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Master Thesis

Environment and Health in the Workplace - Association between Thermal Comfort and the Sick Building Syndrome among Office Workers

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List of Abbreviations

%	percent
°C	degree Celsius
ASR	Ausschuss für Arbeitsstätten
BAuA	Bundesministerium für Arbeit und Soziales
CI	Confidence Interval
Clo	clothing
CO2	carbon dioxide
DGUV	Deutsche Gesetzliche Unfallversicherung e.V.
DOSH	Departement of Occupational Safety and Health
e.g.	for example
FTZ-NK	Forschungs- und Transferzentrum “Nachhaltigkeit und Klimafolgenmanagement”)
g	gram
H_0	null hypothesis
H_1	alternative hypothesis
HAW	Hochschule für angewandte Wissenschaften
HVAC	Heating, Ventilation and Air Conditioning
IAQ	Indoor Air Guality
ICOP	Industrial Code of Practice
IEQ	Indoor Environmental Quality
IP	Internet Protocol
kg	kilogram
m	meter
met	metabolic rate
n	number

N/D	not defined
OR	odds ratio
p	p-value
PhD	Doctor of Philosophy
PMV	Predicted Mean Vote
PPD	Predicted Percentage of Dissatisfied
ppm	parts per million
RH	Relative Air Humidity
RKI	Robert Koch Institute
s	second
SBS	Sick Building Syndrome
SD	Standard Deviation
T	Temperature
U.K.	United Kingdom
URL	Uniform Resource Locator
VDU	Visual Display Unit
W/m^2	watt per square metres body surface
W/m^2xK	watts per square metre Kelvin
WHO	World Health Organization
γ	Pearson’s correlation coefficient

Abstract

Introduction

Approximately 4. Million office staff were employed in Germany in 2011. Although office environments are seen as comfortable and hazard-free, health complaints among office workers were reported, labelled as the Sick Building Syndrome (SBS). As the WHO emphasises the importance of identification and control of environmental factors like thermal comfort parameters (relative air humidity, air temperature and air velocity) to create health promoting working environments (2016), a study was performed in five office buildings in Hamburg. The aim was to determine the prevalence of the SBS among office workers and to assess associations between thermal comfort and SBS.

Methods

The cross-sectional study was conducted in February 2017 among office workers (n=36) from five companies/institutions, working in single- and/or multi-person offices in the service and/or information sector. Instruments applied in this study were a survey (self-administered online questionnaire) and environmental measurements with a multi-functional device. Chi square tests such as the Fisher's exact test and Pearson's chi square test were engaged to assess associations between SBS and thermal comfort as well as between SBS and other risk factors.

Results

19.4 % of the office workers had the SBS. About 42.0 % of the office were disturbed weekly by at least one of the thermal comfort parameters. No association was found between SBS and thermal comfort. Additionally, SBS was not significantly associated to risk factors such as individual factors, psycho-social factors and workplace conditions.

Conclusion

These findings should be regarded with caution, because of several limitations. Moreover, the findings are related just to the winter season and cannot be interpreted for all the seasons. Hence, further research is needed on the associations between SBS and thermal comfort and on other potential risk factors.

Keywords

Sick Building Syndrome, thermal comfort, office workers, office building

1. Introduction

Over time, by the evolvement of the working world from the agriculture sector into a tertiary sector, working conditions shifted to sedentary work performed in office buildings (RKI, 2015). In 2011, approximately four Million office staff were working in Germany (Bundesagentur für Arbeit, N/D). In general, 20 % of employed men and women assume their health to be at risk because of their work environment (RKI, 2014). Even though office environments are seen as relatively comfortable and hazard-free, in the last years, health complaints among office workers were reported (Bux & Polte, 2016; DGUV, 2013; Sullivan et al., 2013; Wiesmüller & Bischof, 2006; Burge, 2004; Hedge et al., 1989).

The reported symptoms are often diverse and non-specific, including complaints of fatigue, headache, irritation of the eyes, nose, throat and skin as well as other complaints like nausea and dizziness and changed sense of taste and smell. Those symptoms are common among the general population and may have a variety of reasons. However, among office workers, these symptoms seem to be associated with occupancy at an office building (Hedge et al., 1989).

Mølhave (1989) designated the constellation of unspecific symptoms, which are attributable to a particular building environment, as the Sick Building Syndrome (SBS). However, there is no general consensus as to which biological, physical, chemical, psycho-social and personal conditions, through interactions or alone are relevant as potential causes (Schneider, 2003).

According to the WHO, the identification and control of environmental factors like pollutants, lightning, noise, ergonomics and thermal comfort is important to prevent diseases and create health promoting environments (2016) since the majority of the European society spends 90 % of its life time in indoor buildings (Silva, et al., 2016, MacNaughton et al., 2015; Kubba, 2012).

One of the environmental factors is thermal comfort, which is a term for the state of mind that expresses satisfaction with the thermal environment. The main factors that influence thermal comfort are air temperature, mean radiant temperature, air velocity, relative air humidity as well as physical activity and isolation value of the clothing (Bux & Polte, 2016; DGUV, 2013; Hahn & Kleine, 2013; Röddecke & Tannenhauer, 2011; Schild & Willems, 2011). Thermal comfort standards for Germany can be found in the legislation (e.g. ASR A3.5, ASR A3.6) and in the standardization (e.g. DIN EN ISO 7730; DIN 33403-3; DIN EN ISO 7726).

Office buildings must meet its workers needs for workspace quality and comfort. These factors are not only important for psychological and physiological reasons, but also play an economical role, because they greatly influence the occupants' productivity. As personal costs are higher than other costs related to building operations, sufficient workplace conditions are necessary for the economic success of companies. "However, comfort issues do not yet play a major role in the day-to-day operation of commercial buildings, mostly due to a lack of understanding of human comfort" (Wagner et al., 2007, p. 759) and its assessment. But, employees are a central target group in medical care as well as in disease prevention and health promotion, because of the high number of resources, which is needed every year for treatment of diseases and injuries, sick leaves, rehabilitation actions and illness related early retirement (RKI, 2015).

Therefore, a study at the Research and Transfer Centre "Sustainable Development and Climate Change Management"[1] (FTZ-NK) was carried out among office workers in Hamburg, Germany to assess the prevalence of the SBS. This study focused on thermal comfort as a risk factor of SBS and investigated the association between SBS and thermal comfort.

This thesis will define in the following chapter the SBS and thermal comfort parameters and will also show the state of research concerning SBS and thermal comfort. Then, study design, study sample, used instruments and procedures and the statistical design will be explained in detail. The results part of this thesis will point out the prevalence of the SBS and the number of satisfied and dissatisfied office workers with the overall thermal comfort conditions at their work. Moreover, it will show whether there is an association between the SBS and thermal comfort. Finally, the methods applied in this study as well as the results will be discussed. Also, recommendations for a healthy indoor environment will be provided. In the end, a conclusion will follow.

[1] In German: Forschungs- und Transferzentrum „Nachhaltigkeit und Klimafolgenmanagement" (FTZ-NK)

2. Background

2.1. Definition, Prevalence and Etiology of the Sick Building Syndrome

2.1.1. Definition of the Sick Building Syndrome

The term Sick Building Syndrome (SBS) is not a medical term, but rather describes a complex of different symptoms that are related to the exposure to a building and are of uncertain etiology. SBS stands for health complains like irritated eyes, dry throat, cough, dry skin on hands and face, irritated nose, fatigue, headache, nausea, dizziness and changed sense of smell and taste (Table 1) among employees working in office buildings (Sullivan et al., 2013; Wiesmüller & Bischof, 2006; Burge, 2004; Mølhave, 1989).

Several SBS definitions exist, but the one from Takigawa et al. is the most precise: A person is suffering from the SBS, when at least one symptom group, for example the group of optical symptoms (Table 1), attributable to a building appears at least once a week (2010). Additionally, the symptoms must be not related to an illness for example an allergy, chronical disease or an influenza. Therefore, the SBS symptoms must be temporarily related to the exposure to a particular building and have to improve or disappear after leaving or being away from the building (Herr et al., 2008; Burge, 2004).

Table 1: The SBS' symptom groups and symptoms

Symptom group	Symptoms
Optical symptoms	itching, burning or irritation of the eyes
Gular symptoms	hoarse, dry throat, cough
Dermal symptoms	dry/flushed facial skin, scaling/itching scalp or ears, dry/itching/redskin hands
Nasal symptoms	irritated, stuffy or runny nose
General symptoms	fatigue, feeling heavy-headed, headache, difficulties concentrating, nausea/dizziness, changed sense of taste and smell

Source: Based on Mølhave, 1989, p.86

Since no consistent SBS definition and standardized method to assess SBS exist, it is difficult to make statements about the prevalence of the SBS. Nevertheless, the following two studies are mentioned to show the prevalence of SBS.

2.1.2. Prevalence of the Sick Building Syndrome

Wang et al. conducted a cross-sectional study in Japan among 296 inhabitants of 91 dwellings (2007). The participants had to fill in a self-administered questionnaire. The inhabitants were classified having the SBS, when symptom(s) were occurring once or twice a week related to the home environment. Among the 296 inhabitants, 15.5 % (n=46) had the SBS. Although the target group of the study from Wang et al. (2007) is not the office staff, the study was considered, because it used a SBS definition similar to the definition from Takigawa et al. (2010).

