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Patterns and Profiles for understanding the indoor environment and its occupants

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Abstract. Research has shown that, even though the indoor environmental conditions seem to comply with current guidelines and those conditions seem 'comfortable' enough, staying indoors is not good for our health. Reasons for this discrepancy might be the fact that these guidelines are based on single-dose response relationships to prevent negative effects, and that the criteria are determined for an average adult person. A more complex model that accounts for all stressors, both positive and negative, interactions, and preferences and needs of the individual for different scenarios and situations was introduced. To validate this 'new' model, several field studies have been executed to determine patterns of stressors and profiles of people for different scenarios (office workers and their workplace; students and their homes; primary children and their classrooms; employees of outpatient areas in hospitals). The outcome shows that it is possible to determine patterns of stressors for different scenario's based on multivariate regression analysis of a survey of the occupants and the buildings they are occupying. Moreover, people differ in their preferences and needs, and it seems possible to distribute them into clusters based on TwoSteps cluster analysis of preferences and needs acquired through a questionnaire. It is concluded that all possible stressors, negative or positive, are important to consider when studying a certain disease or disorder; and that both profiles of IEQ-clusters and profiles of psychosocial clusters are important parts of this 'complex' model. Next steps should focus on interactions at human and environmental level, and how to account for those in the 'New' model.

Keywords. indoor environmental quality, preferences and needs, profiles, patterns of stressors.
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1. Introduction

Although most people are aware of the importance of the outdoor environment, especially in relation to climate change issues but also related more directly to our health, the effects of indoor environment quality are not that common knowledge. There are many diseases and disorders related to staying indoors, such as mental illnesses, obesity, cardio-vascular and chronic respiratory diseases (for example asthma with children and COPD with adults), cancer [1-4], and more recent COVID-19 [5].

Relationships between indoor building conditions and wellbeing of occupants of different buildings are complex (e.g. homes: [1]; offices: [6]; schools: [7]]. 'Bad' indoor building conditions have been associated with discomfort (annoyance), building-related symptoms (e.g. headaches, nose, eyes, and skin problems, fatigue etc.), building-related illnesses (e.g. legionnaires disease), productivity loss and decrease in learning ability [8)] Indoor environmental stressors can cause their effects additively or through complex interactions: thermal factors (e.g. draught, temperature), lighting aspects (e.g. reflection, view, luminance ratios), air quality (e.g. odours, mould, chemical compounds, particulates) and acoustical aspects (e.g. noise and vibration) [9-10]. From these findings, it seems that staying indoors is not good for our health. Even when the conditions seem to comply with the current guidelines for thermal, lighting, acoustical and air quality, people feel uncomfortable and get sick [11]. Those guidelines, such as maximum concentrations of certain pollutants, ventilation rate, and temperature ranges, are meant to prevent diseases and disorders rather than focusing on positive effects; and these guidelines and standards are mainly based on single-dose response relationships [11-12]. IEQ assessment is based on effect modelling of dose or indoor environment related indicators: for each parameter or indicator its effect is determined separately. This tends to work well for health threatening exposures for which a clear dose-response relationship has been determined. However, complexity, number of indoor environmental parameters and lack of knowledge, make a total performance assessment using only

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threshold levels for single environmental-related parameters difficult. It is clear, that we are in need of a more complex model to determine IEQ. A model that accounts for different scenarios (such as homes, offices, schools), possible problems, interactions, people and effects [8]. A model that focuses on situations rather than single-dose response relationships. A model that uses all stressors and factors, whether of psychological, physiological, personal, social or environmental nature, whether with a positive or negative effect. A model that contains other indicators that the environmental or dose-related indicators. Other indicators are available to assess indoor environmental quality: a) indicators concerned with buildings and its components, such as certain measures or characteristics of a building and its components (for example the possibility of mould growth), or even labelling of buildings and its components; b) indicators focused on the occupant such as sick leave, productivity, and number of symptoms or complaints [8;13]. In the category building and its components certain measures or characteristics of a building can be used, while in the category occupants, the emphasis should be on indicators that can give us information on the effects of stress: indicators that can tell us something on changes in the bodily systems and experience of people [8].

