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The influence of carpet flooring on the indoor climate; effects on perceived air quality, symptoms and particle concentrations	23.05.2018 NUMBER OF PAGES/ATTACHEMENTS 42/15
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ABSTRACT

Carpet flooring is a commonly used flooring material and is becoming a trend in offices with open plan landscape. Previous studies have found relations between the presence of carpet flooring and worsening of the perceived air quality, increased severity of symptoms, and higher levels of dust and mite allergens. However, carpet producers and distributors claims that the previous knowledge is obsolete and that modern carpets no longer represent a problem for the indoor air quality.

This study has explored if the presence of carpets leads to worsened perceived air quality, increased severity of symptoms, and higher concentrations of airborne particles. Untrained panels of subjects were used in the studies to assess the perceived air quality and the intensity of symptoms by answering two separate questionnaires, both when carpets were present and when carpets were absent. This was used to determine if the presence of carpets led to worsened perceived air quality and increased intensity of symptoms. Airborne particles were measured in order to explore if the presence of carpets leads to higher concentrations of airborne particles.

The results showed no significant differences in the perceived air quality when carpets were present compared with no carpets. The subjects experienced 4.5 % more intensity of symptoms when carpets were present compared with no carpets, and indicated that the presence of carpets may lead to higher intensity of symptoms. The particle measurements showed no differences in particle concentrations, but indicated that carpets may contain bigger concentrations of particles compared with hard, smooth floors. People don't seem to think about possible negative effects when choosing carpet flooring, the focus is on the noise reduction and aesthetics.

3 KEY WORDS
Carpet
PAQ/Perceived air quality
Symptom

Project description

This thesis is written in cooperation with SINTEF and their research project BEST VENT, which is short for “BEST demand-controlled VENTilation strategies to maximize air quality in occupied spaces and minimize energy use in empty spaces”. “The influence of carpet flooring on the indoor climate; effects on perceived air quality, symptoms and particle concentrations” is the title of this thesis, and Mads Mysen is supervisor and Aileen Yang is assistant supervisor.

Carpet flooring is becoming a popular flooring material, especially in modern offices. Carpet flooring is often chosen because of its noise reducing traits and aesthetics. Offices with open plan landscape, which are becoming a trend, has a need for noise reduction, thus the instalment of carpet flooring is a reasonable solution. Today, there are different opinions about whether the material is good or not for the indoor climate and the air quality. Thus, there is great need for more research regarding carpet flooring and possible negative effects on the indoor climate.

In this project, two separate field studies will be carried out in order to explore the relationship between carpet flooring and perceived air quality, symptoms and particle concentrations. The first study, which is a blind intervention study, will explore if the presence of carpets has an influence on perceived air quality, symptoms and particle concentrations. The second study will explore some of the same relationships to gather more data, especially on the relationship between carpet flooring and perceived air quality which is the main focus of this project.

Acknowledgements

I was very excited about writing my master thesis in cooperation with SINTEF's research project BEST VENT. When presented with different topics to explore, I quickly found out that I wanted to explore carpet flooring and its influence on the indoor climate.

A big thanks to SINTEF for letting me write my thesis in cooperation with them. A huge thanks to my supervisor Mads who has helped and guided me through this intense semester and has helped me with planning the studies, statistics, structure of the report and much more. Also, a huge thanks to my assistant supervisor Aileen who has helped me with the studies, the statistics, the structure of the report and much more.

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Abstract

Carpet flooring is a commonly used flooring material and is becoming a trend in offices with open plan landscape. The material is often chosen because of its noise reducing traits and aesthetics, but health authorities advises to show caution with the use of the material. Previous studies have found relations between the presence of carpet flooring and worsening of the perceived air quality, increased severity of symptoms, and higher levels of dust and mite allergens. However, carpet producers and distributors claims that the previous knowledge is obsolete and that modern carpets no longer represent a problem for the indoor air quality. Thus, there is a need for more research on the effects that carpet flooring has on the indoor climate.

Two separate studies and several interviews has been conducted in order to gather information about the effects carpet flooring has on the indoor climate, and why the material is chosen. Specifically, the studies have explored if the presence of carpets leads to worsened perceived air quality, increased severity of symptoms, and higher concentrations of airborne particles. Untrained panels of subjects were used to assess the perceived air quality and the intensity of symptoms by answering two separate questionnaires, both when carpets were present and when carpets were absent. The results from these questionnaires have been analysed and used to determine if the presence of carpets led to worsened perceived air quality and increased intensity of symptoms. Airborne particles were measured both when carpets were present and absent in order to explore if the presence of carpets leads to higher concentrations of airborne particles.

The results showed no significant differences in the perceived air quality when carpets were present compared with no carpets. The subjects experienced 4.5 % more intensity of symptoms when carpets were present compared with no carpets, and indicated that the presence of carpets may lead to higher intensity of symptoms. The subjects had significantly hoarser/dryer throats, and found it significantly harder to concentrate when carpets were present compared with no carpets. The particle measurements showed no differences in airborne particle concentrations, but indicated that carpets may contain bigger concentrations of particles compared with hard, smooth floors. The results of the interviews showed that people don’t seem to think about possible negative effects when choosing carpet flooring, the focus is on the noise reduction and aesthetics.

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Definitions

PAQ – Perceived air quality

Oslo Met – Oslo Metropolitan University, previously known as Oslo & Akershus University College

IAQ – Indoor air quality

RH – Relative humidity

CO_2 – Carbon dioxide

PPM – Parts per million

VAV – Variable air volume

CAV – Constant air volume

SBS – Sick building syndrome

SBS-symptoms – Symptoms related to poor indoor climate

VOC – Volatile organic compounds

PM – Particulate matter

PM_{10} – Particulate matter with a diameter smaller than 10 µm.

$PM_{2.5}$ – Particulate matter with a diameter smaller than 2.5 µm.

PM_1 – Particulate matter with a diameter smaller than 1 µm.

PPD – Percentage of people dissatisfied

1. Introduction

1.1 Background

Carpet flooring is a commonly used flooring material, especially in office buildings. Offices with open plan landscape are becoming a trend and leads to a need for noise reducing solutions. Such a solution would be the use of carpet flooring which has noise reducing traits, but there are different opinions about whether the material is good or not for the indoor climate and the air quality. Thus, there is great need for research on this topic. Also, there are few studies on modern carpets which increases the need for studies like the present one.

The indoor air quality can vary greatly in buildings, and is an important factor for human health. There are several factors that influence the indoor air quality, such as temperature, CO_2-level, humidity, volatile organic compounds (VOCs), particles, ventilation rate etc (Fang et al., 2004; Fanger, 2006). We spend around 90% of our time indoors, thus it is important that the air we breathe is very low-polluted (Evans & McCoy, 1998). Therefore, one should avoid indoor air pollution sources and choose materials and products that are certified as low-polluting (Fanger, 2000).

"If there is a pile of manure in a space, do not try to remove the odor by ventilation. Remove the pile of manure."- Pettenkofer, 1858.

Previous studies have indicated that carpet flooring can be related to worsening of the indoor air quality and health related symptoms such as headaches, skin irritation, mucosal irritation, etc. Health authorities advices to show caution with the use of carpet floors and that it should be avoided, but this is often ignored (The Norwegian institute of public health [FHI], 2015). Still, the carpet producers and distributors argue that previous studies and knowledge are obsolete and that modern carpets no longer represent a problem for the indoor air quality (Becher et al., 2018).

1.2 Carpet flooring and indoor air quality

Several studies regarding carpet flooring and the effects on indoor climate have been conducted over the years (Wargocki et al., 1999; Wargocki et al., 2000; Wargocki et al., 2002; Dahl et al., 2002; Matheson et al., 2003; Causer et al, 2004; Causer et al., 2006; Stranger et al., 2007; Tranter, 2005; Norbäck et al., 1990; Norbäck et al., 1995; Skov et al., 1990; Bluyssen et al., 2016; Jaakkola et al., 2006; Becher et al., 2018; Sercombe et al., 2007; Bakke et al., 2008; Bakke et al., 2016). Although previous studies indicate that carpets have negative effects on the indoor climate, the material is widely used and is on the rise in the market.

The carpet and rug institute claim that carpets traps particles and keeps them away from the breathing zone, thus improving the indoor air quality. They also claim that carpets are the best flooring choice even for those with asthma and allergies (The carpet and rug institute [CRI], undated). Although there are no scientific studies that supports this, these claims are often what you may hear from carpet producers and distributors. The Norwegian institute of public health (FHI) advises to avoid the use of carpet flooring, especially in schools and kindergartens, unless there is specific need for noise reduction (FHI, 2015).

1.2.1 Source of exposure

Carpets may act as an exposure source in the indoor climate because they are harder to thoroughly clean for dust and dirt compared to hard, smooth floors. Carpet floors can act as a reservoir for dust and mite allergens which over time can be resuspended into the air (Becher et al., 2018). Particles are found in different sizes, PM_1 corresponds to ultrafine particles, $PM_{2.5}$ corresponds to fine particles and PM_{10} corresponds to coarse particles.

Dahl et al. (2002) found significantly larger amounts of dust deposits in carpet floors compared to hard, smooth floors. Causer et al. (2006) concluded that in the same environment, carpet floors contain significantly higher concentrations of allergens from house dust mites compared to hard, smooth floors. Also the type of carpet (loop vs. cut), the pile height and pile density had generally negligible effect on the carpets capacity to entrain mite allergens, but they speculate that low pile height might contribute in minimizing the allergen levels. Matheson et al. (2003) found that installation of carpets resulted in higher amounts of mite allergens, and removal of the carpets significantly reduced the amount. A study of indoor air quality in Belgian schools found that the ratio between the amounts of $PM_{2.5}$ in the indoor air and outdoor air were significantly higher for classrooms with carpeted floors compared with classrooms without carpet flooring. Their findings indicate that carpets may increase the amount of resuspended dust (Stranger et al., 2007). A review-article regarding indoor allergens concluded that higher levels of allergens were consistently found in carpets compared with hard, smooth floors (Tranter, 2005). Overall, there are no clear evidence that carpet flooring in general has dust-reducing capacity (Becher et al., 2018).

1.2.2 Health effects & perceived air quality

Studies have indicated that the presence of carpet flooring can lead to worsening of the perceived air quality and health related symptoms such as headaches, skin irritation, mucosal irritation etc. (Norbäck et al., 1990; Skov et al., 1990; Wargocki et al., 1999; Wargocki et al., 2000; Wargocki et al., 2002; Bluyssen et al., 2016; Jaakkola et al., 2006).

A study from 1990 showed that a relation exists between SBS-symptoms and environmental factors such as VOC and respirable dust. Also, carpets were among several other factors related to SBS-symptoms (Norbäck et al., 1990). Skov et al. (1990) found that the highest prevalence of mucosal irritation was associated with buildings that had loop-woven carpets. Wargocki et al. (1999) carried out a reversible intervention study with the use of a 20 year old carpet as a pollution source. They found that removing the pollution source led to improved perceived air quality, a decrease in SBS-symptoms and an increase in productivity. Wargocki et al. (2002) did a similar study, and the results supported their previous findings. The first results of the European OFFICAIR study found an increase in adverse health effects in offices where carpet was the main type of floor covering (Bluyssen et al. 2016). Wargocki et al. (2000) explored the relationship between perceived air quality and increased ventilation when carpets were present. The results indicated that increased ventilation improved the perceived air quality, decreased SBS-symptoms and increased productivity.

Some studies have indicated that the presence of carpets are related to developing asthma. The Norwegian asthma and allergy federation (NAAF) strongly advises against the use of carpet flooring. They claim that carpet flooring worsens the indoor climate, especially for those with asthma or allergy (The Norwegian asthma and allergy federation [NAAF], 2016). Jaakkola et al. (2006) found that carpet flooring was related to the risk of asthma, and that plastic and textile surface materials in workplaces may be related to an increased risk of adult-onset asthma.

1.2.3 Maintenance

The material of fabric with which the carpets are made of has an influence on the maintenance of them. It doesn’t take much effort to make carpets look clean, which is a factor that makes carpet flooring appealing, but removal of the smaller particles can be problematic. Vacuuming, which is the most commonly used cleaning method for carpets, removes the larger particles, but not the smaller allergen-associated particles. The cleaning of smooth floors seems more efficient regarding removal of these smaller particles (Tranter, 2005). Vacuuming of carpet floors had little effect on removal of dust mites, and led to redistribution within the depths of the carpets (Sercombe et al., 2007). The study by Causer et al. (2004) indicated that there is little difference between wet extraction and dry vacuuming when it comes to removing allergens, but a combination of the two methods is expected to result in a greater removal. In addition to vacuuming, carpet floors should be deep cleaned regularly (Ege, 2015), but this is usually not being done. Overall, the cleaning of carpets seems more difficult, and methods for more thoroughly cleaning are often not being used.

1.3 Perceived air quality

The perceived air quality is a subjective assessment of the indoor air and it is an important indicator of the air quality. If several people perceive dissatisfaction with the air quality, then that is a strong indication that the actual air quality is poor. In order to evaluate the indoor air quality, one can use untrained panels of subjects to assess the perceived air quality. An untrained panel of subjects should be a random and independent group of people, consisting of preferably over 20 subjects. The subjects, which has no training in this matter, are to use their senses in order to give a subjective score of how they perceive the air quality. There are several methods to score the perceived air quality, one can for example use a questionnaire where the subjects answer if they are satisfied or dissatisfied with the air quality (PPD). One can also use the questionnaire that will be used in the present study where the subjects score PAQ between "clearly acceptable" and "clearly unacceptable", this is further explained in chapter 2.2. The concept of using an untrained panel of subjects to assess PAQ has been used in several studies and is an accepted way of evaluating the indoor air quality (Wargocki et al., 1999; Wargocki, et al., 2002; Mysen et al., 2006; Bluyssen et al., 2016).

1.4 Objective

The objective of this project is to provide some updated information about modern carpet flooring and its effects on the indoor climate. Specifically, the studies conducted during this project will explore the relationship between carpet flooring and perceived air quality and if the presence of carpets leads to increased amount of particles in the air. Moreover, the studies will also explore if there is any relation between the presence of carpets and increased intensity of symptoms. In addition, this project aims to provide information about why carpet flooring often is chosen and what the advantages and disadvantages are compared to conventional hard, smooth flooring materials. The maintenance of carpet flooring, and possible relations between carpets and development of asthma has not been explored due to the scope and limitations of this thesis.

1.5 Hypothesis

Three hypotheses were explored during this project.

H.1: The presence of carpet flooring will not influence the perceived air quality (PAQ).

H.2: The presence of carpet flooring will not increase the intensity of symptoms.

H.3: The presence of carpet flooring will not increase the particle concentration in the air.

Hypothesis 1 was the main focus of this thesis, and two separate studies were conducted to explore this. Hypothesis 3 was also explored in both studies, and hypothesis 2 was explored only in the intervention study.

2. Materials and methods

For this thesis, two field studies have been carried out in order to falsify hypothesis H.1, H.2 and H.3. This chapter describes the studies, how they were carried out, and the materials and instruments used in the process.

2.1 The carpet flooring

The studies required carpet flooring that had been in use and preferably weren't older than 10-12 years. After weeks of e-mails and phone calls, we got an opportunity and were able to pick up 60 m^2 of carpet flooring from an office space located in Oslo. The carpets were cut into tiles in different sizes and were easily transported to the study site.

The supplier of the carpet could not provide detailed information about the usage, cleaning history or the age of the carpet. However, we were told that the carpets were 8-10 years old and had been in use in an office space. We can assume that the carpets have been exposed to regularly cleaning, i.e. vacuuming 1-2 times a week, which is how frequently carpeted offices should be cleaned. (Bakke et al., 2016; Ege, 2015)

2.2 Perceived air quality & symptoms

During these studies, an untrained panel of subjects were used to evaluate both PAQ and symptoms by answering two separate questionnaires. The questionnaires shown in figure 1 and 2 were used in order to evaluate the perceived air quality and symptoms. The questionnaire about PAQ, referred to as questionnaire 1, contains one question about the perceived air quality where you score the PAQ by dragging the scale slider between "clearly unacceptable" and "clearly acceptable".

