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Appraisal and identification of different sources of smell by primary school children in the air quality test chamber of the SenseLab

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ABSTRACT
Previous studies have shown that next to 'human smell', 'stuffy air' is one of the discomforts that children report in classrooms. Besides, people's olfactory system is able to recognize the perceived odour intensity of various materials relatively well and in many cases the nose seems to be a better perceiver of pollutants than some equipment. In the underlying study, the aim was to expose 335 primary children to different sources of smell, and ask them to evaluate and identify those sources at individual level with their noses. Additionally, the possible effect of plants on the reduction and/or production of smells was tested. Selected sources of odour were placed in different containers and the children were asked how they feel about the smell and to identify their source. The results showed statistically significant differences among children's evaluations of different smells, a link between preference and recognition of odours, and, no statistical difference in the assessment of the smells when the potted plants were placed inside the CLIMPAQ. The results confirm the need to include sensory assessments in the evaluation of IAQ together with physical evaluations. Future studies on the effect of using active vegetation systems instead of passive systems are recommended.

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KEYWORDS
Indoor air quality; pollution sources; sensory evaluation; primary school children

1. Introduction

Indoor environmental quality (IEQ) is a significant concern in educational buildings, since it is directly related to children's activities and well-being (Mendell and Heath 2005; Bluyssen 2017). Several studies have documented the indoor environment, occupant comfort, productivity and health in offices (Frontczak et al. 2012; Al Horr et al. 2016; Bluyssen et al. 2016; Sakellaris et al. 2016; Mandin et al. 2017) from the point of view of the occupant. For the main occupants of primary schools, the children, there seems less information available on their point of view for comfort, health and performance. Children represent a risk group and are more susceptible than adults to poor IEQ.

IEQ is determined by thermal, light, acoustical and air quality. Poor indoor air quality (IAQ) is a common problem in classrooms, and it has been reported that it causes health and comfort problems among its occupants (Annesi-Maesano et al. 2013; Ferreira and Cardoso 2014; Turunen et al. 2014; Bluyssen 2017; Fisk 2017; Bluyssen et al. 2018a; Jarvi et al. 2018). In a previous study executed in the spring of 2017, 54 classrooms in the Netherlands were visited for a survey on the health and comfort of primary school children in relation to their stay in the classrooms. From the 1145 children that

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completed the questionnaire, 63% of the children was bothered by smell (girls 67% and boys 59%). The most frequently occurring smells in the classroom according to the children were 'human' (56%) and 'stuffy' (27%) (Bluyssen et al. 2018a). While the term 'human' was often related to farting, the term 'stuffy' could not be specifically related to a source.

IAQ is determined by the exposure to pollution over time and this pollution can originate from different sources: people and their activities, building and furnishing materials, outdoor air and even heating, ventilation and air conditioning systems (Bluyssen 2004; 2015). The European projects: the European Database European Database on Indoor Air Pollution Sources in Buildings (Molina et al. 1996) and MATHIS (Oliveira Fernandes et al. 1999) resulted in databases of building materials and products with both chemical and sensory information, which are the basis for the current guidelines used in European countries. AIRLESS, another European project, showed that the main sources of pollution in ventilation systems are filters and ducts and it may vary depending on the design, the use and the maintenance of the system (Björkroth et al. 2000; Bluyssen et al. 2000a; Bluyssen et al. 2003).

The main groups of pollutants found in indoor air are chemical pollutants, which includes gases, vapours and particulate matter (PM); and biological pollutants. Building and furnishing materials can emit volatile organic compounds (VOCs), such as for example formaldehyde (a very VOC) and several alcohols, that have the potential to affect health and well-being. Several studies have shown that formaldehyde can affect the health, comfort and performance of school children (Smedje and Norback 2001; Shu et al. 2014; Bluyssen 2017). It has been well documented that furnishing and flooring materials represent an important source of pollution in classrooms producing inconvenience among the children (Bluyssen 2016; Bluyssen 2017). High PM concentrations are also known to affect health and wellbeing of children in classrooms. Several studies have shown that physical activities of children inside contribute to rising PM concentrations in classrooms, in particular PM10, and that indoor sources are evidently the main contributors to indoors PM concentrations, specially to PM1 and PM2.5 (Branco et al. 2014; Fromme et al. 2008).