In 2014, a first concept of this 'new' model was introduced [8]; an improved version followed five years later [14] (Figure 1). The model takes account of the individual preferences and needs of the occupants (profiles) and the combined effects of stress factors in buildings on people (patterns) for different scenario's, different situations (for example sleeping/eating; meeting/concentrated work; getting lessons); and interactions at human and environmental level.

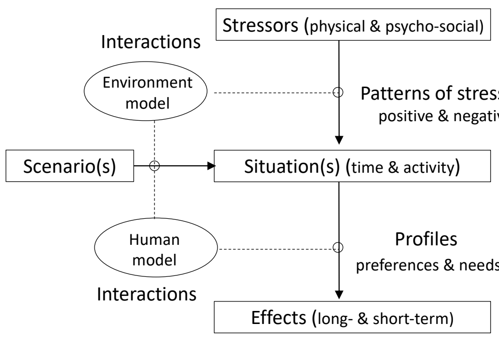

Fig. 1. - New model [14].

This model features the individual differences in needs and preferences (profiles of people as shown in the Human model, Figure 2) and the stress factors caused by the (indoor) environment that a person is exposed to (represented by patterns of stressors and the Environment model, Figure 3), depending on their situation (activity and time).

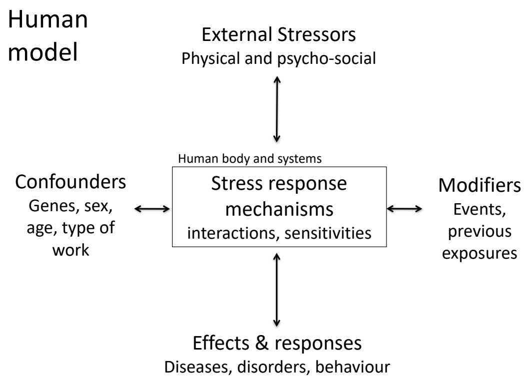

Fig. 2. - The Human model [14].

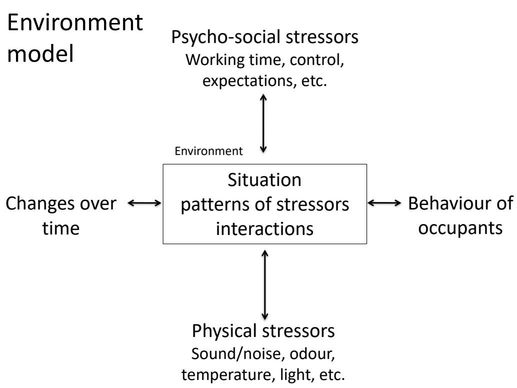

Fig. 3. - The Environment model [14].

For the determination of patterns of stressors of importance to people in different situations, identification of other factors and stressors than the environmental parameters used in guidelines [e.g. 12] is needed [15]. While for the determination of profiles of people for different scenarios and situations, identification of preferences and needs of individuals is needed [15].

Therefore, to validate this 'new' model, several field studies have been executed to determine profiles of people and patterns of stressors for different scenarios.

2. Methods

2.1 Study design

In the field studies, several scenarios were studied: 1) office workers and their workplace; 2) students and their homes; 3) primary school children and their classrooms; 4) employees of outpatient areas in hospitals.

For each scenario, occupant-related indicators and building-related indicators were collected through a questionnaire and checklist(s) to associate patterns of building-related stressors to occupant-related indicators (health: symptoms; comfort: complaints); and to determine clusters of occupants and their profiles.

For each scenario, except for the 'Students and their homes' scenario, a survey was conducted comprising of a questionnaire and a building inspection with the use of checklists (at building and room level). For 'Students and their homes', only a questionnaire was developed, including also questions on building-related indicators, because visiting the homes was not feasible.