Figure 1: Questionnaire 1 - PAQ (translated).

Figure 2 shows an excerpt of the questionnaire about symptoms, which will be referred to as questionnaire 2. Questionnaire 2 contains questions about several symptoms and is based on the MM-questionnaire developed at the Department of Occupational and Environmental medicine in Örebro, Sweden (Andersson, 1998), but has been modified and adapted at

BESTVENT. There are in total 25 questions with most of them being related to subjective assessment of general perceptions of the indoor environment, thermal comfort and symptoms.

The value of the scores were coded on a scale from 0-10, and for questionnaire 1 (PAQ), 0 corresponds to “clearly not acceptable” air quality and 10 corresponds to “clearly acceptable” air quality. A PAQ-score just above 5.00 were set to “just acceptable” air quality, and values just below 5.00 set to “just not acceptable” air quality. For questionnaire 2 (symptoms), 10 corresponds to “yes, very” and 0 corresponds to “no, not at all”. The responses to both questionnaires were easily accessible and could be downloaded in Excel.

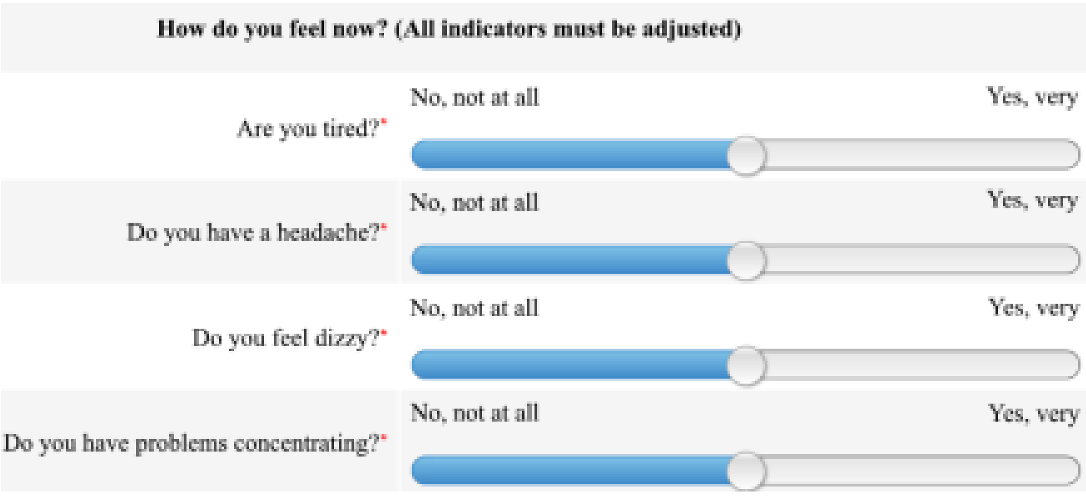


Figure 2: Excerpt of questionnaire 2 - Symptoms (translated).

2.3 Intervention study

The intervention study was executed in a classroom located at Oslo Met in Oslo on February 28th and March 1st. It was carried out in combination with 3-hour lectures, and the students who attended these lectures volunteered as subjects. The subjects were informed about the study in advance, and they were blind to the interventions. The lectures were divided into 3 one-hour stretches with breaks in between. The first day, the carpets were present the first hour, absent the second hour, then present again the third hour. The same procedure was used the second day, but the order was switched to absent-present-absent. The interventions, which was removing or introducing the carpets, was done during each break. The concept of this study was inspired by earlier intervention studies conducted by Mysen et al. (2006), and Wargocki et al. (1999).

The objective of the intervention study was to explore whether the presence of carpet flooring affected the PAQ and if it could cause worsening of symptoms. In order to explore this, the subjects answered the 2 different questionnaires several times during the day for the two cases; carpet present and carpet absent. Also, particle concentrations were measured both with carpets present and with no carpets.

2.3.1 Study site

This study site is used as a regular classroom combined with a part dedicated to computers, located on the 8th floor, and has a floor area of 75 m^2 and a height of 3.2 m. It has a capacity of 30-40 students, figure 3 and 4 shows how the room looked during the study.

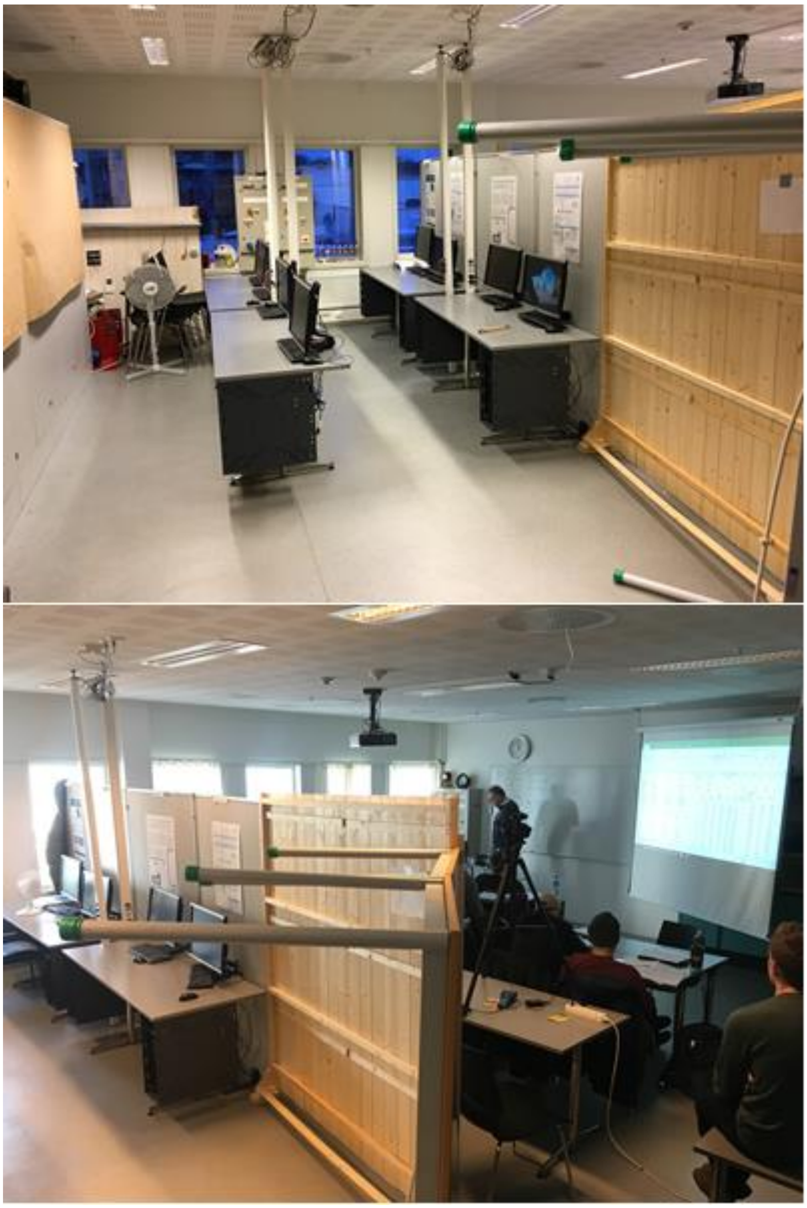


Figure 3: Pictures of the study site during the intervention study when carpets were absent (Hangeland, 2018).

The building where the study site is located was rehabilitated from 2005-2007, and there are 17 air handling units in use. The air handling unit which covers the study site, delivers variable air volume. Due to poor design of the ventilation system, it operates as a CAV unit. Thus, the ventilation in the majority of the rooms is set to maximum when occupied, and the ventilation rate in the study site was measured to be 42.15 m^3/hm^2.

There is a storage room next to the classroom which was used to store the carpets when they were taken out of the classroom. Since we only had 15 minutes to move 60 m^2 of carpets in and out of the classroom, it was essential that the storage room was that close.

Figure 4: Pictures of the study site during the intervention study when carpets were present (Hangeland, 2018).

2.3.2 Study procedure

The study procedure is explained with a timeframe shown in table 1. 16 subjects participated from the start the first day, 4 females and 12 males. Two more subjects, both female, joined from 09.55. 17 subjects participated from the start the second day, 5 females and 12 males. Another subject joined in at 09.35, but left again at 11.00.

	Day 1	**Day 2**
Carpet	Scenarios: Present - Absent - Present	Scenarios: Absent – Present - Absent
Time		
08:30	This day started with 5 minutes of information about the study and how they were to answer the questionnaires.	
08:35	Questionnaire 1 (PAQ)	Questionnaire 1 (PAQ)
08:35-09:35	Lecture	Lecture
09:35	Questionnaire 2 (symptoms)	Questionnaire 1 (PAQ) & 2 (symptoms)
09:40-09:55	Break: the subjects had to leave the room. **Removal** of carpets.	Break: the subjects had to leave the room. **Bringing** carpets into the classroom.
09:55	Questionnaire 1 (PAQ)	Questionnaire 1 (PAQ)
09:55-10:55	Lecture	Lecture
10:55	Questionnaire 2 (symptoms)	Questionnaire 1 (PAQ) & 2 (symptoms)
11:00-11:15	Break: the subjects had to leave the room. **Bringing** carpets into the classroom	Break: the subjects had to leave the room. **Removal** of carpets
11:15	Questionnaire 1 (PAQ)	Questionnaire 1 (PAQ)
11:15-12:15	Lecture	Lecture
12:15	Questionnaire 2 (symptoms)	Questionnaire 1 (PAQ) & 2 (symptoms)
12:20	End of experiment	End of experiment

Table 1: Time frame showing the study procedure during the intervention study.

Questionnaire 1 was answered at the start of each lecture-hour and questionnaire 2 was answered at the end of each lecture-hour. The second day, the subjects also answered questionnaire 1 at the end of each lecture-hour, which led to 6 rounds of PAQ-scores that day. In total, questionnaire 1 was answered three times the first day and six times the second day. Questionnaire 2 was answered three times both days.

The subjects were informed in advance about taking precautions related to the study. The subjects were not allowed to smoke before each day of the study was completed, also food and drinks, with the exception of water, was not permitted to bring into the classroom. They were also told not to use perfume on the days of the study. The reason for the precautions were that we didn't want any distinct smells in the room which could affect the air quality. Since there was a bit of distance between the subjects and the carpets, 2 fans were used in order to mix the air in the room.

In order to transport 60 m^2 of carpet tiles in and out of the study within 15 minutes, we decided to hang the carpet tiles on clothing racks. The concept was that the carpet tiles were cut into appropriate rectangular pieces, then we made holes close to the top centre of each piece, and hanged it onto the clothing racks. Figure 5 shows the concept. The clothing racks used were a type called "IKEA Rigga", which was made in steel and had 4 wheels attached to it. The racks had adjustable height and were 1.11 meters wide. Using this concept made it easy to move the carpets in and out of the study site.

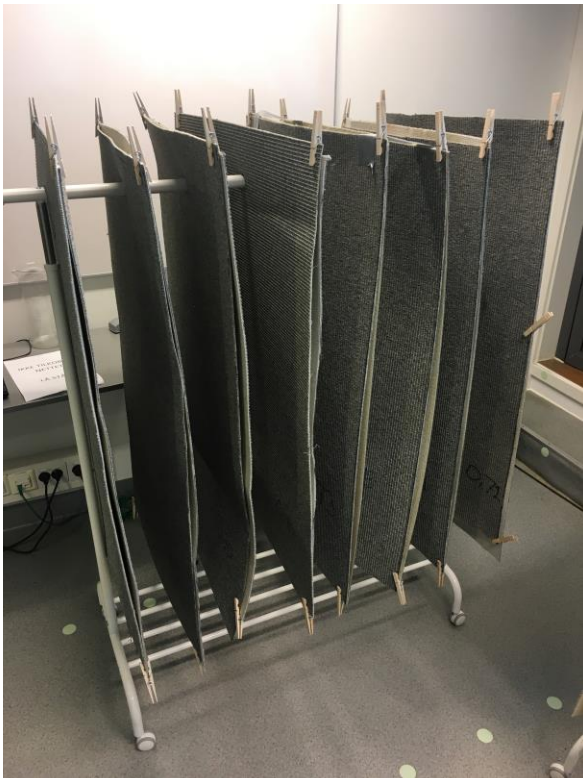


Figure 5: Carpet tiles fitted onto clothing rack (Hangeland, 2018).

2.3.3 Data collection and equipment

Several types of equipment were used during this study. Q-Trak was used to log temperature, CO_2-level and relative humidity at 30 seconds interval. DustTrak II was used in order to measure the concentration of particles in the air. This device has different inlet sizes ranging from 1-10 µm, and the inlets used for the experiment were 1 µm (ultrafine particles) the first day and 2.5 µm (fine particles) the second day. Swema3000 was used in order to calculate the ventilation rate in the classroom. The device measures differential pressure which can be used to calculate the ventilation rate using Equation. (1).

Eq. (1) $q = k * \sqrt{\Delta P}$

Where

q = air flow [l/s]

k = K-value of the valve [l/ (s*$\sqrt{\Delta P}$)]

ΔP = Differential pressure [Pa]

1 l/s = 3.6 m^3/h

The K-value was 35.2 for all the valves. There were seven valves in the classroom and the differential pressure of each valve was measured to be 11.95, 8.9, 7.95, 4.6, 7.9, 8.5 & 8.0 Pa.

According to Eq. (1), the ventilation rate in the room was calculated to be 42.15 m^3/hm^2.

2.4 PAQ study

This experiment was carried out in a laboratory room at Oslo Met on March 22nd & 23rd. 16 subjects participated the first day, and another 16 subjects the second day. This study is very similar to the intervention study, but the subjects were not blind to the intervention this time. When the carpets were present they covered the floor area. The object of this study was to gather further results regarding the effect carpet flooring has on the perceived air quality, and also explore whether the presence of carpets led to higher concentrations of particles. The subjects answered only questionnaire 1 (PAQ), for the two cases; carpet present and carpet absent.

2.4.1 Study site

This study was carried out in a small room inside the laboratory room. The study site is shown in figure 6, and it has a floor area of 4 m^2 and a height of 2 m.

Figure 6: Pictures of outside and inside the study site during the PAQ study (Hangeland, 2018).

It has its own air handling unit, consisting of two valves with diameter Ø125, one for supply air and one for exhaust air. The air handling unit, as shown in figure 7, is of the type “Flexit spirit uni 2” delivered by Flexit, which can deliver air flow at 3 different levels; min, normal and max. The ventilation in the room is balanced.

Figure 7: Pictures of the air handling unit connected to the study site of the PAQ study (Hangeland, 2018).

During the study the room contained one lamp hung in the roof which was off the whole time, and a table where all the instruments were placed. The room was cleaned in advance of the study.

2.4.2 Study procedure

The concept of this study was that the subjects could enter the study site between the yellow periods shown in table 2, then remain in the room for about 15-20 seconds and use their nose to evaluate perceived air quality by answering questionnaire 1. The procedure of this study is described in table 2.

Time	Carpet	Day 1, March 22nd
10:00-11:15	Absent	The subjects could enter the study site when it suited them within this time frame. One by one they went into the smaller room, and answered questionnaire 1 for the first time. 16 subjects in total participated in the first round.
11:15-12:00		By 11.15, all subjects had answered the questionnaire and were told to come back between 12.00 & 13.15. During this time frame, the carpets were brought into the room and covered the floor ($4m^2$).
12.00-13.15	Present	Same procedure as the first round, and when all the subjects had answered questionnaire 1 for the second time, the first day was completed. 20 subjects in total participated in the second round, the same 16 as in the first one and 4 additional subjects.
Time	**Carpet**	**Day 2, March 23rd**
12:00-13:00	Present	Same procedure as the day before, 17 subjects in total participated in the first round.
13:00-13:45		By 13.00, all subjects had answered the questionnaire and were told to come back between 13.45 &14.30. During this time frame, the carpets were removed from the study site.
13:45-14:30	Absent	Again the same procedure, when all subjects had answered questionnaire 1 for the second time, the study was completed. 16 subjects in total participated in the second round, all of them also participated in the first round.