A source that is often not mentioned in the list of polluters, is the plant: a source that can pollute as well as clean the air. There is increasing recognition of the potential for plants to generate an attractive environment that supports social and emotional well-being, recovery from stress, and cognitive performance, especially in classrooms (Kaplan 1995; van den Berg et al. 2017). Several studies have described and evaluated the possible effect of plants on the indoor air quality (Wolverton, Mcdonald, and Watkins 1984; Wolverton, Johnson, and Bounds 1989; Darlington, Dat, and Dixon 2001; Soreanu, Dixon, and Darlington 2013; de la Cruz et al. 2014; Armijos-Moya et al. 2019). However, there is still a lack of solid evidence proofing the real effect of green systems in the indoor environment (Armijos-Moya et al. 2019), especially regarding air quality.

Health and comfort problems have been reported and associated with emissions of materials used in buildings where occupants spend most of their time. From annoying smells to symptoms such as dry eyes, irritated skin, upper and lower airway problems, to even carcinogenic effects have been associated with exposure to VOCs (Fanger 2000; Kotzias 2005; Bluyssen 2015). These problem cases have normally been marked belonging to either Sick Building Syndrome (SBS), which are health problems (biological or psychological) caused by the negative impact of buildings (Vural and Balanlı 2011), or Building-Related-Illness (BRI), such as legionnaires disease and asbestosis (Bluyssen et al. 1997). Therefore, materials need to be evaluated with respect to their VOC and odour emissions (Bluyssen et al. 1997). Odours may cause a variety of undesirable reactions in people, ranging from annoyance to documented health effects. Prolonged exposure to odours can generate undesirable reactions ranging from emotional and psychological stresses, discomfort, headaches, or depression to physical symptoms including sensory irritations, headaches, respiratory problems, nausea, or vomiting (National-Research-Council 1979; Herz 2002; Bluyssen 2014). They are emitted from several construction, consumer and cleaning products, including air fresheners, plants and flowers, food and beverages (Berglund et al. 1999; Oliveira Fernandes et al. 1999; Bluyssen, de Oliveira Fernandes, and Molina 2000b). Odours that result directly or indirectly from human activities and that cause an adverse effect are often classified as contaminants and are subject to regulation (Brancher et al. 2017).

Currently, different methods are available for assessing IAQ, such as chemical and physical monitoring of certain pollutants in the air or at a surface, and sensory assessment with the human nose (e.g Bluyssen and Fanger 1992). Different instrumentation and technologies are used to monitor and assess air quality, such us chemical sensors and gas chromatography. Overall, these instruments can identify a number of substances and their concentrations; however, one of the main limits of this technique is the complexity of concentrations and mixtures of the pollutants and its odours. In real life, the concentrations of the pollutants are usually lower that the instrument detection limit. Additionally, these instruments are in general expensive and they do not provide any information about human perception (Yuwono and Lammers 2004; Brattoli et al. 2011). Series of guidelines and regulations released in many countries, are focused on the concentration limitation of indoor air pollutants based on toxicities (Kotzias 2005; Bluyssen 2015). The intensity of an odour or smell emitted by different indoor materials was introduced as a measure to assess the VOCs emitted, as some VOCs that are commonly present indoors have been associated with odour (Peng, Lan, and Wu 2009) and can also cause a variety of undesirable reactions among people, ranging from annoyances, irritations to documented health issues (Nicell 2009).

In the last years, scientists have focused on developing devices analogue to human senses, such as electronic noses that once calibrated they can be used to perform odour assessment on a continuous basis at a minimum cost (Hudon, Guy, and Hermia 2000; Szulczynski et al. 2018). However, the range of odour mixtures, concentrations and intensities that the device can detect is still limited (Yan et al. 2017). Due to this limitation the use of these devices is still restricted at the moment to monitor environmental odours (Yan et al. 2017). Scientists recommend to combine odour measurement procedures using the human nose as detector together with a scientific method and instruments (Brattoli et al. 2011; Walker 2001).