For each scenario, except for the 'primary school children and their classrooms' scenario, the questionnaire was digitally distributed. The questionnaire for the children was handed out and collected during the visit to the schools.

The checklists (building and room) focused on the indoor and built environment through characteristics of building, systems and rooms (e.g., operable or no windows, type of HVAC system, lighting system, solar screens, reflection on desks, surfaces of ceiling, floor and walls, sources of noise, dampness, mould growth, condensation, pollution sources, and control system), characteristics of the built environment (e.g., busy road and rural/ surroundings), and processes to maintain and operate the building and its activities (e.g., cleaning activities/schedule, renovation and retrofitting activities, and maintenance of HVAC system). The questionnaire included questions about personal data, psychosocial environment, psychological characteristics, events, physical effects, and preferences and needs for IEQ and in some cases also for psychosocial comfort.

2.2 Patterns of stressors

To find patterns of stressors, multivariate analysis was performed on data of 7441 office workers and 167 office buildings [16-17], 396 students and their homes in the Netherlands [18] and of 682 students and their homes in different countries [19], 949 primary school children and 45 classrooms [20], and 556 employees of outpatient areas in six Dutch Hospitals [21].

To examine the relations between an indicator for health or comfort and building characteristics, multivariate linear regressions were fitted, taking into account potential confounders and/or risk factors. First univariate analysis was performed for the building-related aspects, unadjusted and adjusted for confounding variables. Variables associated with a P-value less than 0.20 in bivariate analyses were included. The full model was reduced by sequential elimination of terms for which P-value > 0.20. Collinearity among variables in the model was measured by the variance inflation factor (VIF). No multicollinearity was detected for VIF<4.

2.3 Profiles of clusters

To determine clusters and their profiles, 2-steps cluster analysis was performed based on comfort, health, preferences and needs of 1014 office workers in 20 office buildings in the Netherlands [22], of 949 primary school children of 45 classrooms [23]; 556 employees of outpatient areas in six Dutch hospitals [24], and of 502 employees of 10 office buildings in the Netherlands [25].

Before performing the TwoStep cluster analysis, correlation analysis and Principal Component Analysis (PCA) was performed for all studies except for the OFFICAIR study [22], to statistically strengthen the models. Correlation analysis, the strength between perceived comfort and preferences, were performed to decide if both perceived comfort and preferences could be included in the cluster analysis; multicollinearity may affect the weight of constructs in cluster analysis [26]. PCA was conducted to reduce the number of original variables into fewer independent components [27]. As recommended by Tabachnick and Fidell [28], the number of components was determined by an Eigenvalue greater than 1; sample adequacy with Kayser-Meyer-Olkin was greater than 0.6; for the rotation method a Varimax orthogonal rotation was selected; and strength was determined by loadings within components > 0.4, loadings between components < 0.4 [29].

For the TwoStep analysis, the final sets of components resulting from the PCA were used to conduct the analysis. This clustering technique was used as opposed to other clustering methods, as it allows for the handling of both continuous and categorical data, the optimal number of clusters are automatically selected by the method; and the method is suitable for large data sets [30-31]. Final model validation was carried out with the fulfilment of four conditions [31]: a silhouette of above 0.2; variables predictor importance greater than 0.02; ensuring statistical significance ($p < 0.05$) between variables by conducting Chi^2 tests; applying the model to two random halves of the sample and ensuring that the results are similar.

3. Results

3.1 Patterns of stressors

The building-related patterns of stressors followed from the multivariate regression analysis, taking account of specific confounding factors, for each of the field studies performed are presented in Table 1.

3.2 Profiles of clusters

The outcome of the clustering (including PCA-analysis and TwoSteps cluster analysis) for each of the surveys performed, are presented in Table 2.

Table 1 - Patterns of building-related stressors for different health and/or comfort indicators.