Table 2: Time frame showing the study procedure during the PAQ study.

The air handling unit was set on normal the first day, then max the second day. On both days, the ventilation was on 45 minutes before the first subjects could enter, which is why the time frame between the two rounds were set to 45 minutes. Thus, the number of air exchanges in the room was the same before both rounds began. The number of air exchanges were higher the second day because of the higher ventilation rate. The carpets were introduced 45 minutes in advance of test round the first day, and 24 hours in advance the second day.

2.4.3 Data collection

Several types of equipment were used during this PAQ study. Q-Trak was used to log temperature, CO_2-level and relative humidity at 30 seconds interval. DustTrak II was used to measure the amount of particles in the air. The inlet size used was 10 µm both days and the amount of PM_{10} was logged at 1 minute intervals. The ventilation rates were calculated using equation (1) for the levels normal and max, and the differential pressure was measured with the use of Swema 3000.

The K-value was 6.0, and the differential pressure was measured to be 15.0 at medium, and 43.1 at high, which resulted in a ventilation rate of 20.9 m^3/hm^2 at medium level and 35.45 m^3/hm^2 at max level. The ventilation rates lead to 7.84 air exchanges before the room could be entered the first day, and 13.29 the second day.

Level	Ventilation rate [m^3/hm^2]	Air exchange [45 min^{-1}]	Air exchange [h^{-1}]
Normal	20.9	7.84	10.45
Max	35.45	13.29	17.73

Table 3: ventilation rate and air exchanges during the PAQ study.

2.5 Interviews

To further investigate why carpet flooring is so commonly used in office spaces, several interviews were conducted. The questionnaires in these interviews targets two different sets of people, the distributors and the building owners.

The interviews were conducted by two bachelor- students at the Western Norway University of Applied Sciences (HVL), who are writing their bachelor thesis about carpet flooring. We collaborated on the questionnaires, but they conducted all the interviews and shared the results.

2.5.1 Questionnaires

Two questionnaires were used for the interviews, one for the distributors and one for the building owners. The questionnaires used in the interviews are shown in Appendix A.10 and A.11.

2.6 Data preparation and statistical analysis

Statistical analysis have been made in order to analyse the datasets from the two field studies conducted in this project. These analysis have been done using SPSS version 24 (SPSS Inc, Chicago, USA). Specifically, these analysis were used to determine if the presence of carpets led to lower PAQ-scores and increased intensity of symptoms. A Shapiro-Wilk's test was run to check if the datasets were normally distributed. If normally distributed, paired samples t-tests were run to check for significant differences in PAQ-scores and severity of symptoms when carpets were present compared to when carpets were absent. For non-normally distributed data, the non-parametric test Wilcoxon signed-ranks test was used.

2.6.1 Descriptive statistics

The results of the studies were divided into four sets, one for each day of study. Descriptive statistics, which includes mean, median, standard deviance, minimum- and maximum values were calculated for the PAQ-scores and scores of symptoms. Boxplots were provided to illustrate the distribution of the PAQ-scores in the absence and presence of carpets for each day of the study. Figure 8 shows a typical boxplot and explains the information it gives. The boxplots shown in the results chapter will also have an "x" on them which marks the mean score, and a dashed line which is set on the value 5. As mentioned earlier, the value 5 represents the breakpoint between "just acceptable" and "just not acceptable". Boxplots can also give information about outliers in the dataset. Outliers are scores which are considered to be extreme values, which means that they are much higher or much lower than the majority of the scores (Field, 2009). Outliers can also be a typing error, so one should always double check the data of the outliers. The outliers are marked with either a circle (^{O}) or an asterisk (*). The difference between the types of outliers is that the asterisk represent an extreme outlier, while the circle represent an outlier.

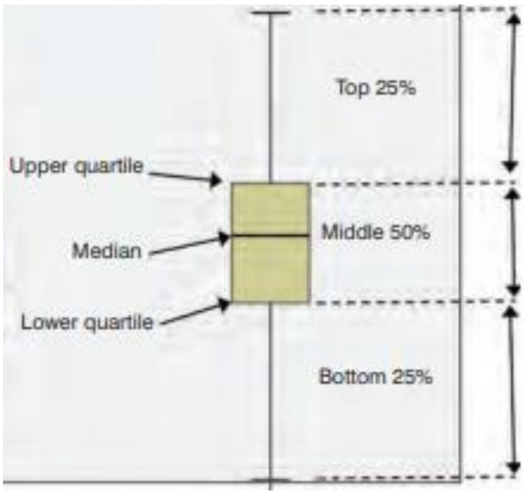


Figure 8: A boxplot and info about what it describes (Field, 2009).

2.6.2 Statistical analysis

To find out which statistical analyses to run, one first need to find out whether the dataset is normally distributed or not. Shapiro-Wilk's test was run for the datasets from the intervention- and PAQ study as it is more appropriate for small sample sizes (<50 samples). If the significance value of the Shapiro-Wilk's test is lower than .05, then the data is significantly different from a normal distribution, i.e. non-normally distributed. If the value is greater than .05, then the data has a normal distribution (Field, 2009).

For datasets that are normally distributed, a paired samples t-test can be used. A paired samples t-test is a statistical test which compares two sets of the same measure and tells you if there's a significant difference between the measurements (Field, 2009). Specifically, in these studies, PAQ and symptoms are scored both with carpets present and absent. By doing a paired samples t-test with these measures, we can compare whether the scores from the questionnaires when there are carpets present are significantly different from the scores when the carpets are absent. Thus, the paired samples t-test can tell us if the presence of carpets led to significantly lower scores of the PAQ or not, and if it lead to higher intensity of symptoms. A significance level lower than .05 indicates that the measures are significantly different. If that value is greater than .05, then the measures are not significantly different.

For non-normally distributed datasets, a Wilcoxon signed-ranks test can be used. This test is the non-parametric version of the paired samples t-test and also compares a pair of measures. If the significance level is lower than .05, then the differences between the measures are statistically significant.

3. Results

The results from both field studies and the interviews will be presented in this chapter. Boxplots are shown for the PAQ-scores and tables including mean and median scores are shown for the results of the symptoms. Tables showing descriptive statistics for PAQ are found in Appendix A.1 and A.2. The results of the interviews are presented as summaries of the two different groups of people interviewed.

3.1 Intervention study

3.1.1 Indoor Parameters

As seen in table 4, the indoor parameters for the two days were very similar. Furthermore, they were also kept stable during both days. A graph showing the indoor parameters throughout this study is found in Appendix A.3.

	Intervention study							
	Day 1				Day 2			
	CO2	Temperature	%RH	Airflow	CO2	Temperature	%RH	Airflow
Mean± Std.Deviation	543±35,68	21,2±0,27	7,3±0,46	42,15±15%	534±32,58	21,1±0,23	7,7±0,38	42,15±15%
Minimum	443	20,5	6,1		440	20,5	6,7	
Maximum	620	21,7	8,5		615	21,5	9,3	
	[ppm]	*[deg C]*	*[%]*	*[m3/(h*m2)]*	*[ppm]*	*[deg C]*	*[%]*	*[m3/(h*m2)]*

Table 4: Indoor parameters during the intervention study.

3.1.2 Particle measurements

The results of the particle measurements from this study is shown in figure 9, and indicated no difference in the particle concentration due to the presence or absence of carpets. The particles measured was PM_1 the first day and $PM_{2.5}$ the second. The average values of PM_1 was 3.59 µg/m^3 when carpets were present and 4.36 µg/m^3 when carpets were absent. The average values of $PM_{2.5}$ were 2.53 µg/m^3 when carpets were present and 1.97 µg/m^3 when carpets were absent. The concentration levels ranged from 1-7 µg/m^3, the highest concentration measured was 7 µg/m^3 the first day, and 4 µg/m^3 the second.

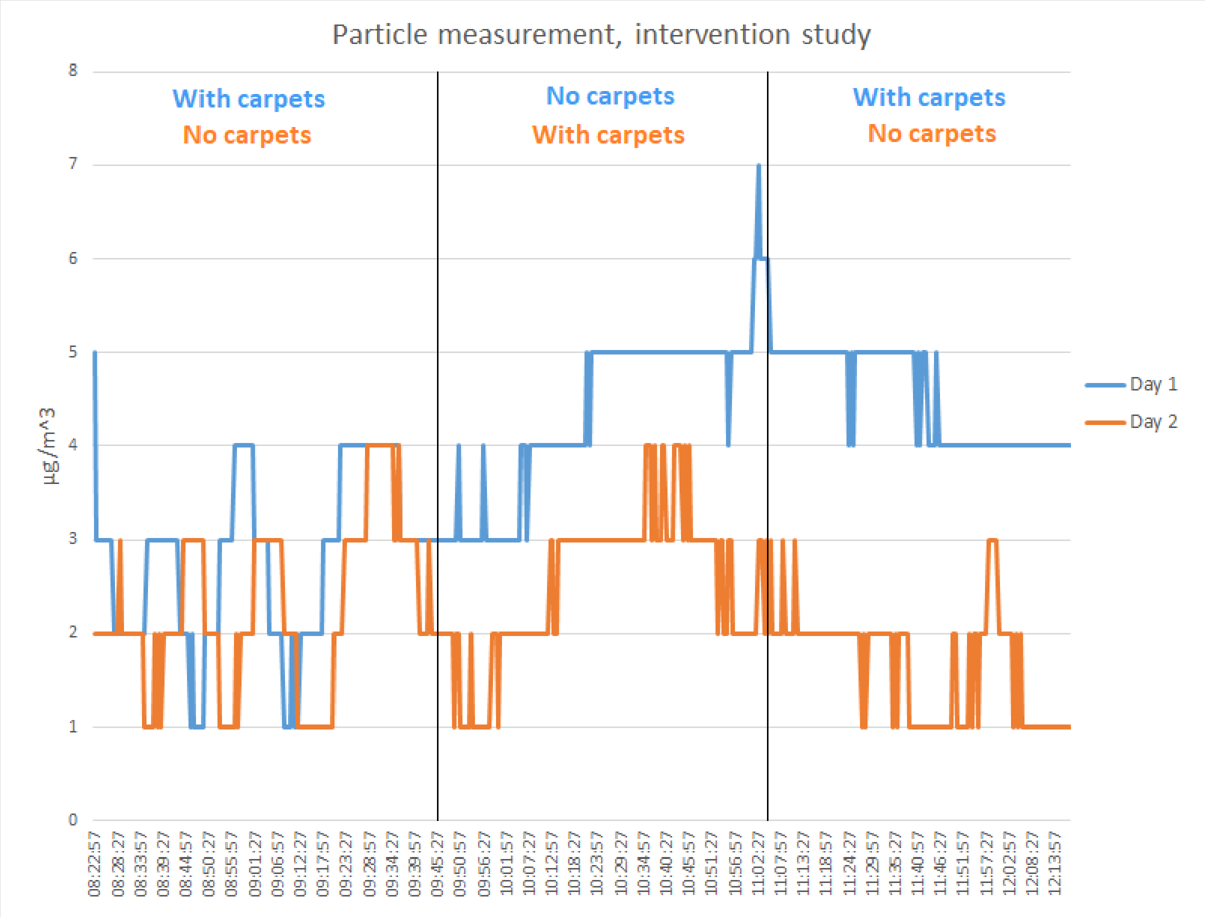


Figure 9: Graph showing the particle concentrations during day 1 (PM_1) and day 2 ($PM_{2.5}$) in the intervention study.

3.1.3 PAQ-scores

Figure 10 shows the variations of PAQ-scores in the presence and absence of carpets during the first day of the intervention study. Three rounds of scoring PAQ were performed. The average PAQ-score was highest during the first round when the carpets were present (mean±st.dev: 7.66±1.73) and lowest during the second round when the carpets were absent (7.36±1.40). Overall, there were minimal differences in PAQ-scores when the carpets were present compared to when there was no carpets in the classroom. The subjects were also satisfied with the air quality, as the mean PAQ-score during the three rounds were above 7.

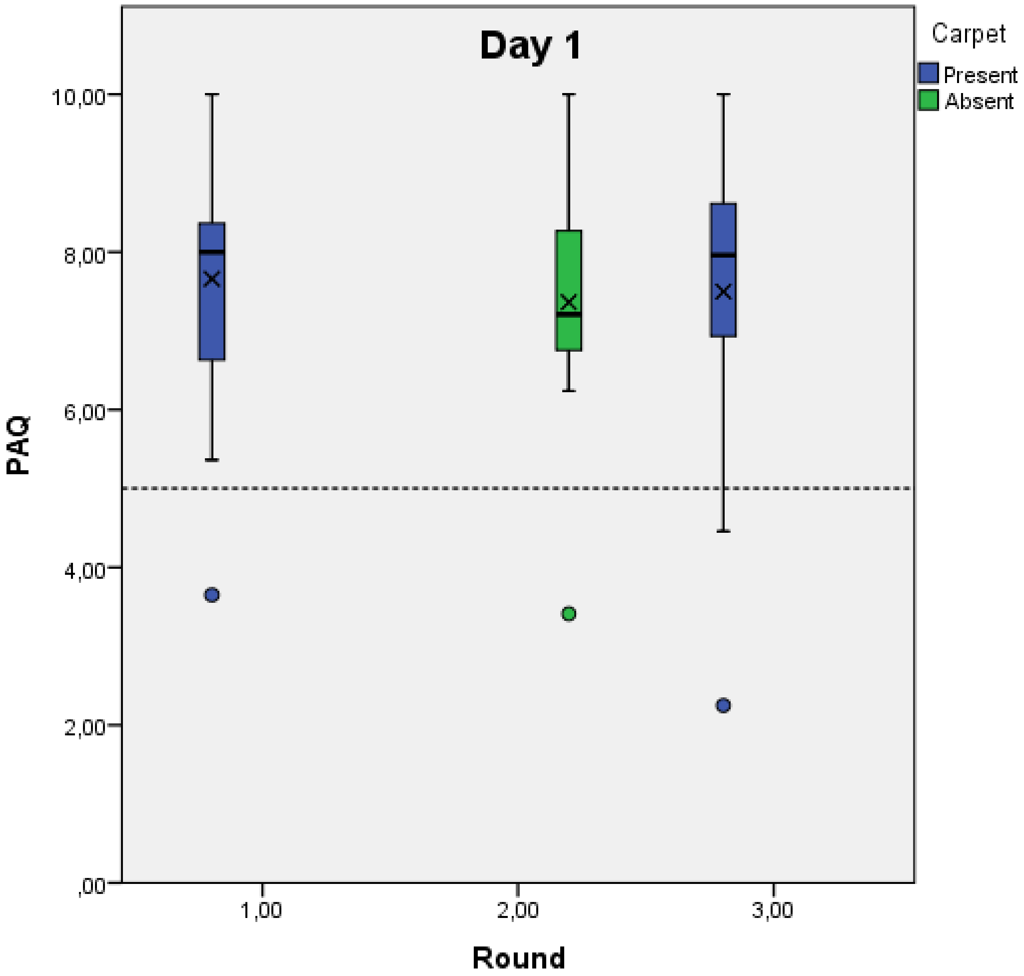


Figure 10: Boxplot of the PAQ-scores from the first day of the intervention study.

For the second round of the intervention study, PAQ was scored both at the start and at the end of each lecture-hour, hence “exposure time” became a factor. Six PAQ rounds were performed, where round 1, 3 & 5 had no exposure time, and round 2, 4 & 6 had one hour exposure time. As shown in the boxplot in figure 11, the mean PAQ-scores were slightly lower when the carpets were present compared to when there were no carpets in the classroom. However, similarly with the first day, the subjects were generally satisfied with the air quality as all the mean PAQ-scores during the second day also were above 7. Overall, no significant differences between the PAQ-scores were found in the intervention study.