Also, Norhidayah et al. (2013) investigated in their cross-sectional comparative study the prevalence of SBS on three selected Malaysian buildings, namely the Perbadanan Perpustakaan Awam Pahag (PPAP), Pahag Museum of Art (PMA) and Perbadanan Kemajuan Bukit Fraser (PKBF). The first and the latter were tourist offices. The respondents were regarded as having SBS, when they had at least one symptom once a week, which showed improvement when leaving or staying away from the office building. A total of 51 respondents answered the questionnaire. The number of employees varied between the buildings from five to 44 workers. Building PPAP had 35.15 % employees having the SBS. Of the respondents from building PKBF, 55.55 % had the SBS and from building PMA, 20.00 % suffered from the SBS.

Rohizan and Abidin (2015) carried out a cross-sectional study in 19 offices at a public university in Malaysia among 175 occupants (2015). The prevalence of SBS was assessed using a self-administered questionnaire. The SBS was defined as the presence of two or more symptoms. However, no temporal relation of the SBS symptoms was clarified. The prevalence of the SBS among the office workers was 9.7 % (n=17).

2.1.3. Path model of the Sick Building Syndrome

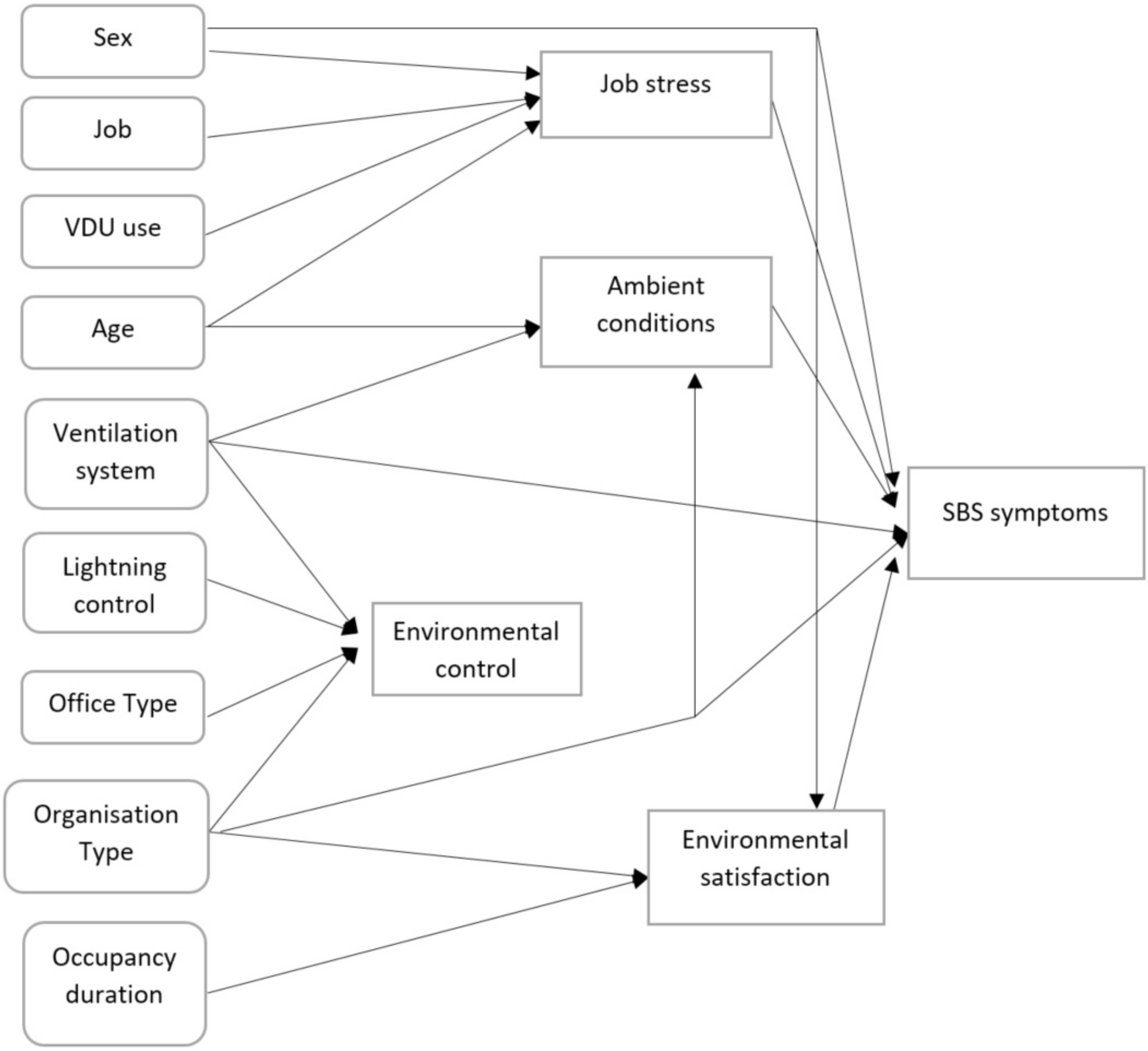

Figure 1: Path model of the SBS symptoms

Source: Based on Hedge et al., 1989, p. 152

In 1989, Hedge et al. were the first ones conducting a survey at 47 offices among 4.373 office workers to assess the etiology of the SBS symptoms and to develop a path model[2] of the SBS (Figure 1) (Hedge et al., 1989).

A worker's sex is directly affecting SBS symptoms, which are more reported by women than men. Although, men have higher job stress than women, they have greater perceived environmental satisfaction (Hedge et al., 1989).

High job stress is more reported by workers in management positions than by workers in clerical jobs or technical/professional positions (Hedge et al., 1989).

[2] The model was tested for goodness of fit. This model reached d=36 and a Q=0.90, which is an acceptable fit of the model (Hedge et al.,1989, p. 153).

Workers aged less than 25 years and those using VDU for less than six hours a day report less job stress. High job stress, in turn, leads to more symptoms. A worker's age also affects the perception of ambient conditions. Those who are older than 30 years rate the environment more favorably (Hedge et al., 1989).

The ventilation system has a direct path to SBS symptoms. On the one side, more symptoms are reported in air-conditioned offices than in unconditioned offices. There is also less environmental control in air-conditioned offices. On the other side, the ambient conditions are rated less favorably in unconditioned buildings. Poor lightning control is associated with poor environmental control (Hedge et al., 1989).

Greater environmental control is also reported among workers from private or up to four-person offices than those in five to nine person offices or those in one to 30+ person offices. Perceived environmental control affects the perception of ambient conditions, which means that more favorable conditions are associated with greater control. Additionally, greater environmental control and greater perceived environmental satisfaction is reported among workers from private sector buildings (type of organization). Office workers from the public sector report more SBS symptoms than workers from the private sector and rate the ambient conditions less favorably (Hedge et al., 1989).

Office workers who are working in the office for less than three years have a greater satisfaction than those who had been employed for more than three years. Perceived environmental satisfaction, in turn, affects SBS symptoms (Hedge et al., 1989).

Thermal comfort as one of the environmental factors from the path model will be explained in detail in the following.

2.2. Definition of the Thermal Comfort Parameters

2.2.1. Definition of the Air Temperature

Air temperature is one of thermal comfort parameters. Air temperature is the temperature of air, which is surrounding a human body without heat radiation. Air temperature is usually expressed in different scales such as Celsius degrees (°C), Fahrenheit (°F) or Kelvin (K). This study will use the Celsius scale (ASR A3.5, 2010).

The recommended minimum air temperature values in indoor workplaces as stated in the ASR A3.5 (2010) are shown in Table 2. The minimum air temperature is dependent on work intensity and working posture. Light work intensity is performed in sitting, staying or in occasional walking while working with the arms/hands. Moderately difficult work with hands/arms or legs in sitting, staying or walking positions is regarded as moderate intensity work. Hard work with hands, arms, legs and torso in staying position or walking is seen as vigorous work intensity (ASR A3.5, 2010).

Office workers typically work in a sitting or standing working position with light work intensity and therefore need a minimum temperature of 19 – 20 °C in their office.

According to the German Social Accident Insurance (DGUV), the air temperature in working areas such as offices shouldn't exceed a maximum of 26 °C (2013).

Thermal comfort is perceived at 19 – 24 °C in winter seasons and at 23 – 26 °C in summer seasons in office workplaces (Bux, 2006).

Table 2: Recommended minimum air temperature (°C) in indoor workplaces in relation to work intensity and working posture

predominant working posture	**Work intensity**		
	light	moderate	vigorous
Sitting	+ 20 °C	+ 19 °C	/
Standing, walking	+ 19 °C	+ 17 °C	+ 12 °C

Quelle: Based on DGUV, 2013, p. 86

2.2.2. Definition of the Relative Air Humidity

Relative air humidity is expressed as a percent (%) and measures the amount of water in air in comparison to the maximum amount of water, which the air can absorb. At a relative air humidity of 100 %, the air cannot absorb any more water (BusinessDictionary, 2017).

The relative air humidity depends on air temperature and should not exceed the maximum values shown in Table 3.

High relative air humidity allows water-soluble toxic chemicals and dust "to dissolve more easily, thus contributing to upper airway irritation, inflammation and cough" (Sullivan et al., 2013, p. 143).

However, low relative air humidity is also a great problem, especially in the winter season. The outdoor air is very dry and leads to a descent of relative air humidity in office rooms. This is physically determined since cold air absorbs a little amount of water. The water content in the outdoor air lies between 2 und 3 g/kg dry air. This corresponds to a relative air humidity of 60 % at a 0 °C air temperature. If this air is heated to 20 °C, relative air humidity will be less than 20 %. Within very low outdoor temperature, relative air humidity can reach values of less than 10 %. Relative air humidity below 20 % can lead to drying of mucous membranes and skin and therefore to irritation (DGUV, 2013).

