**, 33-46.

Lahtinen, M., Sundman-Digert, C., and Reijula, K. (2004). Psychosocial work environment and indoor air problems: a questionnaire as a means of problem diagnosis. *Occup. Environ. Med.,* **61**, 143-149.

Little, R. J. A. (1988). A test of missing completely at random for multivariate data with missing values. *Journal of the American Statistical Association*, **83**, 1198-1202.

Magnavita, N. (2015). Work-related symptoms in indoor environments: a puzzling problem for the occupational physician. *Int. Arch. Occ. Env. Hea.*, **88**, 185-196.

Marmot, A.F., Eley, J., Stafford, M., Stansfeld, S.A., Warwick, E., and Marmot, M.G. (2006). Building health: an epidemiological study of “sick building syndrome” in the Whitehall II study. *Occup. Environ. Med.*, **63**, 283-289.

Mendell, M. J., Mirer, A. G., Cheung, K., Tong, M., and Douwes, J. (2011). Respiratory and allergic health effects of dampness, mold, and dampness-related agents: A review of the epidemiologic evidence. *Environ. Health Persp.,* **119**, 748-56.Muthén, B.O. (1998-2004). *Mplus technical appendices*. Los Angeles, CA: Muthén & Muthén.

Muthén, L.K. and Muthén, B.O. (1998-2012). Mplus User’s Guide. Seventh Edition.
Los Angeles, CA: Muthén & Muthén.

Nelson, R.M. and DeBacker, T.K. (2008). Achievement motivation in adolescents: The role of peer climate and best friends. *J. Exp. Educ.,* **76**, 170-189.

Norbäck, D. and Nordström, K. (2008). An experimental study on effects of increased ventilation flow on students' perception of indoor air environment in computer classrooms. *Indoor Air*, **18**, 293-300.

Nordström, K., Norbäck, D. and Wieslander, G. (1999). Subjective indoor air quality in geriatric hospitals. *Indoor Built Environ.*, **8**, 49-57.

Pereira, L. D., Raimondo, D., Corgnati, S. P., and da Silva, M. G. (2014). Assessment of indoor air quality and thermal comfort in Portuguese secondary classrooms: Methodology and results. *Build. Environ*., **81**, 69-80.

Rubin, D. B. (1976). Inference and missing data. *Biometrika*, **63**, 581-592.

Savalei, V. (2010). Small sample statistics for incomplete nonnormal data: Extensions of complete data formulae and a Monte Carlo comparison. *Structural Equation Modeling*, **17**, 241-264.

Smedje, G., Norbäck, D., and Edling, C. (1997). Subjective indoor air quality in schools in relation to exposure. *Indoor Air*, **7**, 143-150.

Snijders, T.A.B. and Bosker, R.J. (2012). *Multilevel analysis. An introduction to basic and advanced multilevel modeling*, 2nd edition. London, Sage.

Turunen, M., Toyinbo, O., Putus, T., Nevalainen, A., Shaughnessy, R., and Haverinen-Shaughnessy, U. (2014). Indoor environmental quality in school buildings, and the health and wellbeing of students. *Int. J. Hyg. Envir. Heal.,* **217**, 733-739.

Virtanen, M., Kivimäki, M., Luopa, P., Vahtera, J., Elovainio, M., Jokela, J., and Pietikäinen, M. (2009). Staff reports of psychosocial climate at school and adolescents' health, truancy and health education in Finland. *Eur. J. Public Health,* **19**, 554-560.

Wang, J., Smedje, G., Nordquist, T., and Norbäck, D. (2015). Personal and demographic factors and change of subjective indoor air quality reported by children in relation to exposure at Swedish schools: A 2-year longitudinal study. *Sci. Total. Environ.*, **508**, 288-296.

Acknowledgements: This study was funded by Juho Vainio foundation.

Table 4: Parameter estimates for subjective indoor air quality as a function of individual level and school level variables. Multilevel linear regression model (model 1) and multigroup multilevel linear regression models (models 2a and 2b).