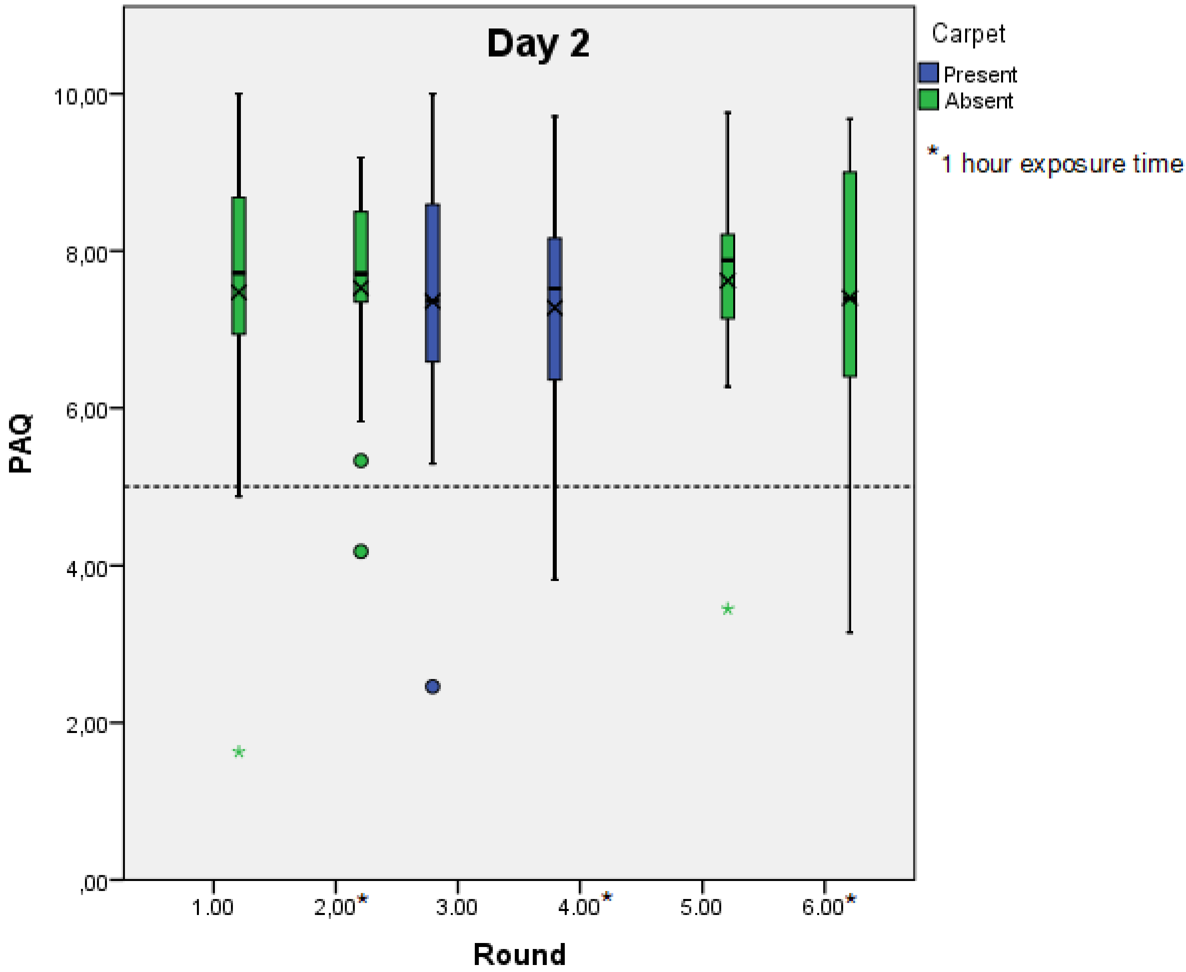


Figure 11: Boxplot of the PAQ-scores from the second day of the intervention study.

3.1.4 Symptoms

Table 5 shows excerpts of the results from questionnaire 2 for both days of the intervention study. For day 1, the scores of all symptoms were generally low (mean scores<5), indicating low intensity of the symptoms explored. Out of all symptoms, the subjects gave the highest score for fatigue during round 3 (carpets present: mean/median= 4.83/6.02). Other symptoms, where the subjects scored higher than 2, were difficulties concentrating, heavy-headed and hoarse, dry throat. The intensity of these symptoms were also higher when carpets were present compared to when they were absent. The difference in scores for hoarse, dry throat with the carpets present (test round 1: mean/median= 2.79/1.47) compared to when the carpet was absent (test round 2: mean/median= 0.93/0) was statistically significant (Wilcoxon: p=0.041). The difference in difficulties concentrating between round 2 (absent: mean/median= 2.46/1.49) and round 3 (present: mean/median= 4.37/4.36) was also statistically significant (Wilcoxon: p=0.017).

For day 2, the scores of the symptoms were generally lower compared to the first day. There were also no significant differences in symptoms with the carpets present compared to when the carpets were absent.

	Intervention study, Day 1			Intervention study, Day 2		
	Round 1	Round 2	Round 3	Round 4	Round 5	Round 6
		Mean/Median (Max/Min)			Mean/Median (Max/Min)	
	09:35	10:55	12:15	09:35	10:55	12:15
	Carpet present	Carpet absent	Carpet present	Carpet absent	Carpet present	Carpet absent
SBS-Symptoms	N=16	N=17	N=18	N=18	N=18	N=17
Fatigue	4.42/5.09 *(10/0)*	3.59/3.4 *(8.76/0)*	4.83/6.02 *(8.59/0)*	3.44/2.64 *(7.93/0)*	2.51/2.225 *(7.4/0)*	2.43/2.09 *(7.06/0)*
Heavy-headed	3.02/3.075 *(7.69/0)*	2.72/2.37 *(7.11/0)*	3.95/3.79 *(6.96/0.64)*	1.92/1.66 *(6.3/0)*	2.5/1.655 *(6.94/0)*	2.67/1.75 *(6.8/0)*
Headache	0.96/0.53 *(2.85/0)*	0.39/0 *(1.18/0)*	0.95/0.33 *(5.52/0)*	0.73/0.29 *(3.46/0)*	1.5/0.215 *(7.59/0)*	0.83/0 *(6.26/0)*
Dizziness	1.98/0.935 *(8.09/0)*	2.11/0.88 *(8.69/0)*	1.82/0.695 *(8.12/0)*	0.72/0.23 *(3.22/0)*	1.30/0.39 *(5.99/0)*	1.22/0.09 *(7.1/0)*
Nausea, unwellness	0.26/0 *(2.68/0)*	0.14/0 *(1.36/0)*	0.32/0 *(4.26/0)*	0.49/0 *(2.9/0)*	0.14/0 *(1.07/0)*	0.4/0 *(1.89/0)*
Difficulties concentrating	3.53/2.655 *(10/0)*	2.46/1.49 *(7,13/0)*	4.37/4.36 *(8.84/0)*	1.66/1.43 *(6.52/0)*	2.08/0.805 *(6.61/0)*	2.22/2.03 *(6.37/0)*
Symptoms						
Itching hands/face	0.88/0 *(6.93/0)*	0.78/0 *(6.85/0)*	0.63/0 *(5.57/0)*	0.78/0.065 *(4.2/0)*	0.21/0 *(1.24/0)*	0.34/0 *(1.32/0)*
Itching, burning eye	1.35/0 *(7.89/0)*	0.56/0 *(3.72/0)*	0.88/0 *(6.04/0)*	0.76/0.005 *(6.28/0)*	0.65/0 *(5.46/0)*	0.39/0 *(2/0)*
Cough	0.91/0 *(7.41/0)*	0.44/0 *(6.76/0)*	0.68/0 *(6.7/0)*	0.65/0.02 *(6.04/0)*	0.78/0.04 *(6.35/0)*	0.55/0 *(6.46/0)*
Hoarse, dry throat	2.79/1.47 *(7.48/0)*	0.93/0 *(7.09/0)*	1.18/0.24 *(7.17/0)*	1.76/0.55 *(7/0)*	1.94/0.36 *(7.37/0)*	0.81/0 *(7.04/0)*
Stuffy nose	2.03/0.77 *(7.46/0)*	0.81/0 *(6.33/0)*	0.7/0 *(6.61/0)*	1.2/0 *(7/0)*	0.75/0.115 *(6.98/0)*	1.01/0 *(6.74)*
Perceived indoor environmental factors						
Stuffy air	2.01/1.275 *(6.03/0)*	2.38/2.6 *(6.55/0)*	3.14/2.01 *(8.28/0)*	2.42/2.035 *(9.06/0)*	3.18/3.305 *(8.48/0)*	1.65/1.18 *(6.33/0)*
Dry air	1.62/0.69 *(6.36/0)*	1.88/0.5 *(5.96/0)*	3.03/1.015 *(9.13/0)*	2.61/0.97 *(9.89/0)*	1.99/0.94 *(8.24/0)*	1.29/0.29 *(6.33/0)*
Unpleasant odor	1.16/0.38 *(6.23/0)*	1.14/0 *(7.65/0)*	1.02/0.235 *(8.02/0)*	0.71/0 *(6.98/0)*	1.38/0 *(5.85/0)*	0.95/0 *(5.96/0)*

Table 5: The table shows descriptive statistics including mean/median and maximum/minimum scores for several symptoms throughout the intervention study.

Figure 12 and 13 shows the stacked scores of the symptoms for both days of the study. These figures show the mean score of the symptoms stacked after each other for each test round. The results from the first day showed that the subjects experienced more intensity of symptoms when carpets were present compared to when carpets were absent. The results from the second day indicated the same tendencies, but the differences with/without carpet were much smaller. With the maximum score on these charts being 110, the figures show that the subjects generally experienced low intensity of symptoms.

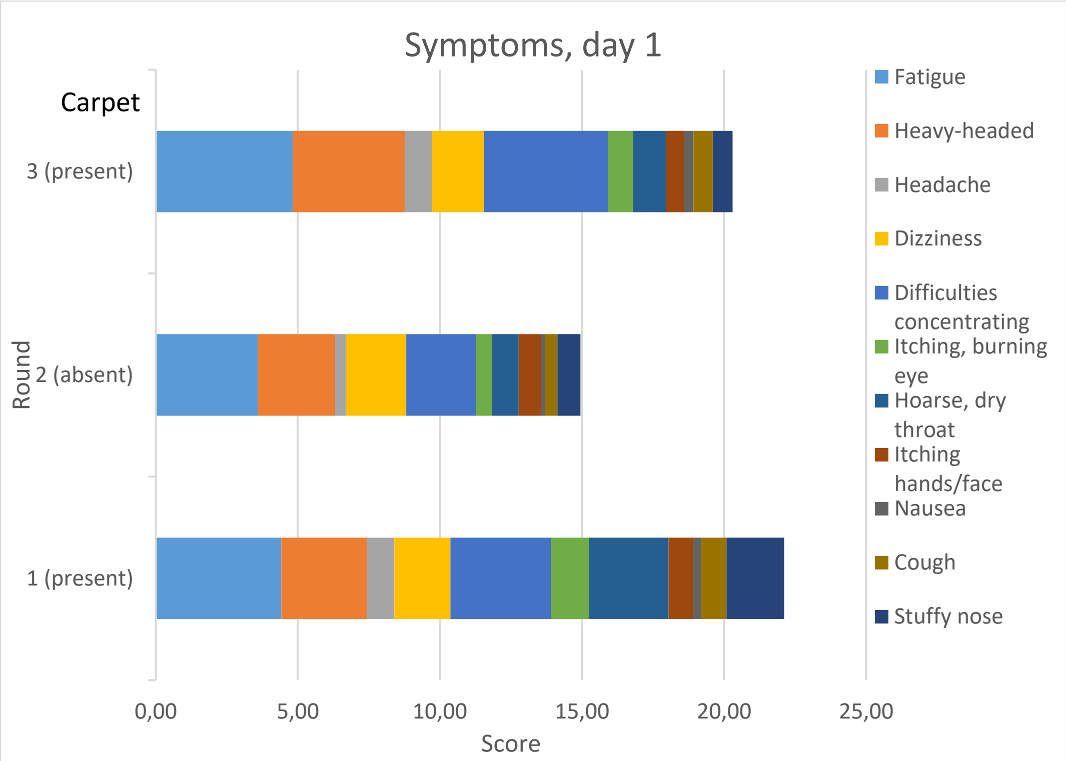


Figure 12: A stacked bar diagram showing the total score of the symptoms from the first day of the intervention study. The maximum score is 110.

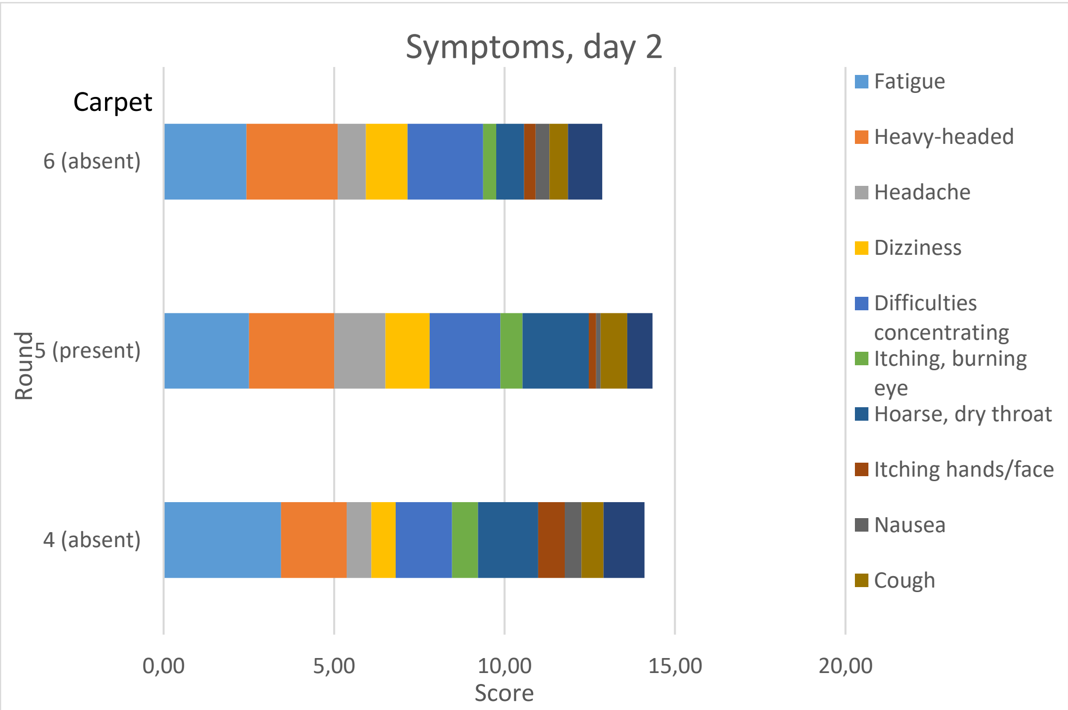


Figure 13: A stacked bar diagram showing the total score of the symptoms from the second day of the intervention study. The maximum score is 110.

3.2 PAQ study

3.2.1 Indoor Parameters

	PAQ study							
	Day 1				Day 2			
	CO2	Temperature	%RH	Airflow	CO2	Temperature	%RH	Airflow
Mean± Std.Deviation	540±85,8	23,1±0,37	19,3±0,83	20,9±15%	490±53,66	22,7±0,25	22,3±0,61	35,45±15%
Minimum	416	22,1	17,6		390	22	21	
Maximum	806	23,7	22,3		613	23	24	
	[ppm]	*[deg C]*	*[%]*	*[m3/(h*m2)]*	*[ppm]*	*[deg C]*	*[%]*	*[m3/(h*m2)]*

Table 6: Indoor parameters during the PAQ study.

Table 6 summarizes the measured indoor parameters during the two days of the PAQ study. The higher ventilation rates on the second day could have resulted in lower temperature- and CO_2-levels, and higher relative humidity. Generally, the indoor parameters were stabile during the two days. Appendix A.4 shows a graph of the indoor parameters throughout the study.