Sensory assessment of IAQ with human subjects as measuring instruments has been used to establish the appropriate ventilation rates that bring body odour intensity to acceptable levels. It also has been used to assess various processes to improve IAQ, based on the use of different materials (Bluyssen 1990; Knudsen, Clausen, and Fanger 1997; Berglund et al. 1999; Wargocki 2004). The nose can detect very low concentrations (parts-per-trillion range) and interpret all at the same time (Bluyssen 2004; Meilgaard, Civille, and Carr 2006). However, some studies have shown that the indoor pollutants with highest chemical concentrations were not the most odour active odorants (Yi et al. 2013).

In the underlying study, the aim was to expose children of some of the same primary schools as that were studied before (Bluyssen et al. 2018a), to different sources of smell, and ask them to evaluate and identify those sources at individual level with their noses. Additionally, the possible effect of plants on the reduction and/or production of smells was tested.

The aims of the study were to evaluate: (1) the perception and identification of smells from known sources in classrooms by children; (2) the relationship between perception in the field study and the lab study; (3) the level of acceptability in relation to recognition of smells by children; (4) the effect of plants on the perception of smells.

2. Materials and methods

2.1 Study Design

This study was part of a series of tests performed during 10 days with children from the previous studied Dutch schools, in the SenseLab (Bluyssen et al. 2018a; Bluyssen et al. 2018b; Bluyssen et al. 2019b). During the winter and spring of 2018, 335 students of seven schools in the Netherlands visited the SenseLab to participate in a series of experiments. The recruitment of these schools was on voluntary basis (Bluyssen et al. 2018a). When the children arrived in the SenseLab, they completed a one-page questionnaire with personal information and were divided into groups (randomly) of maximum 16 children per group. Per day, a maximum of three groups could perform the tests. One group started in the Experience room, one group was divided over the four test chambers (maximum of 4 children per test chamber) and the third group visited the Science Centre (the location in which the SenseLab is located). After approximately 35 min the groups changed: group 1 went to the test chambers, group 2 visited the Science Centre and group 3 went into the Experience room. In each of the test chambers (light, sound, air and thermal), different tests were performed. Every 7–8 min, after the tests were performed, the children changed to another test chamber (Bluyssen et al. 2019a, 2019b; Zhang, Tenpierik, and Bluyssen 2019; Ortiz, Zhang, and Bluyssen 2019). This paper presents the results of the tests performed in the air quality test chamber.

2.2 The SenseLab and the air quality chamber

The experiments were performed in the SenseLab, located in the Science Centre at Delft University of Technology that was described in detail by Bluyssen et al. (2018b). The SenseLab is a laboratory for testing and experiencing single and combinations of indoor environmental conditions. It comprises of an Experience room, where it is possible to study the effects of different combinations of environmental conditions in different scenarios, and four test chambers for each of the indoor environmental factors: indoor air, light, acoustics and thermal aspects. For this specific study, the experiment was carried out in the air quality chamber which had a volume of 17.4 m^3 (floor area 8.3m^2×2.1 m height) (Figure 1), and included a stainless steel ‘Sniffing table’, including different sources of smell, and a table on which the CLIMPAQ 50L was placed. The CLIMPAQ 50 L (Figure 1) is a small test chamber that allows to analyse emissions and pollutants from a wide range of materials. The principal elements of the experimental set-up in the air quality chamber are presented in (Figure 2).

2.3 Ethical aspects

After recruitment of the schools, the parents received an information letter and a consent letter from the school management, which usually happened two weeks before the visit. On the day of the visit, the research team received the consent forms usually from the teachers accompanying the children. For the children without permission to join the experiments, the school management generally decided not to have them join the visit. Furthermore, the children always had the option to opt out if they no longer wanted to participate. The Ethics committee of the TU Delft gave approval for the study.

Figure 1. Air Quality Chamber: CLIMPAQ 50L and sniffing table.