Study	Building-related pattern of stressors	Adjusted/confounding factors
OFFICAIR 2012: 167 office buildings in 8 EU countries with 7441 office workers [16]	**Overall satisfaction**: acoustical solutions, mould growth, complaints procedure, cleaning activities **Health (BSI-5)**: number of occupants, lack of operable windows, presence of carpet and cleaning activities	gender, age mean, current smoker percentage, ERI (Effort-Reward Imbalance), overcommitment and negative affect means
OFFICAIR 2012: 167 office buildings in 8 EU countries with 7441 office workers [17]	**Dry eyes**: proximity (<100 m) to potential sources of outdoor air pollution, absence of operable windows, portable humidifiers in the offices, exposed concrete and/or plaster and dispersion and/or emulsion paint as wall covering in offices and cleaning surfaces at least once per week.	gender, age, level of education, smoking status, alcohol consumption, number of hours working with a VDU, ERI, overcommitment and negative affect means
Student homes 2015: 396 students and homes in the Netherlands [18]	**Rhinitis**: biological pollutants (caused by pets), chemical pollutants (caused by MDF less than 1 year old in bedroom), ventilation (opening window in bedroom) and workout	gender, family rhinitis, smoking status, alcohol consumption, and PANAS negative and positive
Students international 2019: 682 students and their homes in 5 cities [19]	**Rhinitis**: biological pollutants (caused by pets), chemical pollutants (caused by open bookshelves and lack of sweeping floors) **Headaches**: biological pollutants (caused by pets)	gender, age, family rhinitis, smoking status, negative events gender and age, negative events, PANAS negative
Schools 2017: 949 children of 45 classrooms (17 primary schools) [20]	**Health (PSI-9)**: location of school building, heating system, solar devices hampering opening windows **Comfort (PCI-7)**: ventilation type, window frame colour, floor material and vacuum cleaning frequency	mood during completion of questionnaire
Hospitals 2019: 556 outpatient workers of 6 hospitals [21]	**Dry eyes:** rotating heat exchanger, having no windows, type of workplace (office vs consultation room), more than 1 person in room. **Headaches**: having no windows, type of workplace (office vs consultation room)	gender, age, smoking status, alcohol consumption; ERI and over commitment gender, age, suffering from migraine

notes: BSI-5 = Building Symptom Index based on five symptoms: dry eyes, blocked or stuffy nose, dry/irritated throat, headache, and lethargy [32]; ERI = the Effort Reward ratio [33]; PANAS = Positive Affect Negative Affect Scale [34]; PSI-9 is defined based on 9 symptoms: dry eyes, itching or watery eyes, blocked or stuffy nose, running nose, sneezing, dry throat, difficulty breathing, dry, irritated or itching skin, and headache; PCI-7, is defined based on 7 classroom conditions: thermal discomfort, temperature changes, wind/draught, smells, noise, sunlight and artificial light.

Table 2 - Studies performed with clusters and their profiles.

Name study	Profiles
OFFICAIR 2012 NL: 1014 office workers in 20 office buildings in the Netherlands [22]	3 profiles clustered on IEQ-related complaints (comfort): · Healthy and satisfied workers · Moderate healthy and noise-bothered workers · Unhealthy and air and temperature-bothered workers
Schools 2017: 949 children of 45 classrooms (17 primary schools) [23]	6 profiles clustered on self-reported IEQ-comfort and IEQ-preferences: Sound concerned, Smell and sound concerned, Thermal and draught concerned, Light concerned, All concerned, and Nothing concerned.
Hospitals 2019: 556 outpatient workers of 6 hospitals [24]	6 profiles clustered on self-reported on IEQ-comfort and IEQ-preferences 3 profiles clustered on self-reported psychosocial comfort and preferences for psychosocial aspects.
MyWorkplace 2020: 502 employees of 10 office buildings in the Netherlands [25]	4 profiles clustered on self-reported preferences for IEQ and 6 profiles clustered on self-reported preferences for psychosocial comfort

4. Discussion and conclusions

4.1 'New' model

Research has shown that, even though the conditions seem to comply with current standards for indoor environmental quality based on single-dose response relationships, staying indoors is not good for our health. There is a need for understanding the indoor environment and its occupants; we need to acknowledge the fact that we are dealing with people who are different in their needs and preferences and that the indoor environmental quality is more than the sum of its parts.