3.2.2 Particle measurements

Figure 14 shows the amount of particles smaller than 10µm (PM_{10}) in the air during both days of this study. The figure shows no difference in particles concentration (PM_{10}) when carpets were present compared with no carpets. The amount of PM_{10} never exceeded 4 µg/m^3 except for three high points. The first high point was caused by the introduction of the carpets, and during this period the particle concentration reached 65 µg/m^3. The second high point was due to a little test where I dragged my feet across the carpet for about 10-15 seconds to see how that affected the measurements. This had a big impact and the particle concentration reached a high point of 28 µg/m^3. The third high point was during the removal of the carpets where the particle concentration reached 36 µg/m^3.

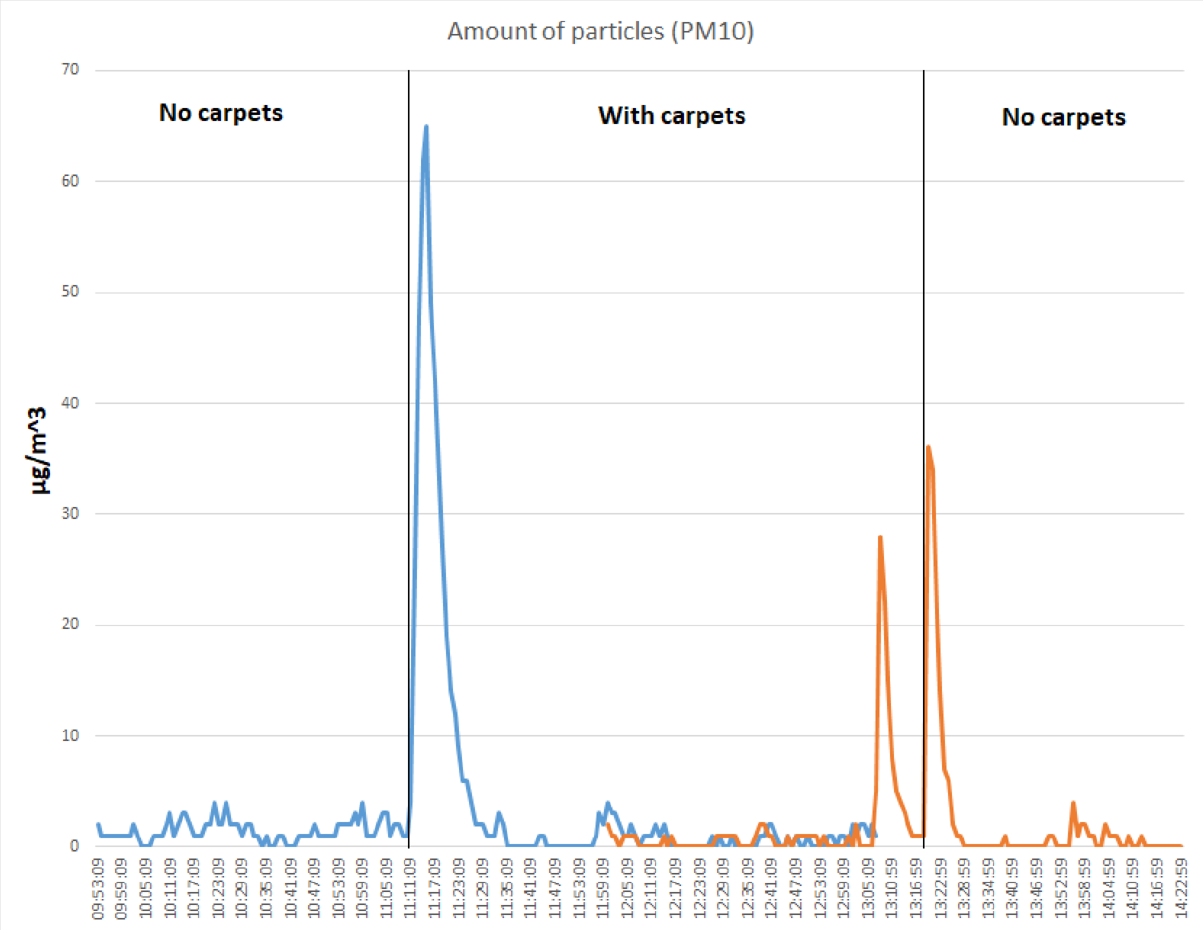


Figure 14: Graph showing the particle concentrations (PM_{10}) during the PAQ study.

3.2.3 PAQ-scores

Figure 15 shows the variation of the PAQ-scores from both days of the PAQ study. Compared to the intervention study, the subjects are less satisfied with the air quality. The average PAQ-score with the carpet present (5.24±2.63) did not differ much from when the carpet was absent (5.10±2.59) during the first day. During the second day, the PAQ-score with the carpet present (4.91±2.27) was much lower than without the carpet (5.97±2.06). However, this difference was not statistically significant (paired t-test, p=0.119).

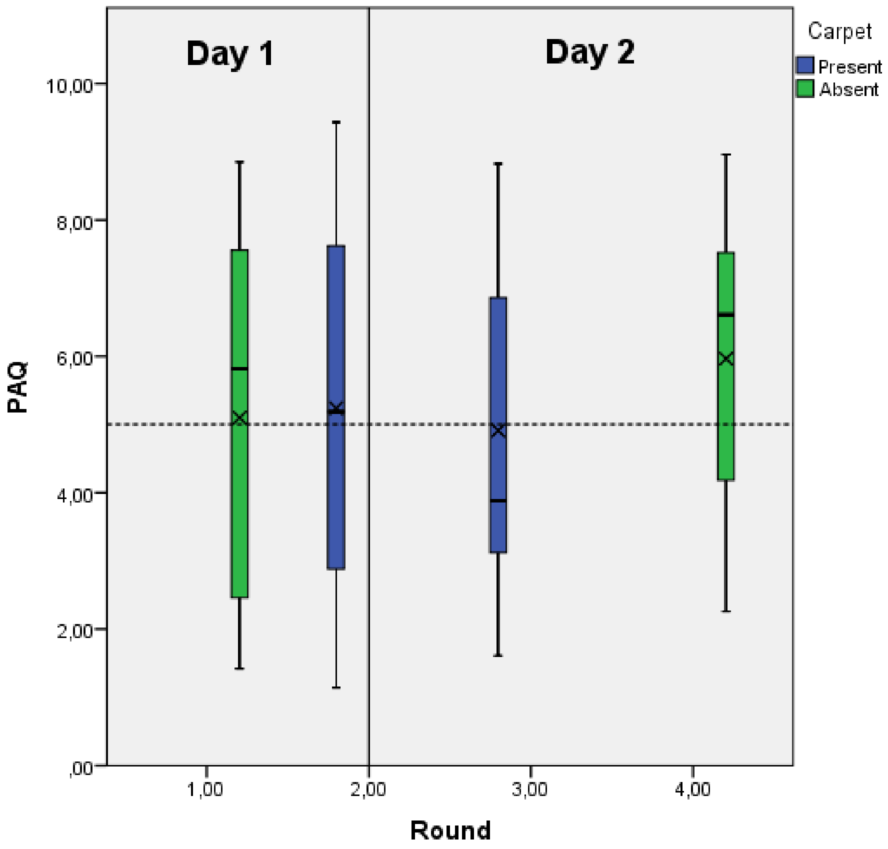


Figure 15: Boxplot of the PAQ-scores from both days of the PAQ study.

3.3 Interviews

The results from the interviews are presented as summaries which includes the information gathered. The summaries are split between the two target groups.

3.3.1 Distributors

Table 7 shows the summary of the information gathered from the distributors. In total, 3 different distributors were interviewed. To simplify, the distributors that exclusively sells carpets are referred to as “Distributor A”, and the distributors that sells several types of flooring material are referred to as “Distributor B”. Distributor B had very different opinions about carpet flooring compared to distributor A.

- Carpet flooring covers around 10-12 % of the marked, and in offices it’s around 80% according to distributor B.
- All distributors believes that carpet flooring is becoming a trend, especially in offices with open plan landscape.
- Distributor A argue that carpet flooring is cheaper than hard, smooth floors. They also claim that the maintenance cost is cheaper for carpet flooring compared to hard, smooth floors. The argument for this is that you don’t have to mop carpet floors, which saves you money.
- All the distributors agreed that carpets provide better acoustics and that this is mostly why their clients are interested in the material. They added that some clients like the material for aesthetic reasons as well.
- Distributor A avoided answering the question when asked about disadvantages with carpets.
- Distributor B did answer when asked about disadvantages and claimed that carpet flooring is more expensive to buy, has higher maintenance cost, has bad influence on the indoor climate and that the material is not good for the environment.
- Distributor A recommended a lifespan up to 20 years, while distributor B recommended up to 10 years.
- Distributor A claims that newer carpets have improved, but distributor B claims that carpets will always have a bad influence on the indoor climate.

Table 7: Summarized information from the interviews with the distributors.

3.3.2 Building owners

Table 8 shows the summary of the information gathered from the interviews conducted with the building owners. In total, 4 building owners were interviewed. All of them had very similar opinions about carpet flooring, and they were all positive about the use of it.

• The building owners often use carpet flooring because they know most clients wants it, and their experiences is that clients often request carpet flooring. • Like the distributors, the building owners comment that carpet flooring is becoming a trend, especially in the offices with open plan landscape. • Carpet tiles are widely used, which they all find to be very convenient because it's easy to remove tiles that are damaged. • Some of them claim that carpets have a longer lifespan than hard, smooth floors. • None of the building owners sees any disadvantages with the use of carpets, but some are aware that the material is not a good fit for hospitals, warehouses, laboratories etc. • They all agree that the acoustics is the biggest advantage with carpet flooring. • Their experience is that carpet floors are rarely maintained the way it is supposed to. Clients seem to think that vacuuming 1-3 times a week is enough, thus the carpets are never thoroughly cleaned. • All the building owners use carpet flooring in 80-90 % of the cases. • One of the building owners had a rehabilitation project in a school where the school specifically requested carpet flooring, but then the department of healthcare got involved and said that they were not allowed to have carpet flooring in that school. • None of the building owners mentioned anything about possible negative effects on the indoor climate.

Table 8: Summarized information from the interviews with the building owners.

4. Discussion

4.1 Perceived air quality

The results from the intervention study showed no significant difference between the PAQ-scores (paired t-test: $p=0.463$) for when the carpets were present compared to when the carpets were absent. The subjects did not notice any difference in the air quality when the carpets were present compared to when they were absent. All the mean scores and median scores were very similar, and there were little difference between them. The results from the second day did point in the direction that the presence of carpets has a negative influence on the PAQ, but this is just a minor indication as the differences were very small. The results from the PAQ study also showed no significant difference between the PAQ-scores with the carpets present compared with no carpets. The results from the first day showed no difference, but the results from the second day did indicate that the presence of carpets led to lower PAQ-scores, however the difference was not statistically significant (paired t-test: $p=0.119$). Overall, hypothesis H.1 has not been falsified based on the results observed in this project, as there were no clear evidence that the presence of carpets resulted in lower PAQ-scores.

There are several factors to be addressed for both of the studies, as they may have influenced the results of the intervention and PAQ-study. These factors will be discussed further in this chapter.

Ventilation rate

An important factor to consider in the intervention study was that the ventilation rate was very high, thus making it hard for the subjects to perceive any differences in the air quality. The ventilation rate was measured to be 2529.2±15% m^3/h, per square meter; 42.15±15% m^3/hm^2. Since we thought the ventilation rates would be much lower than it actually was, we didn't consider it necessary to adjust it. Most importantly, it was also not possible to adjust the ventilation rate. The ventilation rate may have been the reason for the similar PAQ-scores observed when carpets were present compared to when they were absent. The study by Wargocki et al. (1999) found increased perceived air quality when carpets were removed with a ventilation rate of 6.1 m^3/hm^2, which is almost seven times lower than the ventilation rate used in the intervention study. We speculate that perhaps a ventilation rate more equal to the rate used in the study by Wargocki et al. (1999) could have resulted in bigger differences in the PAQ-scores when carpets were present compared to when they were absent.

In the PAQ study, the ventilation rate was set on medium (20.9±15% m^3/hm^2) the first day, and high (35.45±15% m^3/hm^2) the second day. This led to 7.8 air exchanges before the study site could be entered the first day, and 13.3 the second day. Although the ventilation rate was 1.7 times bigger the second day compared to the first, this was where the biggest difference in PAQ was observed. This was surprising given the thought that higher ventilation rates may make it harder to perceive differences in the indoor air quality. The results from the second day gave an indication that the presence of carpet flooring may lead to worsening of the PAQ. The mean difference between the days (Day2-Day1) of the study were +0.87 when the carpets were absent, and -0.33 when the carpets were present. For this study, the subjects actually perceived the air quality to be worse with higher ventilation rates when carpets were present, while they perceived the air quality to be improved with higher ventilation rates when carpets were removed.

Overall, the subjects perceived the air quality to be improved with higher ventilation rates except for one deviation which was when carpets were present in the PAQ study. The PAQ-scores averaged over 7 in the intervention study (higher ventilation rates), and over 5 in the PAQ study (lower ventilation rates). This supports previous studies that found an improvement of the perceived air quality with higher ventilation rates (Wargocki et al., 2000).

Study design

The design of both studies could also have influenced the results. It is clear that the high ventilation rates could have had a big impact on the studies, but the design of the studies could possibly have influenced as well. In the intervention study, the carpets were hanging from clothing racks with a 10 cm gap between each pair of tiles. Also, the total size of the carpets were a bit less than the floor area and this could also have influenced. There was almost 2 meters in distance between the carpets and the subjects, and two fans may not have been enough to properly mix the air. In order to make the intervention study a blind study, the carpets had to be hidden, thus making it impossible to create a fully realistic scenario with carpets as the flooring material. These factors may also have been a reason for the similar PAQ-scores observed in the intervention study.

In the PAQ study, a realistic scenario was created when the carpets were present as they were placed on the floor. This study was therefore not a blind study, and the results could only give indications on whether the presence of carpet flooring could lead to a worsening of the PAQ or not compared with no carpets. The results of the first day showed no difference, but a difference in the PAQ-scores was found the second day. On the second day, the mean value for round 1 was 4.91 (carpet present) and for round 2 it was 5.97 (carpet absent), which indicated a worsening of the PAQ when carpets were present compared to when they were absent. There were a couple of differences between the two days of the PAQ study that may have influenced the results. The fact that the carpets had been present in the study site for 24 hours in advance the second day may have been a factor. The ventilation was off for 23 hours and 15 minutes of these 24 hours and was turned on 45 minutes before the test round began. This may have caused a worsening of the indoor air, thus leading to lower PAQ-scores. Results from previous studies, which has indicated that the presence of carpet flooring can lead to a decrease in the perceived air quality, supports this speculation (Wargocki et al., 1999).

The fact that the subjects could see the carpets when present may also have been a factor. This factor was equally existing both days, but different subjects were used the second day, thus leading to different associations with carpets which may have affected the scores. The most reasonable cause for the lower PAQ-scores when carpets were present the second day, may be the fact that the carpet had been present for 23 hours and 15 minutes longer the second day compared to the first day, thus it may have led to a worsening of the indoor air quality. Also, different subjects may have been a factor as well.

Overall, the results of the studies on perceived air quality gives no clear evidence that carpet flooring may lead to a decrease in PAQ. Previous studies have found an increase in PAQ when carpets were removed (Wargocki et al., 1999; Wargocki et al., 2002). This was also true for both the second day of the intervention study and the second day of the PAQ study, but as mentioned the differences were not statistically significant. The review by Becher et al. (2018) found no evidence supporting the notion that modern carpets are unproblematic, and this project has found a slight indication that modern carpets may cause a worsening of the perceived air quality. Still, the relation between modern carpets and perceived air quality needs further exploring.

4.2 Symptoms

The results from the intervention study showed indications of increased intensity of several symptoms when carpets were present compared with no carpets. The intensity of headaches, fatigue, difficulties concentrating and hoarse, dry throat were found to be higher when carpets were present compared to when they were absent. Our findings are consistent with the study by Wargocki et al. (1999) who found increased intensity of headache and other SBS-symptoms when carpets were present compared to when they were absent. The difference in hoarse, dry throat was statistically significant between round 1 and 2. Since the indoor parameters were kept stabile, this result is likely to be related to the presence of carpets. The highest score of this symptom was for both days found when carpets were present, indicating that the presence of carpets led to increased intensity of hoarse, dry throat. We also found that the subjects found it significantly more difficult to concentrate when there were carpets present, however the difference may not be 100% due to the presence of carpets. This difference could be related to both time and carpets as the highest intensity of this symptom was observed in the last test round for both days.