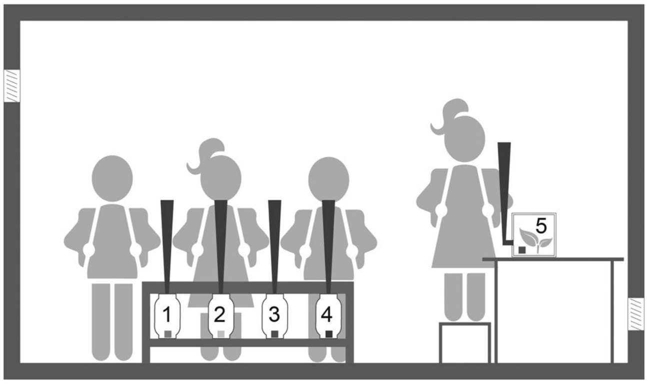

Figure 2. Diagram of the Experimental setup in the Air Quality Chamber. 1. Perfume; 2. Mint leaves; 3. Carpet, MDF (medium density fibreboard), or Vinyl (according to the schedule in Table 1); 4. Crayons; 5. Carpet, MDF, or Vinyl (+plant, according to the schedule in Table 1).

2.4 Experiment

Two similar experiments were conducted to assess the identification of potentially recognizable odours for children. In each session, five odorant sources were used. For the Indoor Air test chamber (Figure 1), different olfactory stimuli were selected to be identified for the children (Table 1). These odorants were selected based on previous studies in Dutch schools (Bluyssen et al. 2018a). The stimuli were placed in four different covered plastic containers located in the 'sniffing table' with sniffing cones (Bluyssen 1990) (Figure 1). Every session 3–4 children entered the chamber and they were asked to take a sniff of each of the sniffing cones, one at the time, and answer a questionnaire regarding the smell they perceived. At the same time, one of the materials in the plastic containers (container no.3) was also located in the CLIMPAQ 50 L (Figure 1;

Table 1. Time schedule and selected sources of smell.

Container No.	Material	Notes and schedule
1	Perfume	
2	Mint leaves	New leaves were used for each session. March 15th: Liquorice. Mint leaves were used in the rest of the sessions.
3	Carpet/MDF/Vinyl	Tuesday, February 13: Carpet Thursday, February 15: Carpet Tuesday, February 20: Carpet Thursday, February 22: Carpet Thursday, March 8: MDF Thursday, March 15: MDF Tuesday, March 20: MDF Tuesday, March 27: MDF Tuesday, April 3: Vinyl Thursday, April 5: Vinyl
4	Crayons	Always the same
Climpaq 5	Carpet/MDF/Vinyl	Tuesday, February 13: Carpet Thursday, February 15: Carpet Tuesday, February 20: Carpet + Plant Thursday, February 22: Carpet + Plant Thursday, March 8: MDF + Plant Thursday, March 15: MDF + Plant Tuesday, March 20: MDF Tuesday, March 27: MDF Tuesday, April 3: Vinyl Thursday, April 5: Vinyl + Plant

Figure 3. Selected materials + Spider plant inside of the CLIMPAQ 50L.

Table 1). The children were asked to match the odour with one of the plastic containers. In half of the sessions, three selected potted plants were placed inside of the CLIMPAQ together with the selected material (Figure 3) according to the schedule (Table 1) to evaluate the effect of the plant on odour depletion/production. The plants selected for these experiments comprised of three *Chlorophytum*, also known as spider plants, which are common potted plants. Previous studies have stated that this kind of plant may have a positive effect on the reduction of pollutant within the indoor environment (Wolverton, Johnson, and Bounds 1989; de la Cruz et al. 2014). Prior to the experiments, a Photoionization Detector (PID), ppbRAE3000 11.7 eV, was used to monitor the VOCs emitted by the selected materials. This VOC-monitoring instrument uses a 11.7 eV lamp that is able to lamp respond to a broad range of compounds, including formaldehyde.

2.5 The questionnaire

The children were asked: 'How do you like the smell?' and 'Can you tell what it is?'. When working with children, who are not always able to clearly communicate and express how they feel, the use of graphic questionnaires could be an alternative option to obtain more information about their experiences. Therefore, the perceived odour was assessed on a five-graphical-grade scale (Figure 4). The questionnaire contained special drawings to make it more attractive and interesting for the children. Before administering the questionnaire in the Air Quality Chamber, it was distributed and tested among the staff, in order to improve and adapt it. During the experiment, before the questionnaire was distributed, an explanation was given of the contents and purpose of the questionnaire. In general, it took the children approximately five minutes to perform the test and fill in the questionnaire.