According to Röddecke and Tannenhauer, thermal comfort is given between 30 and 70 % relative air humidity (2011).

Again, no clear recommendations can be given for relative air humidity, but the DGUV proposes 6 g/kg absolute humidity (water content of air) as the minimum value in winter season and/or 12 g/kg absolute humidity as the maximum value in the summer season (2013).

Table 3: Recommended maximum relative air humidity in relation to air temperature

Air temperature in °C	**Relative air humidity in %**
20	80
22	70
24	62
26	55

Quelle: Based on DGUV, 2013, p. 86

2.2.3. *Definition of the Air Velocity*

Thermal comfort in indoor workplaces is also influenced by air velocity, which is the rate of motion of air in a given direction, expressed in meters per second (m/s).

Limit values for air velocity depend on the air temperature and the degree of turbulence of flow[3]. These factors in combination can led to draught. Draught is a disturbing draft, which leads to cooling down of the body. Draught can be caused by heating, ventilation and air conditioning (HVAC) systems or by natural ventilation (ASR A3.6, 2012). HVAC systems involve air filter, air conditioning, heating and duct work. Its functions are heating, cooling and humidification and maintenance of carbon dioxide and oxygen levels (Sullivan et al., 2013).

At an air velocity under 0.18 m/s usually no unreasonably draught appears. If regarding air temperature, the degree of turbulence of low and air velocity in combination, then office workers won't be suffering from draught at an air temperature of 20 °C, an air velocity of less than 0.15 m/s and the degree of turbulence of flow of 40 % (DGUV, 2013).

Bux states that depending on different factors, at a range of 0.1 – 0.24 m/s air velocity, office rooms are free from draught or rather office workers don't perceive the air velocity as draught (2006).

Abdul-Wahab et al. found out that the best indoor air quality occurs in the winter season at an air velocity of 0.13 m/s and an air temperature of 20 °C as well as an air velocity of 0.14 m/s and an air temperature of 21 °C. A good indoor air quality is also given at an air velocity of 0.16 m/s and an air temperature of 20 °C as well as an air velocity of 0.17 m/s and an air temperature of 21 °C (2015).

Since the air velocity values, where no draught occurs vary between 0.13 – 0.24 m/s, depending on the literature, 0.18 m/s air velocity (DGUV, 2013) will be selected as a standard value in the following parts of this study.

According to Schild and Willems, a draught rate of less than 20 % lies in the recommended values for thermal comfort (2011).

[3] The degree of turbulence of flow is a measure for the variation of air velocity over time

2.2.4. Definition of the Predicted Mean Vote and Predicted Percentage of Dissatisfied

When discussing thermal comfort, the models 'Predicted Mean Vote' (PMV) and 'Predicted Percentage of Dissatisfied' (PPD) are of great importance. They are based on the research findings from Fanger (1970) and are stated in detail in the DIN EN ISO 7730, which was developed for the rating of indoor climate according to thermal comfort.

The PMV forecasts the average perception according to thermal comfort of a larger group of persons on a rating scale from +3 (hot) to - 3 (cold), shown in Table 4. Thermal neutrality is expressed by the value 0. The comfort zone lies within - 0.5 and + 0.5.

The PPD is predicting the percentage of a dissatisfied population with thermal conditions. From person to person there are variations in psychological and physiological satisfaction. Therefore, it is difficult to find optimal thermal conditions. For this reason, the model expects 5 % of the population of interest to be dissatisfied and sees this value at the same time as an optimal comfortable condition. A PPD of 5 – 10 % means that office workers regard their thermal comfort conditions as comfortable (DGUV, 2013; Schild & Willems, 2011).

Table 4: Thermal comfort expressed in PMV and PPD

	hot	**warm**	**slightly warm**		**neutral**		**slightly cool**	**cool**	**cold**
PMV	+ 3	+ 2	+ 1	+ 0.5	0	- 0.5	- 1	- 2	- 3
PPD in %	99	75	25	10	5	10	25	75	99

Source: Based on DIN EN ISO 7730

The PMV and PPD are based on the combination of mean radiant temperature, which is the amount of radiant heat transferred from a surface, air temperature, relative air humidity, air velocity, metabolic rate[4] (Table 5) and clothing insulation[5] (Table 6) (DGUV, 2013; Röddecke & Tannenhauer, 2011).

[4] The total heat emission of a person is determined by its psychical activity, where metabolic processes in the body release chemical energy for a physical activity. W/m² (watt per m² body surface) or met (metabolic rate) are the units for this energy process (DGUV, 2013)

[5] The possibility of a body's heat emission depends on the clothing insulation. Clo (clothing) is the value for the clothing insulation (DGUV, 2013).

Office workers are expecting to have a metabolic rate between 1.0 met and 1.2 met for sedentary work and the clothing insulation of 1 clo for the winter season and 0.8 clo for the summer season.

Table 5: Metabolic rate in different physical activities

Physical activity	Metabolic rate	
	in W/m²	in met
Leaned activity	46	0.8
Sitting, relaxing activity	58	1.0
Sedentary work (office, school, laboratory)	70	1.2
Standing, light work (laboratory, light industrial work)	93	1.6
Standing, moderately difficult work (sales, machine operation)	116	2.0

Source: Based on DIN EN ISO 7730

Table 6: Clothing insulation in different clothing combinations

Clothing combinations	Clothing insulation	
	in clo	in m² x K/W
Naked	0	0
Shorts	0.06	0.01
Panty, t-shirt, shorts, socks, sandals	0.3	0.05
Panty, shirt with short sleeves, light trousers, socks, shoes	0.5	0.08
Panty, shirt, trousers, socks, shoes	0.8	0.13
Panty, shirt, jacket, trousers, socks, shoes	1.0	0.16
Panty, shirt, jacket, vest, coat, trousers, socks, shoes	1.5	0.23

Source: Based on DIN EN ISO 7730

2.3. State of Research on Risk Factors of the Sick Building Syndrome

Although the etiology of the SBS was already described in the path model from Hedge et al. (1989) (Figure 1), since then many studies have been conducted on risk factors of the SBS and will be presented in the following.

In Germany, the ‚ProKlimA‘ study investigated the etiology of the SBS. From 1995 to 1998, 14 office building and about 4.500 office workers were under examination. The study found out that most SBS symptoms occurred in office rooms with air ventilation systems. No relationship was found between pollution and SBS. Personal characteristics, occupational activities and the usability of the workplace were far more associated with SBS than any influence exerted by the office building itself (Umweltbundesamt, 2016).

Kubo et al. investigated in 2006 the association between VDU and SBS among 2.161 Japanese office workers. They found out that men who worked ≥ 4 hours per day on screen, were 2.5 times more suffering of SBS than employees working ≤ 1 hour per day. Women, working ≥ 4 hours per day on screen, were slightly more having SBS than women with a VDU use of ≤ 1, but psycho-social distress might have mediated this relationship in women.

Marmot et al. (2006) carried out a cross sectional study on the physical environment of a selection of buildings added to the data from the Whitehall II study, which is health survey of office based civil servants. A self-administered questionnaire was used to assess symptoms of the SBS and psychosocial work stress. The physical work environment was assessed by an inspection, environmental monitoring in 29 buildings and a self-administered questionnaire. In total, 44 buildings with full or partial assessment were included. Table 7 shows that no significant association was found between physical work environmental factors like, noise level, carbon dioxide and lightning level and symptom prevalence among 3315 participants. Moreover, also no association was found between SBS and thermal comfort factors such as air velocity, relative air humidity, radiant temperature and dry bulb temperature. Also, airborne fungi, airborne bacteria, inhalable dust and volatile organic compounds were not related ($p>0.05$) to SBS.

Table 7: Symptom reporting by physical characteristics of buildings

Exposure based on field work data	Acceptable limits	Number of buildings with average inside/ outside limits	Mean (SE) difference in symptom score for buildings' outside/ inside limits*	Test of significance for mean difference in symptom score*
Based on 3315 participants in buildings with full/partial assessment				
Air velocity	0.05–0.15 m/s	9/20	−0.03 (0.13)	p=0.8
CO_2	⩽500 ppm	25/4	−0.22 (0.16)	p=0.2
Lighting level	250–1000lux	29/0	All within limits	
Radiant temperature	19–22°C	8/21	−0.02 (0.13)	p=0.9
Dry bulb temperature	19–24°C	23/6	0.16 (0.15)	p=0.3
Relative humidity	35–65%	22/7	0.09 (0.14)	p=0.5
Noise level	⩽55Dba	26/3	−0.24 (0.18)	p=0.2
Based on 2523 participants in fully assessed buildings				
Airborne fungi	⩽500 cfu/m^3	13/5	−0.10 (0.14)	p=0.5
Airborne bacteria	⩽1000 cfu/m^3	12/6	0.09 (0.14)	p=0.5
Inhalable dust	⩽0.10 mg/m^3	12/6	0.08 (0.14)	p=0.6
Volatile organic compounds	⩽0.3 mg/m^3	10/8	−0.10 (0.13)	p=0.4
Exposure based on questionnaire data	**Acceptable limits**	**Number of participants**	**Mean (SE) symptom score for participants in each category***	
Control over workstation	0 (no control)	116	2.67 (0.19)	p=0.1
	1	328	2.30 (0.12)	
	2	955	2.30 (0.07)	
	3	1103	2.20 (0.06)	
	4 (most control)	1550	2.34 (0.05)	

*Estimates are adjusted for age, sex, and employment grade using a regression model.