The results from the first day showed higher intensity of several symptoms when carpets were present compared to when they were absent. The results from the second day showed the same tendency, but there were only minor differences. Our results are in line with previous studies which have found that the presence of carpets lead to increased intensity of SBS-symptoms (Wargocki et al., 1999; Wargocki et al., 2002; Bluyssen et al., 2016; Norbäck et al., 1990). Overall, the results of this study indicated more intensity of symptoms when carpets were present compared to when they were absent, but it should be noted that the subjects generally experienced low intensity of all symptoms as the scores were generally low (mean values ranging between 0-5). By pooling the scores for each symptom, the results showed that the intensity of the symptoms was 4.5 % higher when the carpets were present compared to when the carpets were absent. An increased intensity of symptoms can result in worsening of perceived air quality, but this was not the case in this study as the PAQ-scores were very similar.

The presence of carpets did increase the overall intensity of symptoms compared with no carpets, but there were several symptoms where no difference was observed between the presence and absence of carpets. The subjects experienced significantly hoarser, dryer throats and found it significantly more difficult to concentrate when carpets were present. Still, the results only indicate that the presence of carpets may lead to increased intensity of symptoms.

Thus, hypothesis H.2 has not been falsified during this study, but it has showed that there is an indication that the presence of carpet flooring may increase the intensity of symptoms.

4.3 Carpets as an exposure source

Due to limitation of equipment and the scope of this project, only the particle concentration was measured. Hence, the type of compounds present in the study sites has not been explored. Studies have found that carpets may act as a reservoir for dust and mite allergens which over time can be resuspended in the air, and this may cause an increased intensity of symptoms and can lead to a worsening of the perceived air quality (Becher et al., 2018; Norbäck et al., 1990).

The results from the DustTrak measurements showed no difference in the concentration of particles (PM_{10}, $PM_{2.5}$ & PM_1) when carpets were present compared to when they were absent. During the intervention study, PM_1 was measured the first day and $PM_{2.5}$ the second day. Since the studies lasted over several days, different inlet sizes were used to check for differences within the particle sizes. The fact that the carpets were hanging from clothing racks may have influenced the results as no difference in particle concentrations were observed during the intervention study.

Since the carpets were placed on the floor, resuspension of particles became a factor in the PAQ study. However, normal movement on the carpets did not result in higher concentrations of PM_{10} compared with hard, smooth flooring. Despite no measured difference in regular use, the concentration measured when introducing or removing the carpets were high. The amounts of PM_{10} reached a high point of 65 $\mu g/m^3$ when the carpets were introduced, and a high point of 36 $\mu g/m^3$ when removed. Although there was no difference measured in the resuspension of PM_{10} between the floorings, the measurements showed that carpets do contain a much bigger amount of dust and particles compared to hard, smooth floorings. Also, feet-dragging across the carpets led to high point of 28 $\mu g/m^3$, which indicates that excessive use may cause resuspension of particles.

FHI (2015) recommends a daily average value of 15 $\mu g/m^3$ for $PM_{2.5}$ and 30 $\mu g/m^3$ for PM_{10}, and the concentrations never exceeded these values except for when carpets were introduced or removed during the PAQ study. Overall, hypothesis H.3 was not falsified during the studies as the results showed no difference in the particle concentrations when carpets were present compared to when they were absent. Still, the results have indicated that carpets do contain more particles.

4.4 Interviews

The results from the interviews told us that carpet flooring is being frequently used amongst building owners. Clients often request carpet flooring, and the material is becoming a trend in offices with open plan landscape. Distributors A avoided answering when asked about disadvantages and claims that modern carpets have improved. Distributor B were the only person interviewed that saw several disadvantages with the use of carpet flooring. This distributor claimed to have a neutral view on the material, and stated that carpet flooring will always have a negative influence on the indoor climate. The building owners were positive regarding the use of carpet flooring and mostly used carpet tiles since they are easy to remove if damaged.

To summarize, carpet flooring seems to be chosen because of its noise reducing traits and the aesthetics of the material. The results showed that people don’t seem to think about health effects when choosing carpet flooring. The material seems to become a trend despite health authorities’ advice to show caution with the use of it (NAAF, 2016; FHI, 2015). The people choosing to use carpet flooring doesn’t seem to know that larger amounts of dust and mite allergens may assemble within the fabric of the carpets over time, and that these particles may be resuspended into the air again (Becher et al., 2018; Matheson et al., 2003; Stranger et al., 2007; Dahl et al., 2002). A worsening of the perceived air quality has been found when carpets were present (Wargocki et al., 1999; Wargocki et al., 2002), but this seems to be overlooked.

Overall, the results from the interviews supports a need for more studies like the present one and the need for more research on the effects that carpet flooring has on the indoor climate. The people choosing carpet flooring seem to only see the positive effects of the material, therefore it is important to further investigate possible negative effects.

4.5 Strengths and weaknesses

4.5.1 Study design

Intervention study

Since it was not possible to adjust the ventilation rate, the study site might not have been well suited for this type of study. Ideally, we should have been able to adjust the ventilation rate in the study site to a more suitable rate which would be close to the rate of 6.1 used in the study conducted by Wargocki et al. (1999), where the perceived air quality was found to be worsened when carpets were present. Still, there were several strengths in using exactly this room as the study site for the intervention study. A big strength was that we could combine the study with lectures. Combining the study with lectures gave us an opportunity to use the students attending these lectures as subjects, which was a great strength since recruiting subjects can prove to be very difficult. Moreover, having the study combined with lectures gave us the opportunity to investigate if exposure to carpets over time could lead to worsening of symptoms. We also needed a big enough room where we could hide the carpets from the subjects. The classroom already had four partitions in it, therefore we only needed 2-3 more to fully hide the carpets. In addition, the storage room next door was key for being able to carry out the interventions of the study within 15 minutes. Considering the limitations of this project, the study site used was probably the best suited room available for conducting this study.

Since the plan was to conduct a blind intervention study, we had to find a method for hiding the carpets. The idea of hanging the carpets on clothing racks came along after a lot of thinking. A big strength with this method was that it was easy to transport the carpets, thus making the intervention possible. To move 60 m^2 of carpet in and out of the room seemed almost impossible at first, but this method solved that problem. A possible weakness was that the carpet tiles were hanging very close to each other as we used a 10 cm gap between each pair of tiles. There was also some distance between the subjects and the carpet tiles, and perhaps two fans was not enough to properly mix the air.

PAQ study

The strength of having the PAQ study in the study site used was that it was easy to recruit subjects. The fact that the study only required one minute of the subjects time per test round was key for getting enough subjects to volunteer. Also, we were able to use different subjects for each day of the study, which resulted in more data on the relationship between carpet flooring and perceived air quality. The study site had its own air handling unit and the ventilation rate could be adjusted between 3 levels. Ideally, the ventilation rate used should have been at the minimum level, but again we thought that the ventilation rate was much lower than it actually was. Since a realistic scenario was created, the design of this study was well suited for the particle measurements. A weakness with this study was that it could not be carried out as a blind study, thus all differences found would only be indications since the carpets were visible.

4.5.2 Statistical tests

The statistical tests used in this project were the paired samples t-test for normally distributed data, and Wilcoxon signed ranks test for non-normally distributed data. These tests were well suited for analyzing the datasets since the tests compares two sets of measurements with each other by comparing all subjects with themselves. Specifically, the PAQ-scores and scores of symptoms from when carpets were present was compared to when carpets were absent. The strength of using these statistical tests for analyzing the data was that they told us if the subjects perceived the air quality to be significantly improved or not when carpets were absent compared to when they were present. They also told us if the subjects experienced significantly higher intensity of symptoms or not when carpets were present compared to when they were absent.

5. Concluding remarks and further work

The studies conducted in this project has not found conclusive results regarding the relation between carpet flooring and perceived air quality. However, a slight indication was found for two separate days of the studies, relating the presence of carpets with a decrease in PAQ-scores. The subjects generally perceived the air to be better with higher ventilation rates. The results of the intervention study showed that the subjects overall perceived 4.5% more intensity of symptoms when carpets were present compared to when they were absent. Also, the subjects had significantly hoarser/dryer throats, and found it significantly harder to concentrate when carpets were present compared with no carpets. Still, the subjects generally experienced low intensity of symptoms throughout the study. No difference was found in the particle concentrations when the carpets were present compared to when they were absent. Still, the results did show that carpets may contain more particles compared to hard, smooth floors as the particle concentration (PM_{10}) reached up to 65 $\mu g/m^3$ when the carpets were being introduced/removed. None of the hypotheses that were explored was falsified during this study.

This study has indicated that modern carpets may not be unproblematic, but further work needs to be done. Future studies should be made on the relation between modern carpets and the perceived air quality, and a study site where the ventilation rate can be adjusted should be used. Also, longer exposures to modern carpets could be worth exploring. People don’t seem to know about possible negative effects related to carpet flooring, thus there is great need for more research on this topic. Hopefully this study can contribute to further research.

6. References

Andersson, K. (1998). “Epidemiological Approach to Indoor Air Problems*”, *Indoor Air 1998; Suppl. 4:* 32-39. ISSN 0908-5920.

Bakke, J. V. (2008). “Teppegolv og inneklima”, *Allergi i praksis*, 2/2008.

Bakke, J. V., Øvrevik, J., Schwarze, P. E., Hongslo, J. K., Nilsen, S. & Becher, R. (2016). “Teppegulv, inneklima og helsepåvirkning”, *Allergi i praksis*, 2/2016, 46-54.

Becher, R., Øvrevik, J., Schwarze, P. E., Nilsen, S., Hongslo, J. K. & Bakke, J. V. (2018). “Do Carpets Impair Indoor Air Quality and Cause Adverse Health Outcomes: A Review”, *Int. J. Environ. Res. Public Health 2018*, 15, 184. doi:10.3390/ijerph15020184

Bluyssen, P. M., Roda, C., Mandin, C., Fossati, S., Carrer, P., de Kluizenaar, Y., Mihucz, V. G., de Oliveira Fernandes, E. & Bartzis, J. (2016). “Self-reported health and comfort in ‘modern’ office buildings: first results from the European OFFICAIR study”, *Indoor Air 2016*; 26, 298–317.

Causer, S. M., Lewis, R.D., Batek, J. M. & Ong, K-H. (2004). “Influence of Wear, Pile Height, and Cleaning Method on Removal of Mite Allergen from Carpet”, *Journal of Occupational and Environmental Hygiene*, 1: 237–242. ISSN 1545-9624

Causer, S., Shorter, C & Sercombe, J. (2006). “Effect of Floorcovering Construction on Content and Vertical Distribution of House Dust Mite Allergen, Der p I”, *Journal of Occupational and Environmental Hygiene*, 3:4, 161–168. ISSN: 1545-9624. DOI: 10.1080/15459620600572068

Dahl, I. E., Holøs, S. B. & Nilsen, S. K. (2002). “Textile floor covering as part of indoor environment”, *Proceedings: Indoor air 2002*, 986-991.

Ege (2015, 27. November). “Vedlikeholdsveiledning for ege contract-tepper”, obtained from http://catalogs.egecarpet.com/Vedlikeholdsveiledning/?__hstc=221652935.377cfe9501cf23b0cb23dfe2ee459bca.1526136894492.1526136894492.1526207883116.2&__hssc=221652935.4.1526207883116&__hsfp=3946821873&page=2

Evans, G. W. & McCoy, J. M. (1998). “When buildings don’t work: The role of architecture in human health”, *Journal of Environmental Psychology (1998) 18*, 85–94.

Fang, L., Wyon, D. P., Clausenand, G. & Fanger, P. O. (2004). “Impact of indoor air temperature and humidity in an officeon perceived air quality, SBS symptoms and performance”, *Indoor Air 2004; 14 (Suppl 7):* 74–81.

Fanger, P. O. (2000). "Indoor Air Quality in the 21st Century: Search for Excellence", *Indoor Air 2000; 10: 68–73*. ISSN 0905-6947.

Fanger, P. O. (2006). "What is IAQ?", *Indoor Air 2006;* 16: 328–334.

Field, A. (2009). "Discovering statistics using SPSS (3rd edition)", London. Sage Publications Ltd.

Jaakkola, J. K., Ieromnimon, A. & Jaakkola, M., S. (2006) "Interior Surface Materials and Asthma in Adults: A Population-based Incident Case-Control Study", *Am J Epidemiol* 2006; 164: 742–749

Matheson, M.C., Dharmagew, S. C., Forbes, A. B., Ravenz, J. M., Woods, R. K., Thien, F. C. K., Guestz, D. I., Rolland, J. M., Haydn Walters, E. & Abramson, M. J. (2003). "Residential characteristics predict changes in Der p 1, Fel d 1 and ergosterol but not fungi over time", *Clin Exp Allergy 2003*; 33:1281–1288.

Mysen, M., Fostervold, K. I & Schild, P. G. (2006). "An intervention study of the impact of supply air filters on perceived air quality and health symptoms in a primary school", Norway.

Nasjonalt folkehelseinstitutt (FHI). (2015). "Anbefalte faglige normer for inneklima", *Rapport 2015:1.* ISSN 1503-1403

Norbäck, D., Torgén, M. & Edling, C. (1990). "Volatile organic compounds, respirable dust, and personal factors related to prevalence and incidence of sick building syndrome in primary schools", *British Journal of Industrial Medicine 1990; 47:* 733-741.

Norbäck, D. (1995). "Subjective Indoor Air Quality in Schools – the Influence of High Room Temperature, Carpeting, Fleecy Wall Materials and Volatile Organic Compounds (VOC)", *Indoor Air 1995*, 5: 237-246. ISSN 0905-6947.

Sercombe, J. K., Liu-Brennan, D., Causer, S. M. & Tovey, E. R. (2006). "The vertical distribution of house dust mite allergen in carpet and the effect of dry vacuum cleaning", *Int. J. Hyg. Environ.-Health* 210 (2007) 43–50.

Skov, P., Valbjørn, O., Pedersen, B. V. & the Danish Indoor Climate Study Group. (1990). "Influence of indoor climate on the sick building syndrome in an office environment", *Scand J Work Environ Health 1990;* 16: 363-371. ISSN 1795-990X.

Stranger, M., Potgieter-Vermaak, S. S., Van Grieken, R. (2007). "Comparative overview of indoor air quality in Antwerp, Belgium", *Environment International 33 (2007)* 789–797. doi:10.1016/j.envint.2007.02.014

The carpet and rug institute, CRI. (Undated) "Indoor air quality", obtained from http://www.carpet-rug.org/indoor-air-quality.html

The Norwegian asthma and allergy federation, NAAF. (2016, 8. December). Obtained from http://www.naaf.no/fokusomrader/inneklima/fakta-om-inneklima/bruk-av-tepper-i-skolebygninger/

Tranter, D. C. (2005). "Indoor allergens in settled school dust: a review of findings and significant factors", *Clin Exp Allergy 2005*; 35: 126–136. doi:10.1111/j.1365-2222.2005.02149.x

Wargocki, P., Wyon, D. P., Baik, Y. K., Clausen, G. & Fanger, P.O. (1999). "Perceived Air Quality, Sick Building Syndrome (SBS) Symptoms and Productivity in an Office with Two Different Pollution Loads", *Indoor Air 1999;* 9: 165–179. ISSN 0905-6947.

Wargocki, P., Wyon, D. P., Sundell, J., Clausen, G. & Fanger, P.O. (2000). The Effects of Outdoor Air Supply Rate in an Office on Perceived Air Quality, Sick Building Syndrome (SBS) Symptoms and Productivity *Indoor Air 2000;* 10: 222–236. ISSN 0905-6947.

Wargocki, P., Lagercrantz, L., Wyon, D. P. & Fanger, P. O. (2002). "Subjective perceptions, symptom intensity and performance: a comparison of two independent studies, both changing similarly the pollution load in an office", *Indoor Air 2002;* 12: 74–80. ISSN 0905-6947.