2.6 Data management and analysis

All data from the questionnaires were manually typed in and stored in IBM SPSS Statistics version 25.0. A second person systematically checked the input of the questionnaire data. First, descriptive statistics such as percentages, range or arithmetic mean with standard deviation were used to summarize the data. This descriptive analysis was used to describe children's general information (including age, gender, children with allergies, children with cold, etc.). Additionally, comparisons of mean values were performed with one-way ANOVA tests to evaluate the children's level of

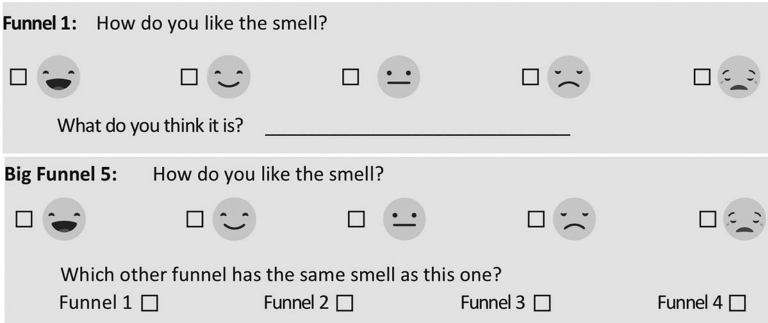

Figure 4. Part of the questionnaire for sniffing test.

acceptability for each of the sources of smell. Finally, independent-Samples T-tests were conducted to evaluate whether statistically significant differences between children's assessment of two same smells (smell 3 and smell 5) occurred.

3. Results

3.1 Participants

335 children, including 166 girls and 169 boys from seven primary schools in the Netherlands, that were visited during the field study in the year before this study, participated. The mean age of these children was 10.6 years old. From the 335 children, 254 (76%) children participated in both the field and the lab studies.

3.2 VOC-monitoring

A VOC-monitoring instrument was used to measure the emissions coming out from the plastic containers. It was found that the 11.7ev PID monitor measured 0 ppb for almost all the sources with the exception of the perfume and the mint leaves. The measurements were recorded after 3 min after placing the materials inside of the containers. In the case of the mint leaves the instrument measured 0ppb after 5 min of placing the leaves inside of the container (Figure 5).

3.3 Experiment

In the first part of the experiment, children performed a smell identification test with four different smell stimuli. In each session, a perfume stick was placed in container number 1. As shown in Table 2, 15% of the children identified the smell as perfume. Most of the children identified the smell as soap or shampoo. Several children identified the smell as similar smells such as fresheners, flowers or perfume. 6% of the children could not give any name to the smell.

In container 2, some mint leaves where placed. 38% of the children identified the smell of mint. The rest of the children identified the smell as plants, tea, spices, flowers, and other. 8% did not identify the smell. In container 4, several crayon pieces where placed. 30% of the children could not identify the smell. Some kids identified the smell as plastic, rubber, carpet, dust, wood and others (Table 2).

During the series of tests, three different materials where placed in container 3. Each material was changed according to the schedule presented in Table 1. The children found it difficult to identify the smell when the vinyl and the carpet where placed in container 3, as shown in Table 3. When pieces of MDF were placed in container 3, 48% of the children identified the smell as wood.