A 'new' model which takes account of the combined effects of positive and negative stress factors in buildings on people (patterns), interactions at and between different levels (human and environment) over time, as well as the (dynamic) preferences and needs of occupants (profiles) in different scenarios and situations, is needed.

Several field studies were performed to determine profiles of people and patters of stressors for different scenarios, as suggested in Almonte et al. 2020 [15].

4.2 Patterns of stressors

From the field studies presented it can be concluded that it is possible to determine patterns of stressors for different scenario's based on multivariate regression analysis of a survey of the occupants and the buildings they are occupying.

After full adjustment, the regression models in all of the studies for health effects confirmed their multifactorial character. Moreover, the studies resulted in 'other' factors and stressors than used in guidelines, confirming the importance of considering all possible stressors when studying a certain disease or disorder. Several building-related stressors, personal factors and psycho-social factors, showed to be related to a disease or disorder.

The outcome, therefore, highlights the importance of considering all possible stressors, negative or positive, when studying a certain disease or disorder.

4.3 Profiles of clusters

From the field studies presented it can be concluded that people can differ in their preferences and needs, and that it seems possible to distribute them into clusters based on TwoSteps cluster analysis of preferences and needs for IEQ and psychosocial comfort acquired through a questionnaire.

Moreover, in a follow-up qualitative study of outpatient workers' preferences and needs, comparing preferences and needs before and during COVID-19 pandemic, it was concluded that occupants' preferences changed over time and were situation-related [35].

The outcome indicates that preferences and comfort of IEQ are related to health; preferences of workers are situation- and gender-driven; and that both the profiles of IEQ-clusters and the profiles of the social clusters are important to study.

4.4 Next steps

For validation and completion of the 'new' model, besides the 'patterns of stressors' and 'profiles of clusters', possible interactions at and between different levels (human and environment) over time need to be explored for different scenarios and situations (e.g. [9], [10], [15]).

Previous studies show that, at environmental level interactions or actions by occupants occur over time, which may affect the needs and preferences of the occupants (e.g. [9], [36]0.

Also, at human level interactions between different acoustical, olfactory, and visual stressors may occur (e.g. [10], [37]). However, more research is needed to explain all of these interactions, and to account for those in the 'New' model.

4.5 Concluding remark

The 'new' model will make it possible to match profiles of people with patterns of positive and negative stressors for a certain situation. The model can also help to create personal indoor environments that can both improve health and comfort of the individual. Clustering of the occupants of different scenario's, each with their own profile, can help designers of building and architects, to anticipate to changing preferences and needs of office workers, students, school children, etc. at cluster level. How the number of clusters vary, how the profiles of these clusters change over time, and how depended these profiles are on the scenario and situation, will need to be studied.

5. References

[1] Bonnefoy X., Annesi-Maesona I., Aznar L., Braubachi M., Croxford B., Davidson M., Ezratty V., Fredouille J., Ganzalez-Gross M., van Kamp I., Maschke C., Mesbah M., Moisonnier B., Monolbaev K., Moore R., Nicol S., Niemann H., Nygren C., Ormandy D., Röbbel N., Rudnai P. Review of evidence on housing and health. 2004. Copenhagen. Denmark.

[2] Fisk W.J., Lei-Gomez Q., Mendell M.J. Meta-analysis of the associations of respiratory health effects with dampness and mold in homes. Indoor Air. 2007; 17:284-96.

[3] Lewtas J. Air pollution combustion emissions, Mutat. Res-Rev. 2007; 636:95-133.