	Model 1: Whole data (N= 26946/195 schools)		Model 2a: School without indoor air problem (N= 16989 pupils/127 schools)		Model 2b: School with indoor air problem (N = 9957 pupils/68 schools)		Differences between slopes in Models 2a and 2b	
	Unstandardized Beta (SE)[a]	95% CI	Unstandardized Beta (SE)	95% CI	Unstandardized Beta (SE)[1]	95% CI	Wald-test[c]	p-value
Intercept	56.57 (1.97)***	52.70 – 60.43	55.00 (2.41)***	50.28 – 59.72	49.53 (3.27)***	43.12 – 55.95		
Student level variables								
Low class spirit[d]	-0.00 (0.01)	-0.02 – 0.02	-0.01 (0.01)	-0.04 – 0.02	0.00 (0.01)	-0.02 – 0.03	0.32	0.569
Bad teacher – student relationship[d]	-0.27 (0.01) ***	-(0.30 – 0.24)	-0.26 (0.02)***	-(0.30 – 0.23)	-0.29 (0.02)***	-(0.33 – 0.24)	0.68	0.410
Little aid received from school personnel[d]	-0.14 (0.01)***	-(0.16 – 0.12)	-0.15 (0.02)***	-(0.18 – 0.12)	-0.12 (0.02)***	-(0.16 – 0.08)	1.26	0.262
High school stress	-0.20(0.01)***	-(0.22 – 0.19)	-0.21 (0.01)***	-(0.23 – 0.18)	-0.20 (0.02)***	-(0.23 – 0.17)	0.10	0.752
SES [b]	0.33 (0.40)	-0.46 – 1.12	-0.10 (0.54)	-1.17 – 0.96	1.05 (0.56)	-0.05 – 2.15	2.18	0.140
Age (y)	0.03 (0.36)	-0.68 – 0.74	0.68 (0.39)	-0.08 – 1.44	-1.05 (0.69)	-2.41 – 0.31	4.75*	0.029
Gender (1 = girl)	-3.14 (0.41)***	-(3.94 – 2.33)	-2.88 (0.50)***	-(3.87 – 1.89)	-3.54 (0.69)***	-(4.90 – 2.19)	0.60	0.438
School level variables								
Low class spirit[d]	0.10 (0.23)	-0.35 – 0.55	0.14 (0.25)	-0.35 – 0.63	0.69 (0.71)	-0.70 – 2.07	0.54	0.464
Bad teacher – student relationship[d]	-0.68 (0.27)*	-(1.22 – 0.14)	-0.33 (0.28)	-0.88 – 0.22	-1.30 (0.92)	-3.10 – 0.51	1.01	0.316
Little aid received from school personnel[d]	-0.20 (0.12)	-0.43 – 0.04	-0.16 (0.12)	-0.40 – 0.08	-0.13 (0.31)	-0.74 – 0.49	0.01	0.919
High school stress[d]	-0.33 (0.37)	-1.05 – 0.39	-1.14 (0.40)**	-(1.91 – 0.36)	0.64 (0.53)	-0.40 – 1.69	7.16**	0.007
SES[b]	-7.10(6.14)	-19.13 – 4.92	-0.05 (7.60)	-14.95 – 14.85	-17.19 (10.20)	-37.17 – 2.80	1.82	0.178
School size (pupil)	0.00 (0.00)	-0.01 – 0.01	0.00 (0.00)	-0.01 – 0.01	-0.01 (0.01)	-0.02 – 0.01	0.56	0.455
Observed biological exposure (=1)	-8.84 (1.49)***	-(11.77 – 5.91)						
σ^2_W	792.45***	777.79 – 807.11	800.37***	782.33 – 818.41	777.93***	753.45 – 802.42		
σ^2_B	61.17***	44.62 – 77.73	40.93***	22.86 – 59.00	75.78***	43.86 – 107.70		
Residual ICC	0.07		0.049		0.089			

*** p<0.001, ** p<0.01, * p<0.05.

[a] A negative value indicates deterioration in subjective indoor air quality.

[b] 1 = university education of father.

[c] Wald test reports whether the slopes in Models 2a and 2b differ significantly from each other.

[d] Scale 0 – 100.