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Measurements of perceived air quality: Correlations between odor intensity, acceptability and characteristics of air

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SUMMARY
The objectives of the present work were to examine the relationships between sensory assessments of air quality made using different methods: odor intensity by category scale, category-ratio scale and equal-intensity matching with acetone as a reference and acceptability scale, and to study whether the assessments of acceptability can be explained by selected characteristics of the air. A sensory panel assessed the air polluted by emissions from different building materials at different area-specific ventilation rates. The three assessments of odor intensity were linearly strongly correlated with each other. Therefore, for practical applications it seems feasible to apply only one of the investigated methods. Odor intensity was strongly correlated with the assessments of acceptability of the air. This suggests that, for the investigated materials, the assessments of acceptability are mainly influenced by odor intensity. The selected descriptors characterizing the air could not explain the assessments of acceptability because the odor intensity levels were generally low.

KEYWORDS
Perceived air quality; Acceptability; Category scale; Category-ratio scale; Odor intensity

INTRODUCTION
Human subjects are used for characterizing the quality of air as it is perceived by people indoors. Different methodologies for sensory evaluations of indoor air quality exist (ECA, 1999), but two methods have been used extensively: sensory assessments of odor intensity and acceptability of air quality. There is no general consensus in the literature on which methods are best suited for practical applications, especially when sensory assessments of air quality are used for setting ventilation requirements in indoor spaces and defining requirements on emissions from building products. For example, ASHRAE Standard 62 recommends that the air quality is evaluated using assessments of acceptability (ASHRAE, 2007). The Danish Labelling Scheme (Wolkoff and Nielsen, 1996) recommends using assessments both of acceptability and odor intensity. Müller et al. (2005) recommend using a method based on equal-intensity matching with acetone as a reference. Considering that different regulations and schemes use different sensory evaluations to characterize the perceived air quality it should be examined whether there are any relationships between the different methods. If so, the results obtained from different tests/experiments using different methods can be compared. Furthermore, in case that relationships do exist it would be possible to examine whether a common method can be selected when perceived indoor air quality is evaluated, based on pragmatic criteria which include repeatability, reliability, and ease of use. The objectives of the present work were to examine the relationships between sensory assessments of air quality made using different methods and to examine what perceptual attributes of air are likely to influence whether the air quality is assessed as

acceptable or not acceptable.

METHODS

A sensory panel of 35 Caucasian students (23.2±1.8 years old; 48% females) assessed acceptability of air quality, odor intensity and characterized the assessed air by different descriptors; the exposure was orthonasal (sniffing) (Pierce and Halpern, 1996). The subjects were non-smokers, had no asthma, allergy or other hypersensitivity, no sensory handicaps and were generally in a good health conditions (did not take regular medication or suffer from upper airway or respiratory infections); their average score on the Chemical Sensitivity Scale (CSS), which examines experience with and exposure to odors and sensory irritants, was 66.8±6.9 (Nordin, 2003). Using different methods the assessments were made independently in a design balanced for order of presentation. Air quality was assessed using the continuous acceptability scale (Wargocki 2001). Odor intensity was assessed using a category scale (Yaglou et al., 1936) and a category-ratio scale, CR10 scale (Borg, 1985), as well as by equal-intensity matching with a reference gas of acetone (Muller et al. 2005) where the reference consisted of seven different concentrations of acetone: 31.4, 40.8, 61.4, 104.8, 144.9, 227.1, 321.4 mg/m^3. Nine descriptors were used in an attempt to characterize the air. They included assessments on whether the air was odorous, irritating, humid, dry, warm, cool, pleasant, stuffy and fresh. They were presented on continuous visual-analogue scales (VAS) with graduated endpoints (Wyon, 1994). The subjects assessed the air exhausted from ventilated 50-L glass chambers, CLIMPAQs (Nordtest, 1998). The air in the chambers was polluted by one of seven 21-month-old building materials: carpet, linoleum, gypsum board, two different paints on gypsum board, wooden floor and gypsum ceiling tiles (Knudsen and Wargocki, 2008). Each material was investigated at three different area-specific ventilation rates corresponding to relatively low, medium and highly polluted air. In addition subjects assessed the air extracted from an empty chamber and from two chambers containing acetone at the concentrations of 88.6 and 217.7 mg/m3. During sensory measurements the temperature of the air extracted from the chambers for assessments was on average 21.4±0.1^{o}C and the relative humidity 47±2%. Prior to the measurements the subjects received instructions and practiced the use of the different sensory methods.

RESULTS

Individual ratings made by the subjects using the different sensory methods were averaged separately for each exposure and for each area-specific ventilation rate. They were then plotted against the logarithm of the area-specific ventilation rate. The results show that the relationship between the assessments of acceptability of air quality and the logarithm of the area specific ventilation rate can be reasonably approximated with linear functions, similarly to previous experiments (Knudsen et al., 1998; Knudsen and Wargocki, 2008). Also the assessments of odor intensity on the category scale, category ratio-scale and the use of a reference gas of acetone were linearly related to the logarithm of the area-specific ventilation rate. Increasing the area-specific ventilation rate increased acceptability and reduced odor intensity. Assessments of the characteristics of the air showed that independently of the area-specific ventilation rate the assessments of whether the air was characterized as dry, humid or warm were unchanged; but increasing the area-specific ventilation rate reduced odor, irritation and air stuffiness, improved freshness and pleasantness of air, as well as caused the exposures to be assessed as cooler. Figure 1 shows that assessments of odor intensity using the three different methods were linearly strongly correlated with each other. Figure 2 shows that the assessments of acceptability of air quality were also strongly linearly correlated with the assessments of odor intensity. To evaluate whether different characteristics of the air can explain why people judge the air quality as acceptable or not acceptable, the descriptors

characterizing the air were compared at equal levels of odor intensity that was determined by using the assessment made on the category scale corresponding to weak odor, moderate odor and strong odor. When the odor intensity was weak, there was no difference between the different descriptors characterizing the air. The difference was more apparent when the odor intensity was strong, but the descriptors did not exhibit a particular pattern.