Appendix

A.1 Intervention study; descriptive statistics PAQ

INTERVENTION STUDY, DAY 1

	Round 1	Round 2	Round 3
	Carpet present	Carpet absent	Carpet present
MEAN±STD. DEVIATION	7.66±1.73	7.36±1.40	7.50±1.75
MEDIAN	8.00	7.21	7.96
MINIMUM	3.65	3.41	2.25
MAXIMUM	10.00	10.00	10.00

INTERVENTION STUDY, DAY 2

	Round 1	Round 2	Round 3	Round 4	Round 5	Round 6
	Carpet absent		Carpet present		Carpet absent	
EXPOSURE TIME	-	1 hour	-	1 hour	-	1 hour
MEAN±STD. DEVIATION	7.47±2.00	7.53±1.33	7.36±1.75	7.28±1.56	7.62±1.37	7.40±1.75
MEDIAN	7.72	7.71	7.37	7.52	7.88	7.39
MINIMUM	1.63	4.18	2.46	3.82	3.45	3.15
MAXIMUM	10.00	9.19	10.00	9.71	9.76	9.68

A.2 PAQ study; descriptive statistics

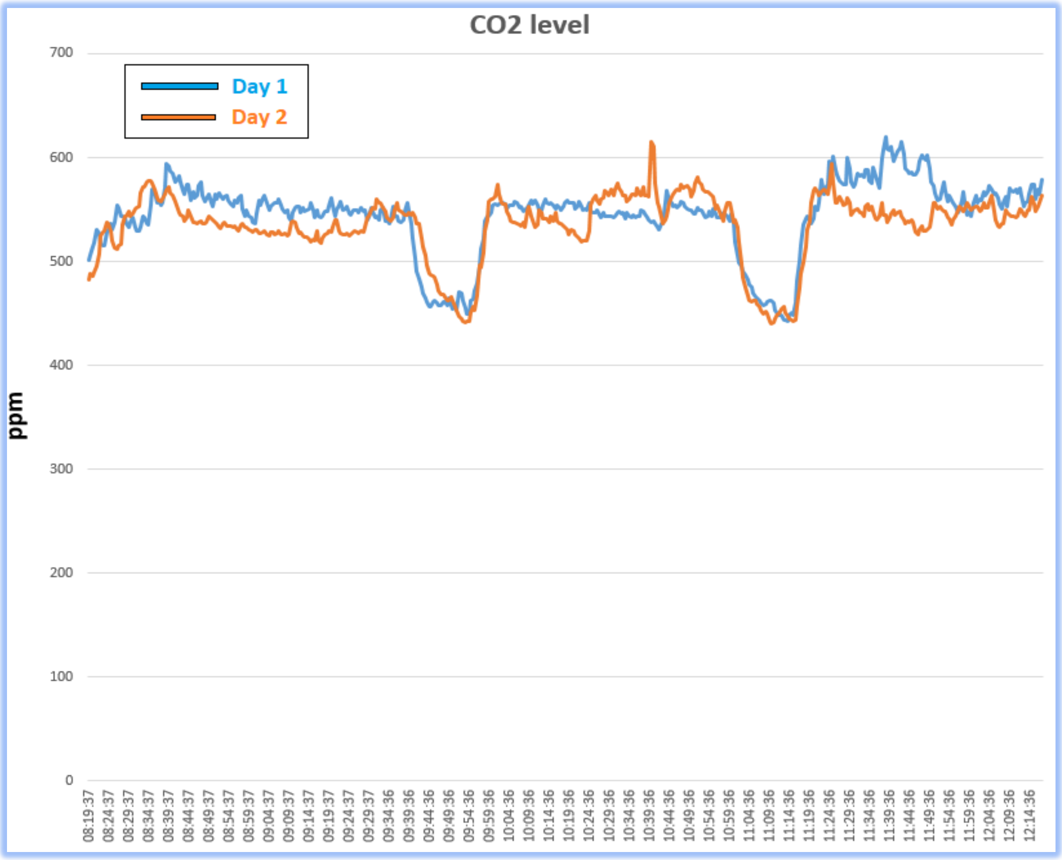
PAQ STUDY, DAY 1

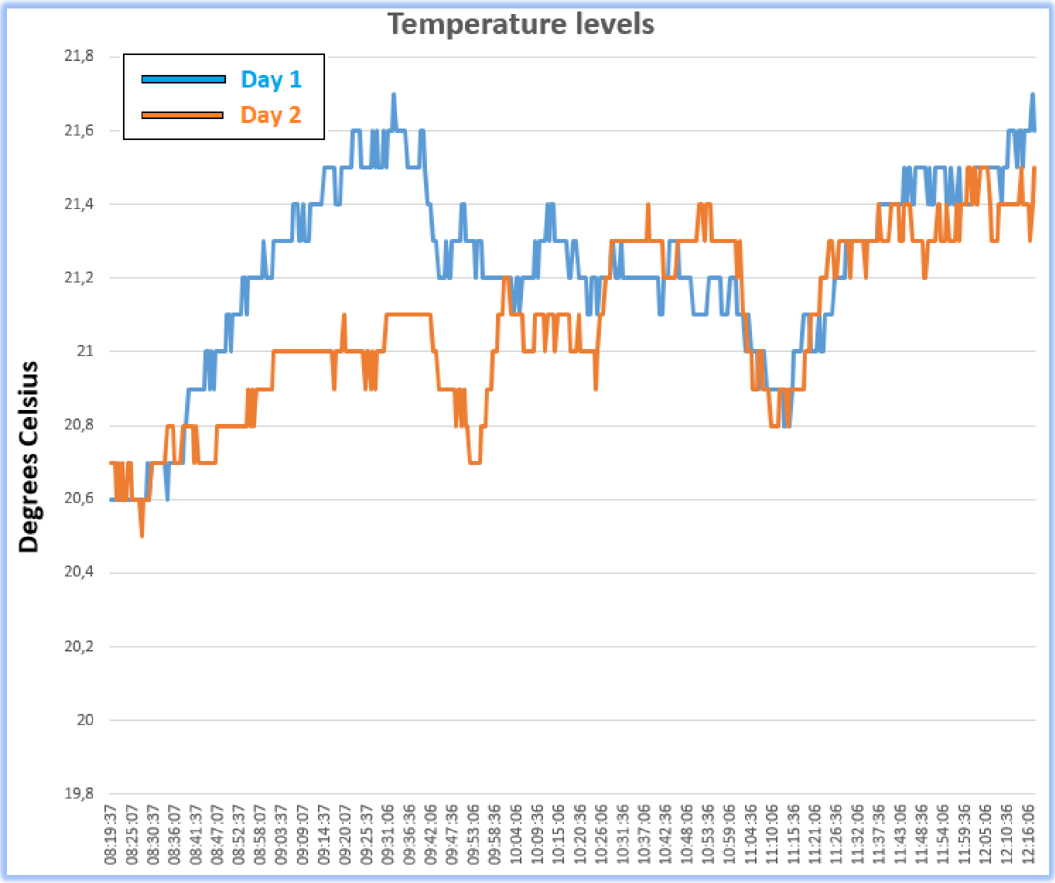
	Round 1	Round 2
	Carpet absent	Carpet present
MEAN±STD. DEVIATION	5.10±2.59	5.24±2.63
MEDIAN	5.82	5.19
MINIMUM	1.42	1.14
MAXIMUM	8.85	9.43

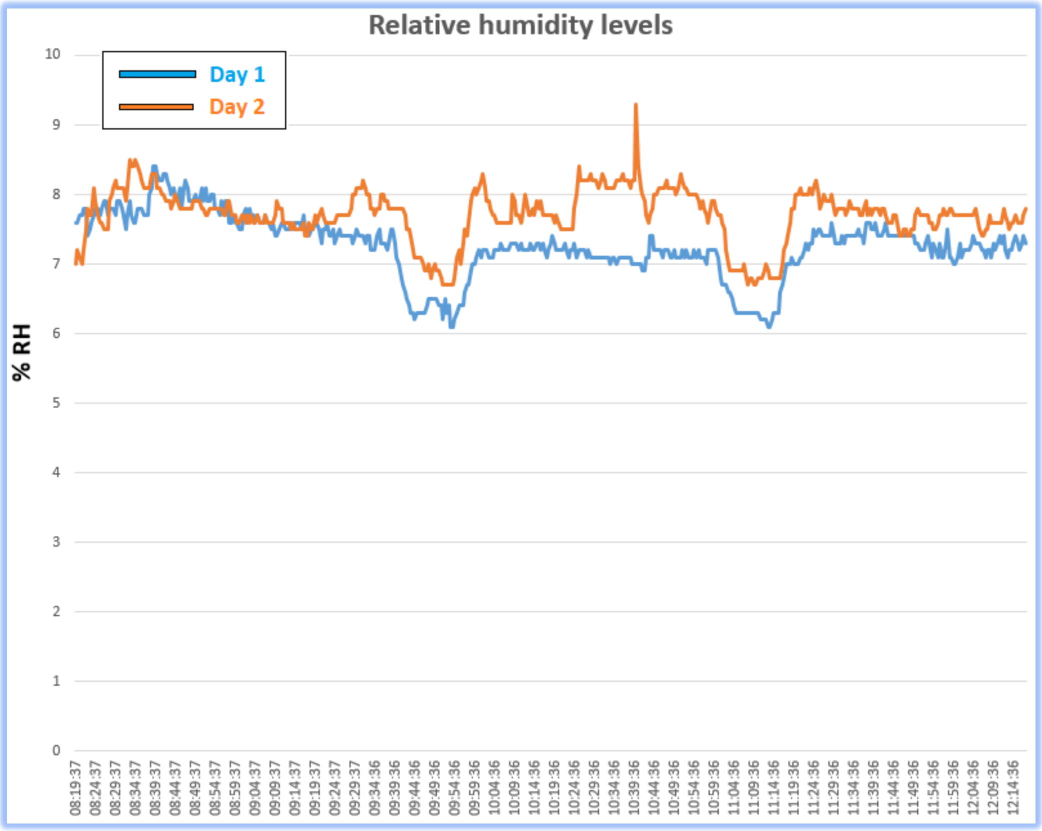
PAQ STUDY, DAY 2

	Round 1	Round 2
	Carpet present	Carpet absent
MEAN±STD. DEVIATION	4.91±2.27	5.97±2.06
MEDIAN	3.88	6.61
MINIMUM	1.61	2.26
MAXIMUM	8.82	8.96