Source: Marmot et al., 2006, p. 285

As stated above (Chapter 2.1.2), Wang et al. (2007) conducted a cross-sectional study in Japan among 296 inhabitants of dwellings. The researchers applied a survey and measured air temperature as well as relative air humidity. Furthermore, fungal spores collection, dust sampling and mite allergen measurements were implemented. Sex, smoking status, alcohol consume, exposure to chemicals, mold colonies and dust were not found to be significantly associated with SBS. Associations were determined between SBS and noticeable odour (OR=2.74, 95 % CI (1.21-6.23), p=0.16), bad air quality (OR=3.81, 95 % CI (1.62-8.96), p<0.05), insufficient sleep (OR=3.43, 95 % CI (1.79-6.60), p<0.05), fungus-like odour (OR=3.60, 95 % CI (1.74-7.47), p<0.05), having an allergy (OR=2.68, 95 % CI (1.39-5.16), p<0.05) and organic compounds like butyraldehyde (OR=3.38, 95 % CI (1.52-7.55), p<0.05), benzaldehyde (OR=3.19, 95 % CI (1.38-7.37), p<0.05) and chloroform (OR=4.05, 95 % CI (1.77-9.29), p<0.05).

Norhidayah et al. (2013) investigated in their cross-sectional comparative study the prevalence of SBS on three selected Malaysian buildings (PPAP, PKBF, PMA). Among these building with a variation in the number of employees between 5 – 44. Differences between SBS and the three buildings were assessed, too. Moreover, differences between the buildings and Indoor Air Quality (IAQ) parameters such as air temperature, air velocity, relative air humidity, carbon monoxide and dioxide as well as fungi were carried out. Data was gathered by a survey and environmental measurements. The respondents were regarded as having SBS, when they had at least one symptom once a week, which showed improvement when leaving or staying away from the office building. The IAQ measurements were performed in the morning and in the evening. The number of measured rooms was not mentioned. A total of 51 respondents answered the questionnaire. Building PPAP had 35.15 % of the employees having the SBS. Of the respondents from building PKBF, 55.55 % had the SBS and from building PMA, 20.00 % suffered from the SBS. All buildings had low levels of fungi, carbon monoxide and dioxide. Building PKBF had a relative air humidity above the acceptable limit of 70 % and an air temperature below the recommended 23 °C by the Industrial Code of Practice (ICOP)[6]. Building PMA was in line with all acceptable limits for IAQ parameters. Building PPAP had a higher air velocity than the advised 0.15 – 0.50 m/s. No significant differences were found between the three selected buildings for SBS. However, they differed significantly in air velocity, air temperature, relative air humidity and carbon dioxide. The study did not assess psycho-social factors, ergonomics, stress level, position in the hierarchy of the organization and job satisfaction.

Rohizan and Abidin (2015) aimed to determine the association between perception of comfort and SBS among 175 office workers in a public university in Malaysia by a cross-sectional study. A self-administered questionnaire and environmental measurements of air temperature, relative air humidity and air velocity were used as instruments. Of the 19 office rooms, where measurements were obtained, two were not within the acceptable limits of ICOP for air temperature. Four offices had levels for relative air humidity which also were not within the recommended limits as well as one office for air velocity. Multiple logistic regressions were performed to assess associations between thermal comfort parameters and SBS as well as between thermal comfort parameters and the perception of comfort. The researchers found out that female sex and SBS (OR=5.12, 95 % CI (1.50-17.30), $p \leq 0.05$) were significantly associated as well as relative air humidity and SBS (OR=4.05, 95 % CI (1.27-12.90), $p \leq 0.05$). Air temperature, age, duration of work per week and years of working in the public university were not significantly associated with SBS. The perception of comfort was significantly linked to air temperature, relative air humidity and sex. The association between air velocity and SBS and the perception of comfort, respectively was not investigated.

Shahzad et al. performed a study to compare building-related symptoms in open plan and personal/single offices. Two Norwegian (single offices with control over thermal environment) and two U.K. office buildings (open plan offices with limited control over thermal environment)

[6] ICOP are recommendation by the Department of Occupational Safety and Health Malaysia (DOSH). The allowable range of air temperature is between 23 – 26 °C, for relative air humidity between 40 – 70 % and for air velocity between 0.15 – 0.50 m/s (Rohizan & Abidin, 2015).

were compared. The study used environmental measurements, a questionnaire assessing building-related symptoms and semi-structured interviews for data collection. 312 respondents were included into this study. Linear regression was applied to assess the association between the type of plan (British and Norwegian approach) and each symptom. In the single office, 90 % of the employees never suffered from headache and 63 % never from fatigue. In the open plan offices, 48% never had headache and 29 % never had fatigue. Office workers occupied in air-conditioned buildings suffered 28 % less from SBS symptoms than from natural ventilated office buildings. Moreover, the study found a significant association between symptoms and the overall environmental control preference and the availability of thermal control, respectively. Furthermore, Shahzad et al. found out, that the more respondents desired to change temperature, the more likely they suffered from SBS symptoms. No significant association was found between SBS and the desire to change air velocity as well as the preference to control the ventilation, respectively. Another finding was, the higher the level of thermal control (over window, blind, door and thermostat), the less occupants suffered from SBS symptoms. In the Norwegian single offices, 78 % of the occupants never suffered from any symptoms, whereas in the U.K. open plan office, 50 % had never experienced any of the symptoms. Interviews were applied to validate the relationship between symptoms and the availability of thermal control. "Occupants of the open plan offices explained that their symptoms are related to a lack of thermal control, as when uncomfortable they had to tolerate the situation and could not apply any change" (Shahzad et al., 2016, p. 17). Those who had their workplace in single offices, "expressed their satisfaction with the availability of control over the thermal environment" (Shahzad et al., 2016, p. 17).

Sakellaris et al. (2016) conducted a study in 167 modern office buildings among 7441 workers in eight countries (Finland, France, Greece, Hungary, Italy, The Netherlands, Portugal and Spain), which is part of the European OFFICAIR project. The aim was to assess the relations between employees' overall comfort (1 = dissatisfied, 4 = neither satisfied nor dissatisfied, 7 = satisfied) and their perception of the indoor environmental quality (IEQ) parameters[7] and to examine potential modifying factors of building and personal characteristics. Perceived IEQ and comfort, health symptoms, individual characteristics, working conditions and psychosocial aspects of office workers were assessed by a self-administered questionnaire (Table 8). Generally, the workers were rather satisfied with their overall comfort (mean: 4.74). Overall

[7] IEQ parameters were noise within the building, from building systems and outside the building, layout, stuffy or fresh air, natural and artificial light, too cold or hot temperature, cleanliness, reflection or glare, humid or dry air, smelly or odourless air, view from the window as well as air movement/velocity (Sakellaris et al., 2016)

satisfaction with the different IEQ components was slightly lower, specifically for noise (mean: 4.26), thermal comfort (mean: 4.48) and air quality (mean: 4.12). Looking at the detailed IEQ parameters, the satisfaction level for air movement was the lowest (mean: 3.75), followed by noise inside the building (mean: 3.84), stuffy or fresh air (mean: 3.91) and humid or dry air (mean: 4.16) (Sakellaris et al. 2016). Regarding the associations between occupants' overall comfort and each IEQ component, overall noise (OR=2.05, CI 95 % =1.99 – 2.12) was the most important factor that affects the overall comfort, followed by overall air quality (OR=1.56, CI 95 % =1.51 – 1.62), overall light (OR=1.49, CI 95 % =1.44 – 1.53) and thermal comfort (OR=1.44, CI 95 % =1.40 – 1.48) (Sakellaris et al., 2016).

Table 8: Description of overall comfort and satisfaction with IEQ and detailed indoor environmental parameters (item-scale: from 1=dissatisfied to 7=satisfied)

Parameters	Number of Respondents	Mean	Standard Error	Confidence Intervals (95%)
Overall Comfort	7366	4.74	0.02	4.70–4.77
IEQ Components				
Light Overall	7377	4.89	0.02	4.85–4.92
Thermal Comfort	7137	4.48	0.02	4.08–4.16
Noise Overall	7371	4.26	0.02	4.22–4.30
Air Quality Overall	7178	4.12	0.02	4.08–4.16
Detailed IEQ Parameters				
Noise Outside the Building	7378	5.61	0.02	5.57–5.65
Artificial Light	7392	5.03	0.02	4.99–5.07
Too Cold or Too Hot Temperature	7047	5.00	0.03	4.95–5.05
Noise from Building Systems	7368	4.97	0.02	4.92–5.01
Natural Light	7353	4.87	0.02	4.82–4.92
Cleanliness	7387	4.69	0.02	4.65–4.73
Smelly or Odorless Air	7093	4.62	0.02	4.57–4.66
View from the Windows	6929	4.42	0.02	4.38–4.47
Reflection or Glare	7377	4.42	0.02	4.38–4.47
Layout	7394	4.30	0.02	4.26–4.34
Humid or Dry Air	7040	4.16	0.03	4.11–4.22
Stuffy or Fresh Air	7071	3.91	0.02	3.88–3.95
Noise within the Building	7399	3.84	0.02	3.80–4.89
Air Movement	7388	3.75	0.03	3.70–3.80

Source: Sakellaris et al., 2016, p. 6

Although thermal comfort was not the most important factor for overall comfort and satisfaction in the study by Sakellaris et al. (2016), it has a substantial effect on health, performance and motivation of the employees. For instance, dissatisfaction with indoor climate (too cold or hot) leads to performance reduction. Moreover, stress can be created due to the inability to shape the indoor climate in the own office. In the heating period in cold seasons employees complain about stinging eyes, itchy skin and dry mucous membranes, which appear because of low relative air humidity. Overheated or underheated air temperature can reduce the concentration, attentiveness and work performance (Bux & Polte, 2016; DGUV, 2013).