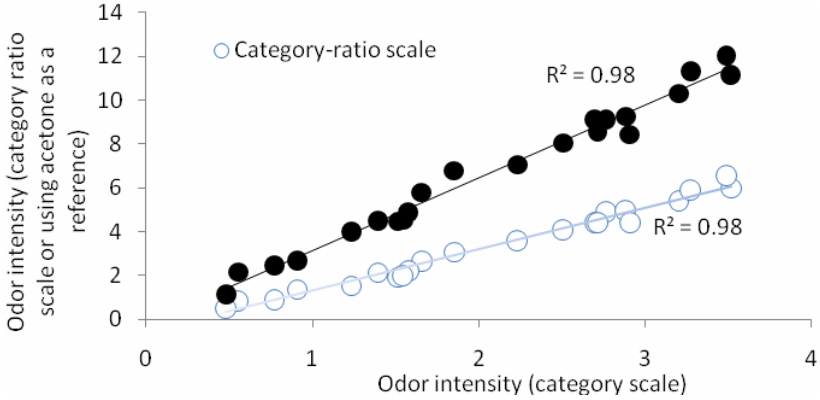

Figure 1. Odor intensity assessed using category-ratio scale and equal-intensity matching with a reference gas of acetone as a function of odor intensity assessed using category scale. The scales were coded as follows: category scale: 0=no odor; 1=slight odor; 2=moderate odor; 3=strong odor; 4=very strong odor; 5=overpowering odor; category-ratio scale: 0=nothing at all; 0,5=extremely weak; 1=very weak; 2=weak; 3=moderate; 5=strong; 7=very strong; 10=extremely strong; equal intensity matching: 0 corresponds to an odor intensity produced by acetone at a concentration of 20 mg/m^3; 1 corresponds to an odor intensity produced by acetone at 40 mg/m^3; 2 corresponds to an odor intensity produced by acetone at 60 mg/m^3, and so on.

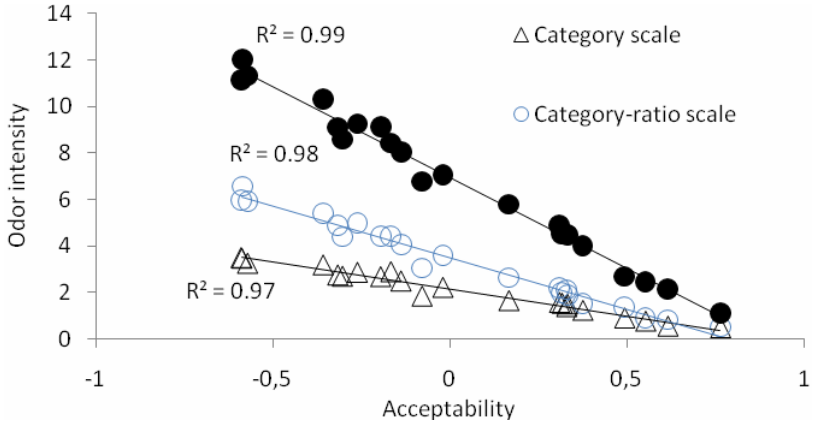

Figure 2. Odor intensity assessed using category scale, category-ratio scale and by equal-intensity matching with a reference gas of acetone as a function of the assessments of the acceptability of air quality; coding of odor intensity scales is explained in Figure 1; acceptability scale was coded as follows: -1=clearly not acceptable; 0=just not acceptable/just acceptable; +1=clearly acceptable.

DISCUSSION

The strong correlations between the assessments of odor intensity carried out using the different methods suggest that for practical applications one of the methods can be selected for future investigations of odor intensity. The selection of method should take into account several criteria including repeatability, reliability and whether it is easy to apply the method. Further studies are needed to define these criteria; however, from a pragmatic point of view the category scale seems to be the most feasible for sensory evaluations in the field.

The strong correlation between the assessments of acceptability of air quality and the assessments of odor intensity suggests that for the air polluted by the investigated materials the assessments of acceptability of air quality are mainly influenced by the odor intensity.

Whether assessments of odor intensity can be used to predict acceptability, should be investigated further for pollution sources and exposures other than those examined in the present experiments. This is especially important for odors considered to be pleasant.

It was not possible to explain the assessments of acceptability using descriptors characterizing the air, probably due to too low, but still realistic levels of odor intensity. In future studies it would be interesting to examine whether there are any sensory descriptors/attributes that can explain the assessments of acceptability at higher levels of odor intensity and whether these assessments are affected by the experience of the panelists. The exposures presented to the subjects should also be selected based not on the area-specific ventilation rate, like in the present experiments, but to obtain equal intensities of odor, so that the differences in odor intensities do not influence the assessments of the characteristics of air.

CONCLUSIONS

For practical applications it seems feasible to apply only one of the investigated methods for assessing odor intensity. Assessments of acceptability of air quality and odor intensity were strongly correlated. The assessments of acceptability of air quality could not be explained by the selected descriptors characterizing the air.

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