[4] Houtman, I., Douwes M., de Jong T., Meeuwsen J.M., Jongen M., Brekelmans F., Nieboer-Op de Weegh M., Dick Brouwer, van den Bossche S.,

Zwetsloot G., Reinert D., Neitzner I., Hauke A., Flaspöler E., Zieschang H., Kolk A., Nies E., Brüggemann- Prieshoff H., Roman D., Karpowicz J., Perista H., Cabrita J., Corral A. New forms of physical and psychological health risks at work. European Parliament. 2008; IP/A/EMPF/ST/2007-19, PE 408.569. Brussels, Belgium.
[5] Morawska L, Tang J., Bahnfleth W., Bluyssen P.M., Boerstra A., Buonanno G., Cao J., Dancer S., Floto A., Franchimon F., Haworth C., Hogeling J., Isaxon C., Jimenez J.L., Kurnitski J., Li Y., Loomans M., Marks G., Marr L.C., Mazzarella L., Melikov A.K., Miller S., Milton D., Nazaroff W., Nielsen P.V., Noakes C., Peccia J., Querol X., Sekhar C., Seppänen O., Tanabe S., Tellier R., Tham K.W., Wargocki P., Wierzbicka A., Yao M. How can airborne transmission of COVID-19 indoors be minimised? Env. Int. 2020; 142:105832.
[6] Kim J. and de Dear R. Nonlinear relationships between IEQ factors and overall workspace, Build. Environ. 2012; 49:33-40.
[7] Bluyssen P.M. Health, comfort and performance of children in classrooms – new directions for research. Indoor Built Environ. 2017; 26(8): 1040-50.
[8] Bluyssen P.M. What do we need to be able to (re) design healthy and comfortable indoor environments? Intell. Build. Int. 2014; 6(2):69-92.
[9] ASHRAE. Guideline 10P, Interactions affecting the achievement of acceptable indoor Environments. 2016. Atlanta, USA.
[10] Torresin S., Pernigotto G., Cappelletti F., Gasparella A. Combined effects of environmental factors on human perception and objective performance: A review. Indoor Air 2018; 28:525-38.
[11] Bluyssen P.M. The Healthy Indoor Environment, How to assess occupants' wellbeing in buildings. 2014. Taylor & Francis, London, UK.
[12] CEN. EN 16798-1:2019, Energy performance of buildings - Ventilation for buildings - Part 1: Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics - Module M1-6, 2019. CEN-CENELEC Management Centre, Brussels, Belgium.
[13] Bluyssen P.M. Towards new methods and ways to create healthy and comfortable buildings, Build. Environ. 2010; 45:808-18.
[14] Bluyssen P.M. Towards an integrated analysis of the indoor environmental factors and its effects on occupants. Intell. Build. Int. 2020; 12(3):199-207.
[15] Allomonte S., Allen J., Bluyssen P., Brager G., Heschong L., Loder A., Schiavon S., Veitch J., Wang L., Wargocki P. Ten questions concerning well-being in the indoor environment, Build. Environ. 2020; 180:106949.
[16] Bluyssen P.M., Roda C., Mandin C., Fossati S., Carrer P., de Kluizenaar Y., Mihucz V.G., de Oliveira Fernandes E., Bartzis J. Self-reported health and comfort in 'modern' office buildings. Indoor Air 2015; 26:298-317.
[17] Kluizenaar de Y., Roda C., Dijkstra N.E., Rossati S., Mandin C., Milhucz V.G., Hanninen O., de Oliveira Fernandes E., Silva G.V., Carrer P., Bartzis J., Bluyssen P.M. Office characteristics and dry eye complaints in European workers – The OFFICAIR study, Build. Environ. 2016; 102:54-63.
[18] Bluyssen P.M., Ortiz M., Roda C. Self-reported rhinitis of students from different universities in the Netherlands and its association with their home environment. Build. Environ. 2016; 110:36-45.
[19] Bluyssen P.M., Zhang D., Ortiz-Sanchez M. Self-reported rhinitis and headaches of students from universities in Taiwan, Chile, Suriname, China and the Netherlands, and its association with their home environment. Intell. Build. Int. 2021; 1964424.
[20] Bluyssen P.M., Zhang D., Kurvers S., Overtoom M., Ortiz M. Self-reported health and comfort of school children in 54 classrooms of 21 Dutch school buildings. Build. Environ. 2018; 138:106-23.
[21] Eijkelenboom A., Ortiz M., Bluyssen P.M. Building characteristics associated with the prevalence of dry eyes and headaches of outpatient workers in six hospital buildings in the Netherlands, Indoor Built Environ. 2021; 1420326X211023125.
[22] Kim D.H. and Bluyssen P.M. Clustering of office workers from the OFFICAIR study in the Netherlands based on their self-reported health and comfort, Build. Environ. 2020;176: 106860.
[23] Zhang D., Ortiz M., Bluyssen P.M. Clustering of Dutch school children based on their preferences and needs of the IEQ in classrooms, Build. Environ. 2019; 147:258-66.
[24] Eijkelenboom A. and Bluyssen P.M. Profiling outpatient workers based on their self-reported comfort and preferences of indoor environmental quality and social comfort in six hospitals. Build. Environ. 2020; 184:107220.
[25] Ortiz M. and Bluyssen P.M. Profile office workers based on their self-reported preferences of indoor environmental quality at their workspace during COVID-19. Build. Environ. 2022; 211:108742.
[26] Ketchen D.J. and Shook C.L. The application of cluster analysis in strategic management research: an analysis and critique. Strat. Manag. J. 1996;17(6):441-58.
[27] Wold S., Esbensen K., Geladi P. Principal component analysis. Chemometr. Intell. Lab. Syst. 1987; 2:37-52.
[28] Tabachnick B.G. and Fidell L.S. Using Multivariate Statistics. 2007. Pearson Education.
[29] Howard M.C. A review of exploratory factor analysis decisions and overview of current practices: what we are doing and how can we improve? Int. J. Hum. Comput. Interact. 2016; 32(1):51-62.