3. Research Question, Objectives and Hypotheses

Since there is a lack of new evidence according to thermal comfort and the SBS among employees in Germany, a cross-sectional study was performed in Hamburg city among office workers as a subgroup of employees.

The study was conducted to answer the following main research question: 'Is there an association between SBS and thermal comfort in single- and/or multi-person offices in the tertiary sector in Hamburg?'.

The study was pursuing the subsequent objectives: The general objective is to provide recommendations to the management of office buildings to reduce the prevalence of SBS among office workers in single- and/or multi-person offices in the tertiary sector in Hamburg.

To reach this objective, the first specific objective was to determine the prevalence of the SBS among the above-mentioned target group. The second specific objective was to study associations between overall thermal comfort and SBS among office workers.

By conducting this study, the following null Hypotheses (H_0) and alternative Hypothesis (H_1) were tested:

1. Hypothesis

- H_0: There is no association between office worker's perception of overall thermal comfort and SBS.
- H_1: There is an association between office worker's perception of overall thermal comfort and SBS.

The office worker's perception of overall thermal comfort is the individual overall perception of the thermal environment and its parameters like air temperature, air velocity and relative air humidity.

2. Hypothesis

- H_0: There is no association between individual factors and SBS.
- H_1: There is an association between individual factors and SBS.

Age, sex, educational level, smoking status and usage of contact lenses of office workers are regarded as individual factors.

3. Hypothesis

- H_0: There is no association between psycho-social factors and SBS.
- H_1: There is an association between psycho-social factors and SBS.

Psycho-social factors of office workers are interesting and stimulating work, excessive work demands in term of time and content, the possibility to reduce disruptive factors (environmental control) as well as help from colleagues in case of specific problems.

4. Hypothesis

- H_0: There is no association between workplace conditions' factors and SBS.
- H_1: There is an association between workplace conditions' factors and SBS.

Workplace conditions' factors are the office building itself, duration of employment at current office building, employment position, weekly working hours, VDU use at work per day, office type and the geographical location of the office. Furthermore, the presence of HVAC systems, possibility for natural ventilation and the use of natural ventilation are counted to factors of the workplace conditions.

5. Hypothesis

- H_0: The subjective perception of thermal comfort is not different from the objective measured thermal comfort parameters.
- H_1: The subjective perception of thermal comfort is different from the objective measured thermal comfort parameters.

Office worker's responses according to their perception of draught, too low or too high air temperature, changing air temperature and dry air will be compared to environmental measurements of air temperature, relative air humidity, air velocity, draught rate, PMV and PPD.

4. Methods

4.1. Study Design

A cross-sectional study was performed in the winter season in 2017 among office workers from five office buildings in Hamburg, Germany. Data collection was performed in February 2017.

4.2. Study Sample

The study group is composed of a convenience sample of office workers from five companies/institutions from Hamburg, Germany. At this point, a selection bias cannot be excluded, because of a possible unequal distribution in the study sample (Norhidayah et al., 2013).

The study participants were recruited via a contact person from the office buildings, who was asked for permission to measure thermal comfort parameters and to send an online survey to the contact person itself for further distribution to office staff.

Office workers, whose workplace were single and/or multi-person offices met the inclusion criteria (Table 9). The reason to choose this type of offices was to get comparable results, since those offices are of a similar nature compared to big open-plan offices. ASR A1.2 (2013) summarizes single and multi-person offices as 'cubicle offices' with one to six workstations on an area of 8 – 10 m² per workstation. Group offices/open-plan offices have up to 25 workstations on an area of 12 – 15 m² per workstation, which are separated from each other with movable walls or adaptable space structuring. Hence, open-plan offices were excluded.

Moreover, office workers should be employed in the tertiary sector, because mainly sedentary activities are taking place here (Shahzad et al., 2016). This sector is based on direct services to its consumers and includes services related to hotels, retail, sales, transportation and other. The quaternary sector is actually part of the tertiary sector, but is regarded as an improved form and involves intellectual services and activities like media, culture, research and development as well as information and communications technology. The quinary sector is also part of the tertiary sector and involves services requiring higher education level from its workers than in the quaternary sector. It includes services focusing on the creation of services, evaluation of new technologies and the interpretation of existing or new ideas, services and technologies (Sheth, 2016). The quaternary and quinary sector were also included, as they belong to the tertiary sector.

Employees from the primary sector, which is related to the retrieval and production of raw materials (e.g. farmers) were excluded. Also employees from the secondary sector, which "involves the transformation of the raw material into the finished or manufactured goods" (Sheth, 2016, p.1) were not part of the study sample. Although these sectors also have office workplaces, they were excluded to prevent responses from employees not exclusively working at the office.

Since the office workers had to participate in a self-administered online survey in German language, additional exclusion criteria were insufficient German language skills and illiteracy.

Table 9: Inclusion and exclusion criteria of study sample

Inclusion criteria	
1	Employees working in single- and/or multi-person offices
2	Employees working in the tertiary sector
Exclusion criteria	
1	Employees working in open-plan offices
2	Employees working in the primary and/or secondary sector
3	Insufficient German language skills
4	Illiteracy

4.3. Instruments and Procedures

4.3.1. Questionnaire Survey

One of the instruments applied in this study was a self-administered online questionnaire. The development of this instrument will be described in detail in the following.

The questionnaire was constructed based on the 'MM questionnaire' (Andersson et al., 2017), which was created in Örebro, Sweden and released in 1989 to assess SBS symptoms and environmental factors in offices, care, dwellings and schools. The questionnaire is broadly used in Scandinavian countries "and has set a standard for the phrasing of questions on the SBS" (Engvall et al., 2004, p. 25). It also contains several questions on the perception of the indoor environment. The MM questionnaire is available in different languages, among others, also in German. Although according to Andersson et al. it showed an acceptable validity and reliability (1988), it also has certain limitations related to the assessment of the SBS. The questionnaire doesn't ask whether the SBS symptoms occurred due to other illnesses than allergic diseases and it also ignores the temporal aspect, namely whether the symptoms disappeared or improved after leaving the office building.

Since it was missing several important items, a new questionnaire was developed to supplement additional items based on literature research. Moreover, it allowed changes in the linguistic expression and wording. Literature support tools from Moosbrugger and Kelava (2012), Raab-Steiner and Benesch (2010) and Statistisches Bundesamt (2016) were used when designing the survey.

The questionnaire was divided into six sections. In the first section, questions on personal characteristics (e.g. sex, age, educational level, smoking status and wearing contact lenses) were asked. The questions in this section, also referred to as items, were constructed as dichotomous choice items (e.g. male or female) and multiple-choice items (e.g. lower secondary school leaving certificate, higher school certificate, postgraduate degree/bachelor's degree/master's degree and doctorate/PhD) with item specific answer formats, where just one applicable answer had to be selected. Respondents had also the possibility to add information into the free text space, if the answer categories were not appropriate (Moosbrugger & Kelava, 2012).

In the second section, workplace characteristics (e.g. job type, duration of employment, employment position, working hours per week, office type, geographical location of the office) were assessed. Demographic items such as employment position (employee with tasks following instructions, employee with tasks following self-responsibility but limited responsibility for others, employee with management tasks and decision-making authority, official in the lower grade of the civil service, official in the middle grade of the civil service, official in in the upper grade of the civil service, official in the higher grade of the civil service, student trainee or apprentice) were phrased according to Statistisches Bundesamt (2016). Here, multiple-choice items (e.g. single office, multi-person office, other) with item specific answer formats and free text spaces were present as well as (Moosbrugger & Kelava, 2012).

The third section, namely the thermal comfort section, asks the participants whether they were feeling physically or mentally disturbed in the last three months due to too high or low air temperature, draught, dry air or changing air temperature in the last three months. Furthermore, it asks for the presence of HVAC systems at the office and for the possibility for natural ventilation. This section contains solely multiple-choice items, partly with a verbal three-stage rating scale (yes, often; yes, sometimes; no, never) (Moosbrugger & Kelava, 2012).

In the fourth part, items according to psychosocial factors (e.g. environmental control, help from fellow workers, excessive work demands, interesting and stimulating work) were asked in the form of multiple-choice items in a four-stage rating scale (yes, always; yes, mostly; yes, but seldom; no, never) (Moosbrugger & Kelava, 2012).

Finally, the last section requests the participants to answer questions on 13 symptoms of the SBS: Optical symptoms (itching, burning or irritation of the eyes), nasal symptoms (irritated, stuffy or runny nose), gular symptoms (hoarse, dry throat, cough), dermal symptoms (dry/flushed facial skin, scaling/itching scalp or ears, dry/itching/redskin hands) and general symptoms (fatigue, feeling heavy-headed, headache, difficulties concentrating, nausea/dizziness, changed sense of taste and smell) (Andersson et al., 2017; Mølhave, 1989). For each symptom, office workers are asked whether they had this symptom (always (every week), sometimes (one to three times a month) or never) in the last three months. If they experienced the symptom every week, they were also asked whether the symptom has disappeared or improved after the employee leaved the building of her/his workplace and whether the symptom occurred according to an illness such as an allergy, cold or a chronical disease. The items in this part are of multiple-choice nature (Moosbrugger & Kelava, 2012).