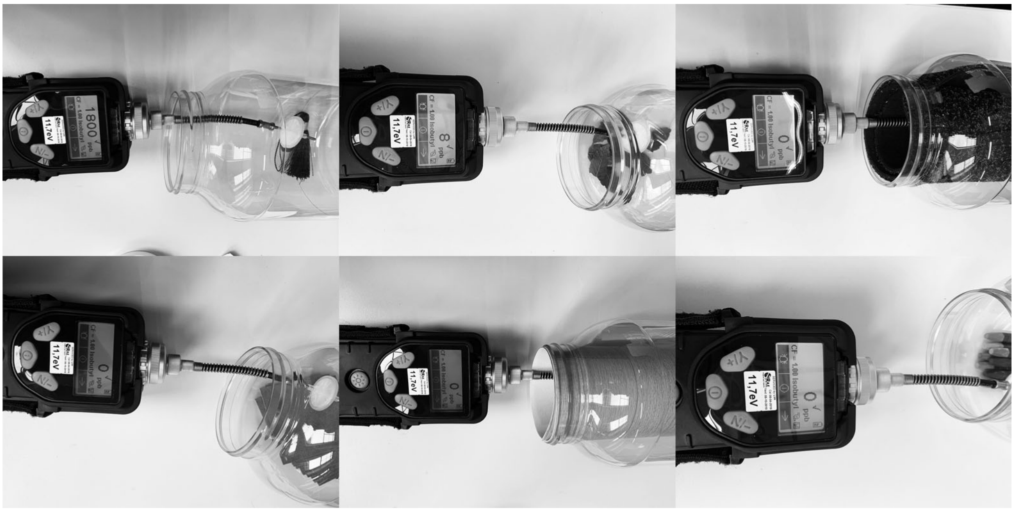

Figure 5. VOCs emitted by the selected materials: (a) perfume; (b) mint leaves; (c) carpet; (d) MDF; (e) vinyl; and (f) crayons.

The children were also asked: How do you like this smell? The result of the ANOVA test showed that there were statistically significant differences among children's evaluations of different smells ($p = 0.00$). They liked perfumes most (mean value of 4.2), followed by mint leaves (mean value of 3.4), carpet, MDF and vinyl (mean value of 2.7 and 2.9). They liked crayons the least with a mean value of 2.6 (Table 5).

Table 4 shows that in general, the children could identify which container emitted the same smell as in the CLIMPAQ 50L. Children in general liked smell 5 more than smell 3 (Tables 5 and 6). However, the results of the t-tests, comparing the two same smells in funnel 3 and in the CLIMPAQ with the plants inside of the CLIMPAQ, showed no statistically significant difference between these two evaluations (Tables 7 and 8). Furthermore, the results of the t-tests between the perception of the

Table 2. Identification of the smells in containers 1, 2 and 4 by the children.

Funnel 1: perfume (n^* = 335)		Funnel 2: mint leaves (n = 309)		Funnel 4: crayons (n = 335)	
Fresheners	9.6%	Plants	15.5%		
Flowers	10.1%	Tea	6.5%	Dust	6.6%
Soap/Shampoo	49.3%	Flowers	4.9%	Wood	5.4%
Perfume/Deo/Cream	15.2%	Mint/Mint tea	38.2%	Plastic/Rubber/Carpet	8.7%
Candle	1.5%	Spices	6.1%	Spices/Tea/Vinegar	6.9%
Other	8.1%	Other	21.0%	Other	42.1%
Empty/I don't know	6.3%	Empty/I don't know	7.8%	Empty/I don't know	30.4%

Note: *Number of children that performed the identification test.

Table 3. Identification of smell in container 3 by the children.

Carpet (n^* = 118)		MDF (n = 128)		Vinyl (n = 89)	
Carpet	9.3%	Wood	47.7%	Clay	11.2%
Rubber/Plastic	22.9%	Cardboard	12.5%	Rubber/Plastic	16.9%
Dust	5.1%			Metal	9.0%
Leather	5.9%				
Gasoline	5.9%				
Other	33.9%	Other	27.3%	Other	43.8%
Empty/I don't know	16.9%	Empty/I don't know	12.5%	Empty/I don't know	19.1%

Note: *n = number of children that performed the test.

Table 4. Which other funnel has the same smell as this one?

Funnel 3	5. Climpaq	*n**	Who identified the smell?
Carpet	Carpet	56	66.1%
Carpet	Carpet + Plant	62	59.7%
Mdf	Mdf	70	79.3%
Mdf	Mdf + Plant	58	81.8%
Vinyl	Vinyl	46	58.7%
Vinyl	Vinyl + Plant	43	81.0%

Note: *Number of children who participated in each individual test.

Table 5. Mean evaluations of children when asked 'How do you like the smell?' All the children.