A.3 Indoor parameters; Intervention study

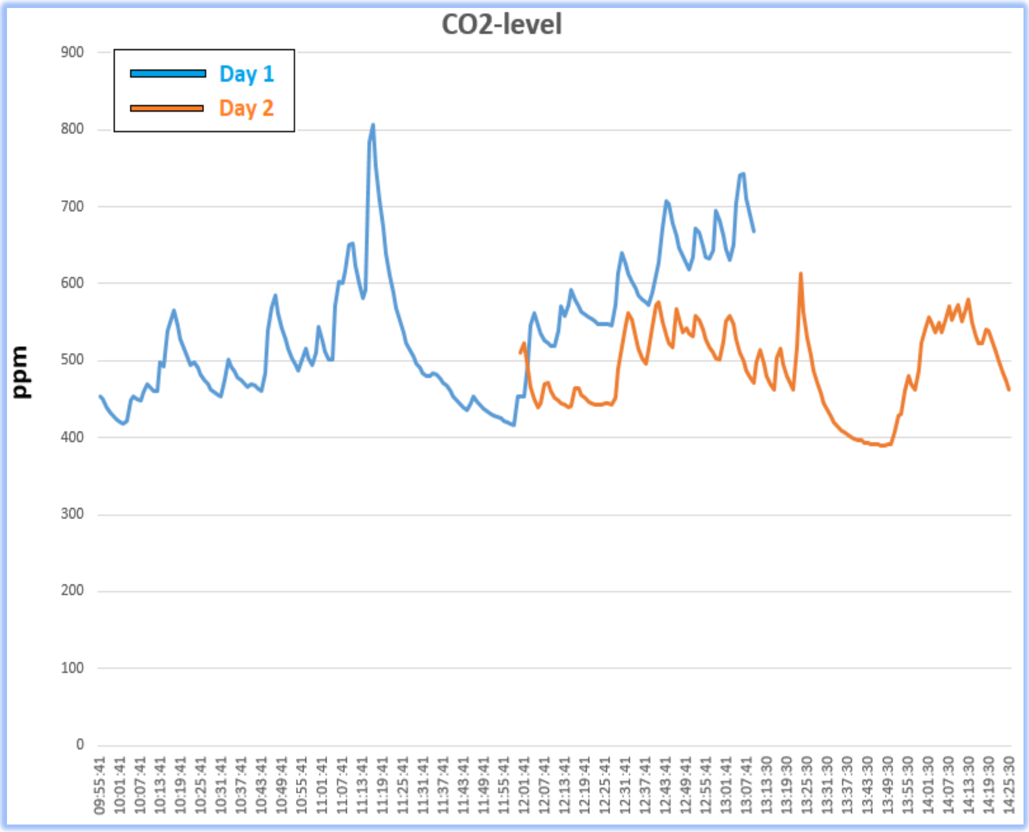


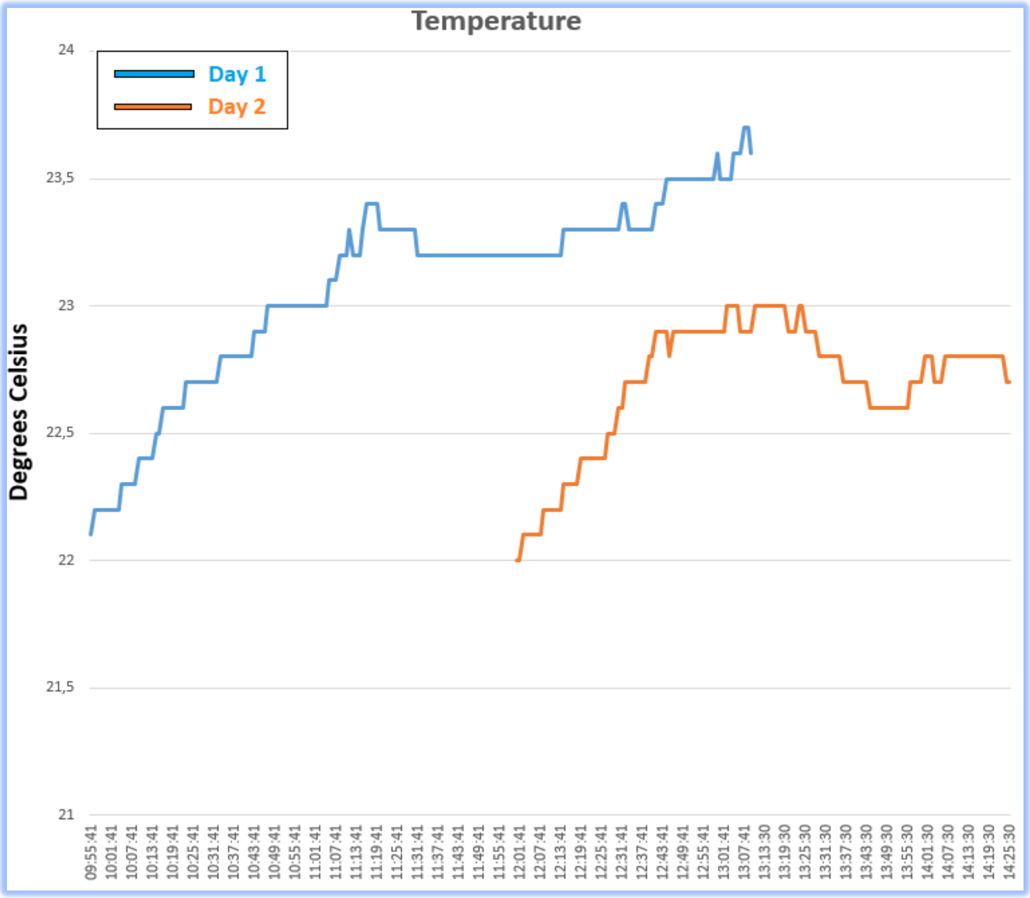


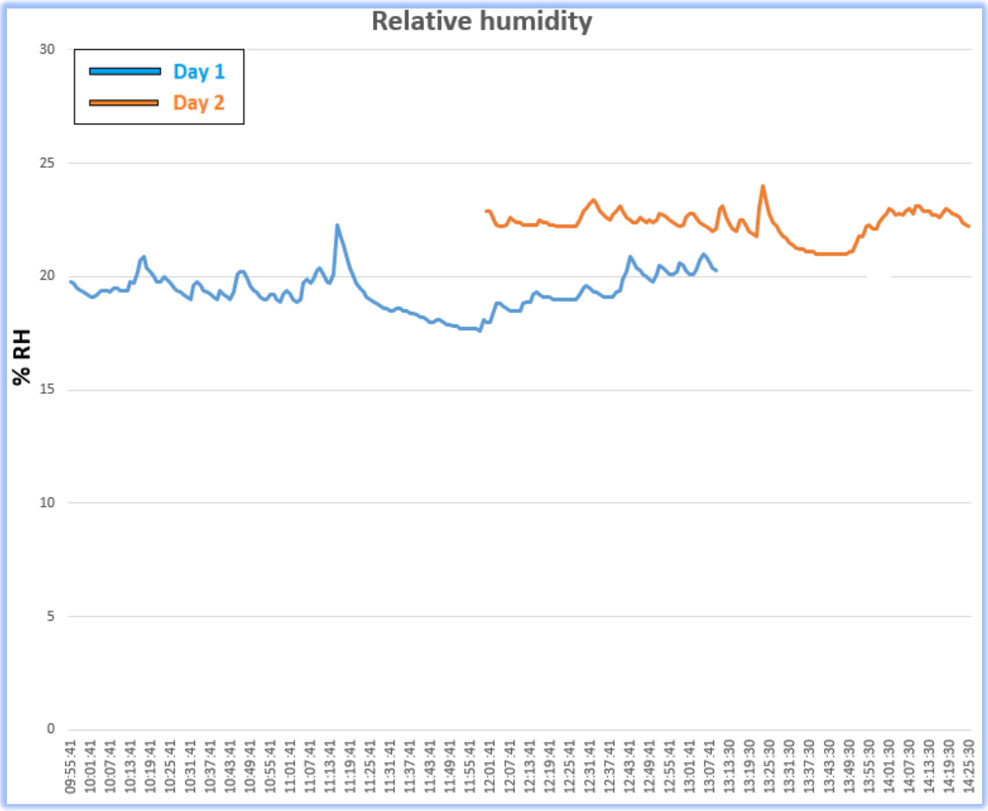


Relative humidity levels
Day 1
Day 2
% RH
10
9
8
7
6
5
4
3
2
1
0
08:19:37
08:24:37
08:29:37
08:34:37
08:39:37
08:44:37
08:49:37
08:54:37
08:59:37
09:04:37
09:09:37
09:14:37
09:19:37
09:24:37
09:29:37
09:34:36
09:39:36
09:44:36
09:49:36
09:54:36
09:59:36
10:04:36
10:09:36
10:14:36
10:19:36
10:24:36
10:29:36
10:34:36
10:39:36
10:44:36
10:49:36
10:54:36
10:59:36
11:04:36
11:09:36
11:14:36
11:19:36
11:24:36
11:29:36
11:34:36
11:39:36
11:44:36
11:49:36
11:54:36
11:59:36
12:04:36
12:09:36
12:14:36

A.4 Indoor parameters; PAQ study






Relative humidity
Day 1
Day 2
% RH
30
25
20
15
10
5
0

A.5 Statistical analysis; Perceived air quality, intervention study day 2

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Round1	,160	17	,200*	,878	17	,029
Round3	,132	17	,200*	,931	17	,225

*. This is a lower bound of the true significance.
a. Lilliefors Significance Correction

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Round3	,132	17	,200*	,931	17	,225
Round5	,217	17	,032	,839	17	,007

*. This is a lower bound of the true significance.
a. Lilliefors Significance Correction

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Round2	,212	17	,042	,886	17	,040
Round4	,159	17	,200*	,940	17	,324

*. This is a lower bound of the true significance.
a. Lilliefors Significance Correction

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Round4	,157	17	,200*	,942	17	,341
Round6	,149	17	,200*	,923	17	,169

*. This is a lower bound of the true significance.
a. Lilliefors Significance Correction

Shapiro Wilk's test, which showed that all pairs are non-normally distributed except the pair "Round4-Round6".

T-Test

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Round4	7,2347	17	1,59595	,38708
	Round6	7,4029	17	1,75443	,42551

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Round4 & Round6	17	,323	,205

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	Round4 - Round6	-,16824	1,95294	,47366	-1,17235	,83588	-,355	16	,727

A paired samples t-test of the pair "Round4-Round6" which shows no significant difference (p=0.727)

Wilcoxon Signed Ranks Test

Ranks

		N	Mean Rank	Sum of Ranks
Round3 - Round1	Negative Ranks	7[a]	11,57	81,00
	Positive Ranks	10[b]	7,20	72,00
	Ties	0[c]		
	Total	17		
Round3 - Round5	Negative Ranks	9[d]	9,72	87,50
	Positive Ranks	8[e]	8,19	65,50
	Ties	0[f]		
	Total	17		
Round4 - Round2	Negative Ranks	10[g]	9,20	92,00
	Positive Ranks	7[h]	8,71	61,00
	Ties	0[i]		
	Total	17		

a. Round3 < Round1

b. Round3 > Round1

c. Round3 = Round1

d. Round3 < Round5

e. Round3 > Round5

f. Round3 = Round5

g. Round4 < Round2

h. Round4 > Round2

i. Round4 = Round2

Test Statistics[a]

	Round3 - Round1	Round3 - Round5	Round4 - Round2
Z	-,213[b]	-,521[b]	-,734[b]
Asymp. Sig. (2-tailed)	,831	,603	,463

a. Wilcoxon Signed Ranks Test

b. Based on positive ranks.

A Wilcoxon signed ranks test of the pairs "Round3-Round1", "Round3-Round5" and "Round4-Round2", which shows no significant differences.

A.6 Statistical analysis; PAQ study day 2

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
PAQ2_1	,211	16	,054	,934	16	,286
PAQ2_2	,159	16	,200*	,946	16	,425

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Results of the Shapiro-Wilk's test, PAQ study day 2, which showed that the datasets were normally distributed, thus a paired samples t-test was run.

T-Test

```
[DataSet1] C:\Users\s187818\Downloads\PAQ Forsøket begge dager (1).sav
```

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	PAQ2_1	4,7213	16	2,19995	,54999
	PAQ2_2	5,9650	16	2,05813	,51453

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	PAQ2_1 & PAQ2_2	16	,004	,989

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	PAQ2_1 - PAQ2_2	-1,24375	3,00677	,75169	-2,84594	,35844	-1,655	15	,119

Results of the paired samples t-test, PAQ study day 2, which showed that the difference in PAQ was not statistically significant (p=0.119).

A.7 Difficulties concentrating; Statistical analysis

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Round2	,197	17	,079	,868	17	,020
Round3	,158	17	,200*	,931	17	,230

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

The results of the Shapiro-Wilk's test showed that round 2 was non-normally distributed. Therefore, a Wilcoxon signed ranks test was run.

Wilcoxon Signed Ranks Test

Ranks

		N	Mean Rank	Sum of Ranks
Round3 - Round2	Negative Ranks	5[a]	4,40	22,00
	Positive Ranks	11[b]	10,36	114,00
	Ties	1[c]		
	Total	17		

a. Round3 < Round2

b. Round3 > Round2

c. Round3 = Round2

Test Statistics[a]

	Round3 - Round2
Z	-2,379[b]
Asymp. Sig. (2-tailed)	,017

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

The results of the Wilcoxon signed ranks test showed that the differences between round 2 (carpet absent) and round 3 (carpet present) are statistically significant (p=0.017). Thus, the subjects found it significantly harder to concentrate when the carpets were present compared with no carpets.

A.8 Hoarse, dry throat; Statistical analysis

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Round_1	,253	15	,010	,772	15	,002
Round_2	,398	15	,000	,591	15	,000

a. Lilliefors Significance Correction

The results of the Shapiro Wilk's test showed that the datasets were non-normally distributed, hence a Wilcoxon signed ranks test was run.

Wilcoxon Signed Ranks Test

Ranks

		N	Mean Rank	Sum of Ranks
Round_2 - Round_1	Negative Ranks	9[a]	6,22	56,00
	Positive Ranks	2[b]	5,00	10,00
	Ties	4[c]		
	Total	15		

a. Round_2 < Round_1

b. Round_2 > Round_1

c. Round_2 = Round_1

Test Statistics[a]

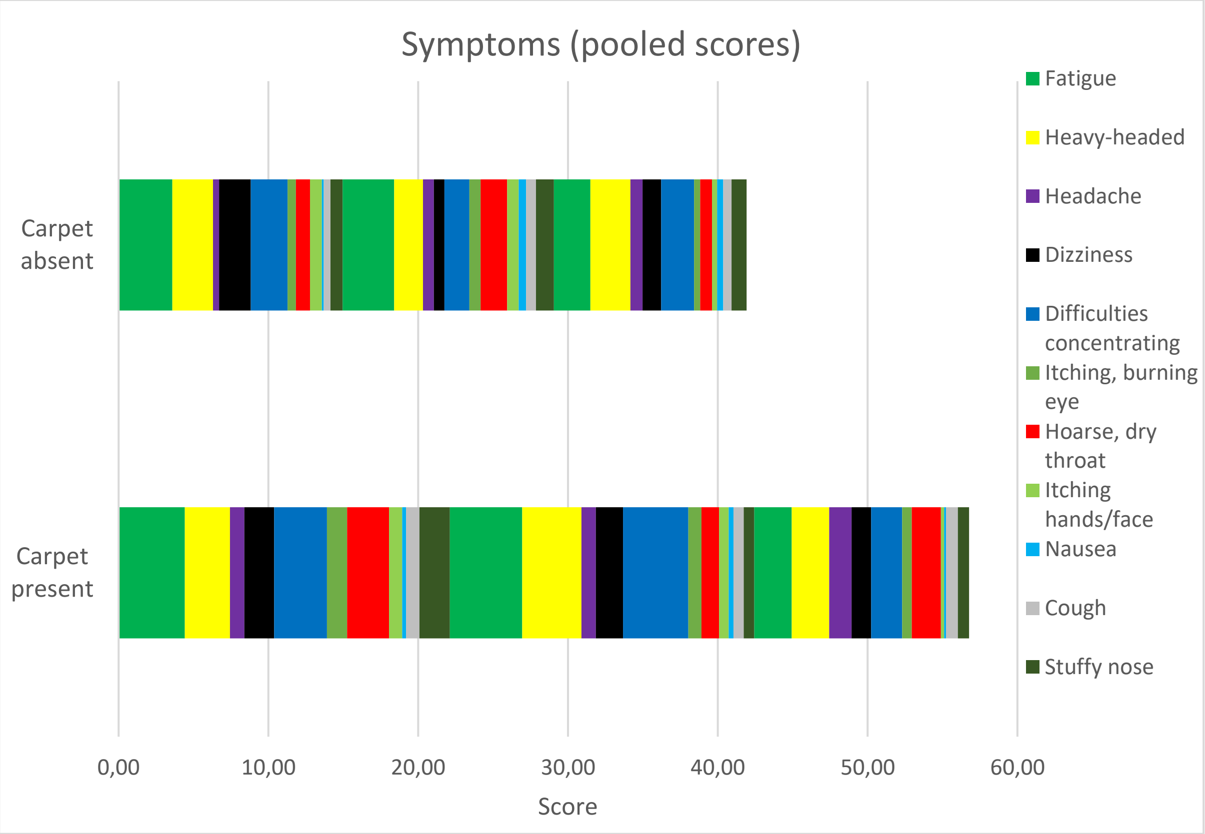
	Round_2 - Round_1
Z	-2,045[b]
Asymp. Sig. (2-tailed)	,041

a. Wilcoxon Signed Ranks Test

b. Based on positive ranks.

The results of the Wilcoxon signed ranks test showed that the differences between in hoarse, dry throat between round 1 (carpet present) and round 2 (carpet absent) were statistically significant (p=0.041).

A.9 Stacked bar diagram; symptoms (pooled scores)



Stacked bar diagram that shows the pooled scores of symptoms. 11 symptoms, which are scored 3 times when carpets were present and 3 times with no carpets, resulting in 33 separate rectangles in each bar. The total score of these symptoms was 41.92 when carpets were absent and 56.77 when carpets were present. Resulting in (absent: 41.92/330=12.7% intensity) and (present: 56.77/330=17.2% intensity).

A.10 Questionnaire for distributors (In Norwegian)

Spørsmål til leverandør

(1) Hvilke anbefalinger gir dere kunden når de skal velge gulvbelegg?

(2) Hvorfor bør man velge teppegulv fremfor glatte gulvbelegg?

(3) Hvorfor tror du kunden velger teppegulv?

(4) Hvilke argumenter brukes for å ”selge” teppegulv fremfor andre gulvbelegg?

(5) Finnes det noen ulemper ved å velge teppegulv som gulvmateriale?

(6) Finnes det noen glatte gulvbelegg som gir de samme akustiske egenskapene som tepper?

(7) Hvor stor er prisforskjellen mellom teppegulv og glatte gulvbelegg per m^2? (f. eks linoleum, laminat, parkett)

(8) Har dere noen markedstall på hvor stor andel av markeder, kunder eller areal som velger å gå for teppegulv?

(9) Må man ta noen spesielle hensyn med teppegulv, for eksempel må det rengjøres oftere enn glatte gulvbelegg?

(9b) Hva er normal renholds prosedyre for teppegulv?

(9c) Hvor stor er prisforskjellen på renhold av teppegulv og glatte gulvbelegg pr m2? (f.eks linoleum, laminat, parkett)

(10) Har dere dokumentasjon på om teppene blir tilstrekkelig rengjort ved de anviste rengjøringsinstruksene?

(11) Hvor lang levetid anbefaler dere for teppegulv?

(12) Hvor lang levetid anbefaler dere for glatte gulv?

(13) Vi ser at enkelte teppeleverandører argumenterer med at forskningen på teppegulv er foreldet og at de nye teppene er bedre. Hva er forskjellen på de "gamle" teppegulvene og de "nye"?

A.11 Questionnaire for building owners (In Norwegian)

Spørsmål til byggherrer/eiendomsforvaltere.

(1) Har dere teppegulv i noen av deres kontorbygg?

- Når startet dere med dette?

(2) Hvorfor velges teppegulv?

(3) Hva er fordelene ved å velge teppegulv fremfor glatte gulvbelegg?

(4) Hvor ofte velger dere teppegulv fremfor glatte gulvbelegg?

(5) Hva er i fokus ved valg av gulvmateriale? Inneklima, investeringskostnad, levetid, utseende eller annet?

(6) Er det noen ulemper ved å velge teppegulv fremfor glatte gulvbelegg?

(7) Er det spesielle hensyn som må tas der det er teppegulv?

(8) Finnes det noen glatte gulvbelegg som har de samme akustiske egenskapene som teppegulv?

(9) Har dere dokumentasjon på om teppene blir tilstrekkelig rengjort ved de anviste rengjøringsinstruksene?

(10) Har det hendt at kundene etterspør teppegulv i bygget?

A.12 Personal communication with the carpet supplier (In Norwegian)

[redacted]
til meg

Hei!
På Parkveien 53B i andre etasje revet ca 200 kvm tepper i 1-2 kvm biter ogligger på etasje. Teppe er brukt og maks 8-10 år gammelt.
Hvis du kan hente det i dag så kan du kontakte [redacted]

Hilsen [redacted]

mob [redacted]

[redacted]

In this mail, the carpet supplier claims that the carpets has been in use and are 8-10 years old at most.