Control questions were not part of this questionnaire to save respondent's time. An example for control questions is "Do your fellow-workers help you with problems you may have in your work?" and "Do you have a good working relationship with your fellow-workers?" (Moosbrugger & Kelava, 2012).

Google Forms©, a cloud based online survey development software was utilized for the online survey.

The self-administered online questionnaire was pre-tested in December 2016 at the Faculty of Life Sciences at the University of Applied Sciences (HAW) Hamburg, where employees were asked to answer the 49-itemed long survey.

54 university employees filled out the questionnaire and provided ideas for improvements. Afterwards, the pilot survey was improved by adding new items, changing the phrasing and scale types. Finally, the number of items was extended to 64 items. Questions like whether the office worker is wearing contact lenses, the worker's position within the company/institution, geographic location of the office, presence of air ventilation systems and the possibility for natural ventilation were not part of the first version and were therefore added. The pilot questionnaire was asking female respondents whether they were pregnant in the last three months as some of pregnancy related complaints could be the same as for the SBS (e.g. nausea). Since, nobody has respondent to this question, it was excluded in the final version.

The questionnaire was discussed with two experts from the HAW to avoid further mistakes or missing information. The final version is presented in Appendix A or can be found under the following URL link: https://goo.gl/forms/25mHgo3HqX27UeRH3.

The items were not selected according to item or factor analysis (Moosbrugger & Kelava, 2012). This procedure is useful, when there is a desire to reduce the data set "from a group of interrelated variables to a smaller set of factors" (Field, 2011, p. 629). However, all variables were chosen carefully on the basis of literature research and the MM questionnaire to assess SBS, thermal comfort and possible confounders. Therefore, a reduction of variables was not an option. Moreover, to apply a factor analysis, a sample size of an amount of "a ten respondents to one variable ratio" (Hiew et al., 2015, p. 3) is needed. This means that a sample size of 640 office workers was necessary. Hence, the validity of the new designed online questionnaire was not given.

The reliability of the questionnaire was not evaluated either. Reliability statistics would follow the item and factor analysis to assess internal consistency of the factors using Cronbach's alpha coefficient (Moosbrugger & Kelava, 2012). The reason for skipping this step is the same as for item and factor analysis. Another method to test reliability would be to asks the same office workers twice to fill out the survey since the "reliability of a questionnaire refers to what extent the respondent's gives the same information when the questionnaire is applied repeated times" (Engvall et al., 2004, p. 25). Due to resource limits, this was not an option.

4.3.2. Patient Information and Informed Consent

All participants received the informed consent together with the self-administered online questionnaire (Appendix A, first page), where the content of the survey and privacy policy is described.

The following information was provided to office workers before they were able to participate in the survey: First, the purposes of the research were explained. Second, the expected duration of five to ten minutes to answer the survey, was provided. Third, participants' anonymity was guaranteed by the analysis of just overall outcomes and by the assessment of no personal identification data such as Internet Protocol (IP) addresses. Finally, contact details of the researcher who can be contacted to answer any queries about the research and the information about the organisation were given. By the completion of the questionnaire participants agreed to participate.

The informed consent is missing a "clear statement that the participation is voluntary, that the refusal to participate will involve no penalty or loss of benefits to which the participant would otherwise be entitled and that the participant may decide, at any time, to discontinue participation without penalty" (European Commission, 2013, p. 14). Although the name of the research institution "Forschungs- und Transferzentrum „Applications of Life Sciences"[8], where the responsible researcher is coming from is stated, an explicit wording, that this institution is also the founder of the research project is missing. Additionally, no information according the measures to protect the data obtained from the survey as well as the duration of the storage of the data was available on the informed consent. Also, procedures in case of incidental findings as well as possible risks expected to occur were lacking (European Commission, 2013).

[8] The FTZ-NK was named in February 2017 as Forschungs- und Transferzentrum „Applications of Life Sciences

4.3.3. Environmental Measurements

The second instrument involved in this study is the environmental measurement of thermal comfort parameters. The intention of this procedure was to assess objective data on temperature (T, °C), relative air humidity (RH, %), indoor air velocity (m/s) as well as the PMV and PPD values of the five selected office buildings.

The measurements were performed in accordance with DGUV (2013) as well as Röddecke and Tannenhauer (2011). First, the measurement is required to be done during the working hours and the usual occupancy rate. Therefore, appointments for measurements were only arranged during the working time. Second, while measuring, adequate distance to staff has to be ensured, because breathing air can influence the measurement results (DGUV, 2013; Röddecke & Tannenhauer, 2011).

According to DGUV (2013), several measuring points should be established, when measuring thermal comfort in larger room. Since only single and multi-person offices were included into this study and no open plan offices, it was decided to measure from one sampling point per one room located in the north and one office room in the south per building, respectively.

The measurement of air temperature, air velocity and air humidity should be done at workplaces for seated activities at a height of 0.6 m above the ground (DGUV, 2013; Röddecke & Tannenhauer, 2011). The measurement height was fulfilled by mounting the measurement instrument on a tripod at 0.6 m.

The measurements should be done at hourly intervals (DGUV, 2013; Röddecke & Tannenhauer, 2011). This recommendation was not fulfilled. The measurement of thermal comfort parameters was performed only on one day for 30 minutes per office room. The reason for that was to reach a higher number of participating office buildings by lowering the measurement time and therefore the disturbance of the ongoing working operations.

Furthermore, the outside air temperature should also be measured during the working hours of office staff at hourly intervals but without the action of direct sunshine. The recommended distance is 4 m from the wall of the office building and in a height of 2 m (DGUV, 2013; Röddecke & Tannenhauer, 2011). No outside measurements were performed to avoid obtaining approval for additional measurements on the company’s property and therefore discourage office buildings to participate.

The thermal comfort parameters were measured by the multifunctional device ‘testo 480’ (figure 2). The instrument conducted one measurement every 30 second. In total, 45 measurements per parameter were performed.

Figure 2: Measurement instrument 'testo 480'

This device involved three probes, such as the ‘comfort probe’, ‘Indoor Air Quality (IAQ) probe’ and the ‘globe thermometer’ (Table 10). The comfort probe is suitable for determining air temperature, air velocity and indoor air turbulence in accordance with DIN EN 13779. Turbulence is equivalent to the extent of fluctuations in air velocity over time and is needed to calculate the draught risk. The indoor air quality probe measures relative air humidity, carbon dioxide concentration (CO_2)[9], air temperature and absolute pressure (DIN EN ISO 9001). The globe thermometer (thermocouple type K) enables checking of radiant heat by detection of significant temperature difference between the ambient and globe temperature. The cause could be high solar radiation through the window. All three probes together measure comfort (PMV) and relative discomfort (PPD). The measurement accuracy for testo 480 corresponds with the recommendations from ASR A3.5 (2010).

[9] Although the CO^2 level is an important environmental parameter for indoor workplaces, it was not of interest in this study, which only focused on thermal comfort

For the PMV (scale -3 to +3) and PPD (scale 0 – 100 %) calculation, the metabolic rate of 1.2 met for sedentary work (office, school, laboratory) (Table 5) and the clothing insulation of 1 clo for a clothing combination of a panty, shirt, jacket, trousers, socks, shoes (Table 6) (DGUV, 2013; Röddecke & Tannenhauer, 2011) was entered into 'testo 480', so that the device was able to calculate the values.

Table 10: Measured thermal comfort parameters by the comfort probe, IAQ probe and the globe thermometer

	Comfort probe		**Indoor air quality probe**			**Globe thermometer**
Measured parameters	Air temperature (°C)	Air velocity (m/s)	Air temperature (°C)	Relative air humidity (%)	CO_2 (ppm)	Radiant heat (°C)
Measuring range	0 to +50 °C	0 to +5 m/s	0 to +50 °C	0 to +100	0 to +10000 ppm	0 to +120 °C
Accuracy	± 0.5 °C	± 0.03 m/s	± 0.5 °C	± 1.9 %	± 105 ppm	Class 1

Source: Based on Testo SE & Co. KGaA, 2017

4.3.4. Primary and Secondary Outcomes

The mentioned instruments were used to gather data for analysis in order to obtain primary and secondary outcomes.

The primary outcomes in the following are variables answering the two specific objectives. The first primary outcome is the proportion of SBS among office workers. The second primary outcome is the odds ratio (OR) of unsatisfied office workers with thermal comfort conditions having the SBS.

The secondary outcomes are 1) the proportion of SBS symptoms among office workers, 2) the temperature, air velocity, draught rate and relative air humidity values and 3) the PMV and PPD values.

4.4. Statistical Design

4.4.1. Sample size

Based on the first primary outcome, the sample size (n) was calculated with 'OpenEpi Version 3.01' (Dean, Sullivan, & Soe, 2013). The required sample size for the calculation of the prevalence of SBS within office workers in Germany is n=135 office workers for a Confidence Interval (CI) of 95 %. This number arrived from the population size of 3.900.118 office staff [10] contributing to the social insurance in the year 2011 (Bundesagentur für Arbeit, N/D) and the hypothesized frequency of 9.7 % ± 5 for SBS in the population (Rohizan & Abidin, 2015).

4.4.2. Power and Statistical Analysis

The power was calculated after the recruitment of the study sample by post hoc power analysis with G*Power 3.1.9.2 (Faul et al., 2009) for the second primary outcome. The input parameters are shown in Table 11. The calculated power resulted in 45 % for a medium effect size of Pearson's correlation coefficient $\gamma = 0.3$, which is a medium effect size meaning that the "effect accounts for 9 % of the total variance" (Field, 2011, p. 57). However, a power of a study should be minimally 0.8 or an 80 % chance of identifying an effect (Field, 2011).