Container N.	Material	*n**	Mean	Std. Deviation
1	Perfume	332	4.24	0.843
2	Mint leaves	328	3.43	1.147
3	Carpet/MDF/Vinyl	324	2.73	1.043
4	Crayons	326	2.6	1.084
5 Climpaq	Carpet/MDF/Vinyl	305	2.97	1.067
	Total	1615	3.2	1.201

Note: *Number of children Anova Test between groups ($p = 0.00$).

Table 6. Mean evaluations of children when asked 'How do you like the smell?': Without children who had a cold.

Container N.	Material	*n**	Mean	Std. Deviation
1	Perfume	153	4.29	0.76
2	Mint leaves	152	3.39	1.14
3	Carpet/MDF/Vinyl	149	2.78	1.006
4	Crayons	149	2.68	1.054
5 Climpaq	Carpet/MDF/Vinyl	139	3.12	1.043
	Total	742	3.26	1.163

Note: *Number of children ANOVA Test between groups ($p = 0.00$).

Table 7. 'How do you like the smell?': Is there any plant in the chamber = NO.

Container N.	Material	*n**	Mean	Std. Deviation
1	Perfume	157	4.29	0.785
2	Mint leaves	156	3.34	1.199
3	Carpet/MDF/Vinyl	156	2.82	0.891
4	Crayons	158	2.72	1.016
5 Climpaq	Carpet/MDF/Vinyl	146	3.16	0.959
	Total	773	3.27	1.128

Note: *Number of children, Anova Test between groups ($p = 0.00$), T. Test: Is any plant in the chamber (0.05).

smells in funnel 3 and in the CLIMPAQ without the plants, showed a statistically significant difference between the two evaluations (Tables 7 and 8).

In addition, five t-tests were conducted to compare the evaluations of children with a cold and without a cold. The results showed that children who had a cold didn't differ significantly with healthy children regarding their evaluations (Tables 5 and 6).

4. Discussion

4.1 Perception versus chemical measurements

The results of the present study show that even though the chemical measurements didn't show any emission from most of the materials tested (Figure 5), the children could perceive a smell with their noses. The outcome confirmed earlier findings and recommendations with regards to performing both sensory evaluations as well as chemical and physical measurements, (Bluyssen et al. 1997): some pollutants can just not be monitored by the instruments available, while our nose can. Our sensory system (nose) can assess the perceived odour intensity of various materials relatively well, and, in many cases the nose seems to be a better assessor of pollutants than some equipment. The indoor environment comprises thousands of chemical compounds in low concentrations, of which not all can be measured and interpreted by currently available equipment (Bluyssen 2004). Sensory evaluation seems therefore a necessary instrument for the measurement of the perceived indoor air quality because chemical and physical analysis alone can in most situations not be used to predict how chemicals will be perceived among users.

4.2 Level of acceptability vs. identification of smells

One of the aims of this study was to only include odours that are well known and able to be correctly identified by a majority of children. Previous studies have demonstrated that the ability to identify odours increases with age in children. This is due to an ongoing process of odour learning rather than an actual increase in olfactory function (Schriever et al. 2018). The evaluation of air quality expressed in acceptability reflects perceptual information in combination with psychological and social values.

The present study showed that the level of acceptability given by the children to the different sources of smell increased when they were more familiar with the source of the smell (able to recognize) and when they had visual contact with the source, as shown in Tables 5–8. In addition, results showed that children who had a cold didn't differ significantly with healthy children in their assessment. This can be explained by a psychological point of view: each stimulation introduced in the indoor environment needs explanation; therefore, smells that are present and which cannot be recognized will lead to some discomfort (Vroon 1990). This is shown in Tables 5 and 6 that indicates that children prefer the smells that they could easily identify, while the smells that were more difficult to identify were less likeable. However, it is important to mention that an unpleasant odour for some children may be perceived as indifferent or even pleasant by others.

4.3 Stuffy air

Stuffy air seems to be an important factor to consider to qualify indoor air quality. It has been used as a descriptive for air quality in a large number of studies in offices, schools and other indoor environments. In the previous field study, it was found that most of the children were bothered by smell: 56% used 'human' to describe the smell they were bothered with and 27% used 'stuffy' (Table 9) (Bluyssen et al. 2018a). However, they couldn't describe what stuffy air meant or where it came from. We could assume that stuffy air can be caused by bad ventilation within the classrooms or by emissions emitted by building materials. Therefore, in this study some building materials were included to evaluate how children assess these materials (Bluyssen 2016; Bluyssen 2017). As can be seen in Tables 5 and 6, children, in general did not like the odour emitted by the selected building materials and in most cases, they could not identify the source of the smell (Table 3).