[30] Tkaczynski A. Segmentation using two-step cluster Analysis. in: Dietrich T., Rundle-Thiele S., Kubacki K. (Eds.), Segmentation in Social Marketing: Process, Methods and Application, 2017:109-125. Springer Singapore, Singapore.
[31] Norusis M.J. IBM SPSS Statistics 19 Statistical Procedures Companion. 2012 Prentice Hall.
[32] Raw G.J., Roys M.S., Whitehead C., Tong D. Quesitonnaire design for sick building syndrome: an empirical comparison of options, Environ. Inter. 1996; 22:61-72.
[33] Siegrist, J., Starke D., Chandola T., Godin I., Marmot M., Niedhammer I., Peter R. The measurement of effort-reward imbalance at work: European comparisons. Soc. Sci. Med. 2004; 58:1483-99.
[34] Thompson E.R. Development and validation of an internationally reliable short-form of the positive and negative affect schedule (Panas). J. Cross-Cultural Psychol. 2007; 38:227-42.
[35] Eijkelenboom A., MA. Ortiz, P.M. Bluyssen Preferences for indoor environmental and social comfort of outpatient staff during the COVID-19 pandemic, an explanatory study, International Journal of Environmental Research and Public Health 2021; 18:7353.
[36] Zhang D and Bluyssen PM Actions of primary school teachers to improve the indoor environmental quality of classrooms in the Netherlands, Intell. Buildings Int. 2019; 13(2):103-115.
[37] Bluyssen PM, Zhang D, Kim DH, Eijkelenboom A, Ortiz M First SenseLab studies with primary school children: exposure to different environmental configurations in the Experience room, Intelligent Buildings International 2019; 13(4):275-292.

Data access statement

Data sharing not applicable to this article as no datasets were generated or analysed during the current study. All studies reported have been published.