Table 11: Post hoc power analysis for the association between the SBS and overall thermal comfort

Test family	t tests
Statistical test	Correlation - point biserial model
Analysis:	Post hoc: Compute achieved power
Input:	Tail(s) = Two
	Effect size γ = 0.3
	α error probability = 0.05
	Total sample size = 36
Output:	Noncentrality parameter δ = 1.8869127
	Critical t = 2.0322445
	Df = 34
	Power (1-β error probability) = 0.4497780

*Source: Based on G*Power 3.1.9.2.*

[10] Office staff is defined by the 'Bundesagentur für Arbeit' (2012) as employees who are contributing to the health-, pension- and nursing insurance. Excluded are civil servants, self-employed persons and soldiers.

In order to test the five hypotheses, all data analyses were performed using the statistical software program SPSS version 22.0 (IBM Corp., 2013). The hypotheses were tested with a two-tailed significance (alpha) level of 0.05.

Descriptive statistics were carried out to show means with standard deviation (SD) for continuous variables and percentages (%) for categorical and dichotomous variables.

To examine the association between SBS and thermal comfort, first these variables had to be computed. Basis for this was the logical ANY function: ANY(1, var1, var2, var3). It can be used to scan a list of variables for a value. The function returns for example a value of 1, if any of the specified variables have a value of 1, otherwise it will return a value of 0 (IBM Corporation, 2011). The syntax for the SBS and thermal comfort variables can be find in on the attached CD-ROM (Appendix B).

Unsatisfaction with overall thermal comfort was defined as being physically or mentally affected by any of the thermal comfort parameter (too high or low air temperature, draught, dry air or changing air temperature) every week (value 1 = Yes, often (every week)). Satisfaction with thermal comfort was defined as being not every week physically or mentally disturbed by any of the thermal comfort parameter. That means that being affected one to three times a month and/or being never affected by any of the thermal comfort parameters was regarded as satisfaction with thermal comfort.

As stated before, SBS was defined as having any of the SBS symptoms every week (value 1 = Yes often (every week)), which improved or disappeared after leaving the office building (value 1 = Yes, symptoms improved or disappeared) and were not because of a pre-existing illness (value 2 = No, symptoms not due to an illness).

The associations between the categorical outcome variable SBS (yes/no) and categorical predictor variables were tested with chi square tests.

The association between SBS and the office worker's perception of thermal comfort (satisfied/unsatisfied) was analysed with Fisher's exact test. The reason for using this test was, that it is suitable for small sample sizes on 2x2 contingency and does not require to meet the following assumptions: The first assumption states that each participant must contribute to only one cell of the contingency table. The second assumption requires that the expected frequencies in each cell of the contingency table should be greater than five. The first assumption was fulfilled. However, the second assumption was not achieved due to a small sample size.

Phi was used as the measure of the strength of association, since SBS and thermal comfort had only two categories (Field, 2011).

Additionally, the OR was calculated as the measure of effect size. OR of 1 indicates that the exposure does not affect odds of the outcome. OR greater than 1 "indicates that as the predictor increases, the odds of the outcome occurring increase. Conversely, a value less than 1 indicates that as the predictor increases, the odds of the outcome occurring decreases" (Field, 2011, p.271).

To test the association between SBS and other potential risk factors, for example sex, employment position, smoking status etc. either Fisher's exact test or Pearson's chi square test were performed, depending on whether the risk factor has more than two categories or not. Since, it was not possible to carry out the Fisher's exact test for risk factors with more than two categories such as the educational level (lower secondary school leaving certificate, secondary school leaving certificate, higher school certificate, Postgraduate degree/bachelor's degree/master's degree, doctorate/PhD), the Pearson's chi square test was used. However, the second assumption was violated and "making significance tests of the chi-square distribution inaccurate" (Field, 2011, p. 690).

When using Pearson's chi square test, Cramer's V was preferred as a measure of the strength of associations for categorical variables with more than two categories (Field, 2011).

5. Results

5.1. Office Building and Office Room Characteristics

Table 12 shows the characteristics of five office buildings and ten office rooms, where environmental measurements were conducted.

The office buildings were all located in different districts in Hamburg. In every office building, one office room located in the south and one located in the north was chosen for point measurements, except for Office Building A and E. In office building A only the measurement in one office was permitted and in office building E an additional measurement was desired.

All offices had windows and natural light except for office room in the south in office building C. Office buildings A to D had also manually openable windows. The windows from office building E were not openable. The number of employees varied per building from 15 to 600 employees. In office buildings C and D, the employees shared a multi-person office. Other office buildings had a mix of single and multi-person offices.

Table 12: Characteristics of office building and office rooms

	Office buildings									
	A	B		C		D		E		
City district of office building	Hamburg-Mitte	Barmbek-Süd		Harburg		Altona		Wilhelmsburg		
Geographical location of office room	North	North	South	North	South	North	South	South	North	South
Office room type	Single office	Single office	Multi-person office	Multi-person office	Multi-person office	Multi-person office	Multi-person office	Multi-person office	Single office	Single office
Presence of windows in office room	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
Number of employees per office building	95	15		20		16		600		

5.2. Respondent Characteristics

36 of 736 possible participants answered the self-administered online questionnaire. The respondent rate was 5 %.

Baseline characteristics of the sample are shown in Table 12. There is an unequal distribution between the assorted characteristics. Almost three quarters were male respondents, were working in multi-person offices and had at least a postgraduate, bachelor's or master's degree. The majority were non-smokers and did not wear contact lenses. 72 % were working more than 35 hours per week.

Half of the respondents were employed for less than two years and were employees with tasks following self-responsibility but having limited responsibility for others. Almost all the respondents were working more than four hours per day on screen/computer. All participants had the possibility for natural ventilation in their office room. The majority (72.2 %) was always using this possibility.

63.9 % of the office workers had an interesting and stimulating work, but seldom. For the majority (88.9 %), excessive working demands regarding time and content of the work were seldom. The half of the respondents rarely had the possibility to reduce disruptive factors (e.g. noise). Almost the half of the office workers always got help from colleagues and the other half mostly got help.

Table 13: Characteristics of respondents

Characteristics			**Total N**
Sex (%)	male	69.4 (n=25)	36
	female	30.6 (n=11)	
Age (mean ± SD)	34.1 years ± 10.1		33
Age groups (%)	< 17	0 (n=0)	33
	18 – 29	36.1 (n=13)	
	30 - 44	41.7 (n=15)	
	45 - 64	13.9 (n=5)	
	> 65	0 (n=0)	
Educational Level (%)	Secondary modern school qualification (Hauptschulabschluss)	0 (n=0)	36
	high school diploma (mittlere Reife)	5.6 (n=2)	

	higher education entrance qualification (allgemeine/Fachhochschulreife)	25.0 (n=9)	
	Postgraduate degree, bachelor's degree, master's degree	66.7 (n=23)	
	doctorate/PhD	2.8 (n=1)	
Smoking status (%)	non-smoker	83.3 (n=30)	36
	smoker	16.7 (n=6)	
Use of contact lenses (%)	User of contact lenses	13.9 (n=5)	36
	Non-user of contact lenses	86.1 (n=31)	
Number of employees per office building (%)	Office building A	11.8 (n=4)	34
	Office building B	29.4 (n=10)	
	Office building C	17.6 (n=6)	
	Office building D	29.4 (n=10)	
	Office building E	11.8 (n=4)	
Duration of employment at current office building (%)	0-2 years	58.3 (n=21)	36
	from 2-5 years	11.1 (n=4)	
	from 5-10 years	11.1 (n=4)	
	from 10-20 years	16.7 (n=6)	
	more than 20 years	2.8 (n=1)	
Employment position (%)	employee with tasks following instructions	33.3 (n=12)	36
	employee with tasks following self-responsibility but limited responsibility for others	50.0 (n=18)	
	employee with management tasks and decision-making authority	2.8 (n=1)	
	official in the lower grade of the civil service	0 (n=0)	
	official in the middle grade of the civil service	0 (n=0)	
	official in in the upper grade of the civil service	0 (n=0)	
	official in the higher grade of the civil service	2.8 (n=1)	
	Student trainee	2.8 (n=1)	
	Apprentice	5.6 (n=2)	
	Partly employed and self-employed	2.8 (n=1)	
Average weekly working time (mean ± SD)	35.8 ± 11.5		36
Average weekly working time groups (%)	< 15	2.8 (n=1)	36
	16 - 34	25.0 (n=9)	
	> 35	72.2 (n= 26)	
VDU use per day (%)	0 – 2 h	0 (n=0)	32

	3 – 4 h	6.2 (n=2)	
	More than 4 h	93.8 (n=30)	
Office type (%)	Single office	17.1 (n=6)	35
	Multi-personal office	74.3 (n=26)	
	other	8.6 (n=3)	
Geographical location of the office (%)	North	32.0 (n=8)	25
	East	52.0 (n=13)	
	South	4.0 (n=1)	
	West	12.0 (n=3)	
Presence of air conditioning systems (%)	yes	58.1 (n=18)	31
	no	41.9 (n=13)	
Possibility for natural ventilation (%)	yes	100 (n=36)	36
	no	0 (n=0)	
Use of possibility for natural ventilation (%)	Yes, always	72.2 (n=26)	36
	Yes, but seldom	27.8 (n=10)	
	No, never	0 (n=0)	
Interesting and stimulating work (%)	Yes, always	0.0 (n=0)	36
	Yes, mostly	19.4 (n=7)	
	Yes, but seldom	63.9 (n=23)	
	No	16.7 (n=6)	
Excessive demands in terms of time and content (%)	Yes, always	0.0 (n=0)	36
	Yes, mostly	8.3 (n=3)	
	Yes, but seldom	88.9 (n=32)	
	No	2.8 (n=1)	
Possibility to reduce disruptive factors (%)	Yes, always	13.9 (n=5)	36
	Yes, mostly	27.8 (n=10)	
	Yes, but seldom	58.3 (n=3)	
	No, never	0.0 (n=0)	
Help from colleagues in case of a problem (%)	Yes, always	47.2 (n=17)	36
	Yes, mostly	44.4 (n=16)	
	Yes, but seldom	8.3 (n=3)	
	No, never	0.0 (n=0)	

5.3. Thermal Comfort Satisfaction among Office Workers and Measured Thermal Comfort Parameters

The number of respondent feeling physically or mentally affected by draught, too high or low air temperature, changing air temperature and dry air is shown in Table 14.