Table 8. 'How do you like the smell?': Is there any plant in the chamber = SI.

Container N.	Material	*n**	Mean	Std. Deviation
1	Perfume	175	4.21	0.892
2	Mint leaves	172	3.51	1.095
3	Carpet/MDF/Vinyl	168	2.65	1.164
4	Crayons	168	2.5	1.137
5 Climpaq	Carpet/MDF/Vinyl	159	2.81	1.133
	Total	842	3.15	1.262

Note: *Number of children, ANOVA Test between groups ($p = 0.00$). T, Test: Is any plant in the chamber (0.05).

Table 9. Type of smells in classrooms pointed out by children ((Bluyssen et al. 2018a).

Type of smells in classrooms pointed out by children	
Flower	9%
Fruit	13%
Vegetables	4%
Stuffy	27%
Human	56%
Paint	14%
Hospital	3%

4.4 Effect of plants

One of the objectives of the study was to evaluate the effect of potted plants on the depletion or production of smells. In the present study, it is shown that the presence of a potted plant inside of the CLIMPAQ did not have a big influence on the identification of the same smell within the sniffing table, with the exception of the vinyl for which the smell in general was more difficult to identify for the children (Table 4). Previous lab studies have indicated a possible effect of vegetation on IAQ (Wolverton, Johnson, and Bounds 1989; Soreanu, Dixon, and Darlington 2013; de la Cruz et al. 2014), but all of these tests were chemical tests. There is still a lack of solid and relevant data available to understand the true pollutant-removal mechanisms and factors in these systems (Armijos-Moya et al. 2019). In fact, existing research suggests that in an active vegetation system (green systems in combination with mechanical fans), air-cleaning rates may be significantly higher than in a passive vegetation system (potted plants) (Darlington, Dat, and Dixon 2001), which was applied in the study reported here.

4.5 Limitations

With respect to the limitations of this study, three main weaknesses can be identified. One is the limited time provided to execute each test, especially regarding the evaluation of the effect of the potted plant in the depletion or production of smells. Future experiments should analyse the effects of green systems in relation to the mitigation of odours over a longer period of time.

The second limitation is that the equipment applied to monitor the VOCs emitted by the different sources, comprised of a direct reading instrument that monitored total VOCs (including also VVOCs) at pbb level. For identification of the individual components of ‘stuffy air’, it might be required to perform long-term measurements that collect enough material for identification.

Finally, the children that performed the tests had to undergo also other tests and activities related with other environmental factors, which resulted in some cases that they didn’t complete their questionnaire. The aim of these series of experiments in the SenseLab was to generate a general overview on how the children assess different aspects in the indoor environment. In future tests, it is recommended to focus on specific factors that affect the indoor air quality and on how some elements, such as plants or new materials, can affect the perceived indoor air.

5. Conclusions and recommendations

One of the aims of the study was to evaluate children’s perception and identification of smells from known sources in classrooms. The present study showed that the level of children’s acceptability of smells from the different sources, seems to have a relation with their level of recognition of the smell. Children found the smell in general more acceptable, when they recognized the smell, even though the smell might be unhealthy. For the assessment of emissions of sources found in classrooms, combined sensory and chemical measurements, as recommended in several guidelines, is therefore required as well.

Another aim of the study was to identify where the 'stuffy smell', found during the study field, came from. For that reason, some building materials were included in this study. It was found that in general children did not like the smell of those materials and in most of the cases they could not identify the source of the smell. However, whether there is a correlation between the smells from those materials and the 'stuffy air' that children identified in the classrooms, needs to be studied more in depth.

Finally, the effect of (passive) plants on the perception of smells showed no effect. In future studies, it is therefore recommended to perform tests with an active green system, over a longer period of time. It might take time for the plant to 'clean' the air, and an active green system might improve the air quality faster than a passive one.

Disclosure statement

No potential conflict of interest was reported by the authors.

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