Too low air temperature was the most disturbing factor, which occurred every week, followed by dry air. However, this proportion is below 20 %. Of the parameters, which affected the employees mentally or physically one to three times a month, the most prevalent were changing air temperature and dry air. More than half of the respondents was never affected by draught, too high or too low air temperature or changing air temperature. For 44.4 % of the respondents dry air was never an affecting factor.

In general, 58.3 % (n=21) of the respondents were satisfied with the overall thermal comfort of their office room, which means they were not affected every week by any of the thermal comfort parameters. 41.7 % (n=15) were affected at least by one thermal comfort parameter every week and were therefore unsatisfied with the overall thermal conditions.

Table 14: Percentages of office workers feeing physically or mentally affected by parameters of thermal comfort

Thermal comfort parameter	Every week		1-3 times per month		No, never	
	n	%	n	%	n	%
Draught	3	8.3	10	27.8	23	63.9
Too high air temperature	4	11.1	11	30.6	21	58.3
Too low air temperature	5	19.2	5	19.2	16	61.5
Changing air temperature	1	2.8	14	38.9	21	58.3
Dry air	6	16.7	14	38.9	16	44.4

Thermal comfort was additionally assessed by environmental measurements. Table 15 shows the assessed parameters and whether they were in line with the thermal comfort recommendations based on DGUV (DGUV; 2013and Röddecke & Tannenhauer (2011). For air velocity, all five office buildings met the recommendation of having an air velocity of less than 0.18 m/s. The same applies for having a draught rate less than 20 %. Both offices located in the North and in the South in office building B had a lower relative air humidity than 30 %. Other offices lie within the acceptable of 30 – 70 % relative air humidity.

All offices had an air temperature between the recommended 19 – 24 °C. Nine office rooms had the proposed PMV of +0.5 to -0.5, but one office room from building B located in the North had a PMV value of -0.71. Also, the predicted percentage of office workers being dissatisfied (PPD=16.3) lies not in the recommendations of 5 to 10 % in this office room.

Table 15: Comparison of recommended thermal comfort values and measured values

Thermal comfort parameters	**Recommen-ded values**		**Environmental measurements (mean ± SD)**								
			Office Buildings								
		A	B		C		D		E		
		North	North	South	North	South	North	South	North	South	South
Air velocity (m/s)	< 0.18	0.05±0.00	0.07±0.02	0.05±0.01	0.06±0.05	0.05±0.01	0.05±0.00	0.06±0.01	0.05±0.01	0.07±0.02	0.06±0.21
Draught (%)	< 20.00	0.00±0.00	4.00±0.00	0.00±0.00	1.00±0.00	1.00±0.00	3.00±0.00	1.00±0.00	1.00±0.00	6.00±0.00	2.00±0.00
Relative air humidity (%)	30.00 – 70.00	37.54±1.77	25.82±0.37*	28.25±0.80*	36.69±0.65	37.57±0.32	40.72±0.58	42.99±0.16	33.64±0.57	36.72±2.20	35.27±0.28
Air temperature (°C)	19.00 – 24.00	21.43±1.28	20.95±0.08	20.41±0.55	23.27±0.09	23.63±0.05	22.48±0.22	22.07±0.21	23.30±0.17	23.47±0.99	24.0±0.30
PMV	+ 0.5 – - 0.5	-0.12	-0.73*	-0.25	-0.03	0.04	-0.11	-0.42	0.00	0.21	0.28
PPD (%)	5.00 – 10.00	5.30	16.30*	6.30	5.00	5.00	5.30	8.80	5.00	5.90	6.60

* value lies not in the recommended range for thermal comfort parameters

5.4. Comparison between the Subjective Perception of Thermal Comfort and the Objective Measured Thermal Comfort Parameters

Since the sample size was too small[11] to perform a statistical analysis to compare the subjective perception of the thermal comfort with the objective measurements of the thermal comfort parameters, a descriptive analysis will be shown in the following.

Regarding the subjective perception of overall thermal comfort (Table 14), more than a half (58.3 %) of the respondents was never disturbed physically or mentally by a single thermal comfort parameter, like draught, too low or too high air temperature and changing air temperature in the last three months. 2.8 % were feeling disturbed every week by changing air temperature, 8.3 % by draught and 11.1 % by too high air temperature. For too low air temperature and dry air, the proportion of every week affected office workers was almost one fifth.

This condition is comparable to the objectively assessed thermal comfort parameters by the multifunctional measurement instrument (Table 15). Almost all measured values (air temperature, air velocity, draught, PMV, PPD) were lying in the recommended ranges, except for relative air humidity. Here, one of five buildings did not meet the required minimum value of 30 % of relative air humidity.

Moreover, almost all office rooms had a PMV between +0.5 and -0.5 and a PPD between 5 – 10 %, which predicts that office workers perceived the thermal climate as neutral and therefore comfortable and that only 5 - 10 % were dissatisfied with respect to the thermal comfort. The PMV and PPD of only one office room from building B predicted that office workers feel the thermal condition in their office as slightly cool and thus, are up to 16 % dissatisfied.

All in all, the subjective perception of thermal comfort conditions corresponds to the objective measurements of thermal comfort parameters.

[11] From some office buildings, just four office workers answered the self-administered online questionnaire.

5.5. Sick Building Syndrome and Symptoms among Office Workers

The prevalence of SBS symptoms among office workers in the last three months is illustrated in Table 16.

Among symptoms occurring every week, fatigue is the most prevalent, followed by itching/burning/irritated eyes, scaling/itching scalp or ears and dry/itching/reskin hands. 66.7 % of the office workers had an irritated/stuffy/runny nose one to three times per month, followed by 61.1 % having fatigue and 55.6 % having headache. The majority had never suffered from nausea/dizziness and changed sense of taste and smell in the last three months. Only few office workers had never experienced fatigue in the last three months.

Table 16: Percentage prevalence of SBS symptoms

SBS symptoms	**Every week**		**1-3 times per month**		**Not at all**	
	n	%	n	%	n	%
Itching/burning/irritated eyes	6	16.7	11	30.6	19	52.8
Irritated/stuffy/runny nose	3	8.3	24	66.7	9	25.0
Hoarse/dry throat	1	2.8	16	44.4	19	52.8
Cough	2	5.6	17	47.2	17	47.2
Dry/flushed facial skin	5	13.9	16	44.4	15	41.7
Scaling/itching scalp or ears	6	16.7	4	11.1	26	72.2
Dry/itching/redskin hands	6	16.7	8	22.2	22	61.1
Fatigue	11	30.6	22	61.1	3	8.3
Feeling heavy headed	2	5.6	10	27.8	24	66.7
Headache	1	2.8	20	55.6	15	41.7
Difficulties concentrating	5	13.9	18	50.0	13	36.1
Nausea/dizziness	0	0	4	11.1	32	88.9
Changed sense of taste and smell	0	0	2	5.6	34	94.4

Table 17 shows that of those symptoms, which occurred every week in the last three months, itching/burning/irritated eyes, dry/flushed facial skin, dry/itching/redskin hands and fatigue improved or disappeared after leaving the office building. But the proportion of symptoms not improving or disappearing after leaving the workplace is higher. In many cases, the respondents were not sure whether the symptom improved or disappeared or not.

Table 17: Percentage prevalence of improved or disappeared SBS symptoms after leaving the office building

SBS symptoms	**Symptom occurring every week**		**Improvement or disappearance of symptom occurring every week after leaving the office building**					
			Yes		**No**		**Don't know**	
	n	%	n	%	n	%	n	%
Itching/burning/irritated eyes	6	100	2	33.3	3	50.0	1	16.7
Irritated/stuffy/runny nose	3	100	0	0	2	67.0	1	33.0
Hoarse/dry throat	1	100	0	0	1	100	0	0
Cough	2	100	0	0	2	100	0	0
Dry/flushed facial skin	5	100	1	20.0	4	80.0	0	0
Scaling/itching scalp or ears	6	100	0	0	6	100	0	0
Dry/itching/redskin hands	6	100	2	33.3	3	50.0	1	16.7
Fatigue	11	100	1	9.1	8	72.7	2	18.2
Feeling heavy headed	2	100	0	0	0	0	2	100
Headache	1	100	0	0	1	100	0	0
Difficulties concentrating	5	100	0	0	3	60.0	2	40.0
Nausea/dizziness	0	100	0	0	0	0	0	0
Changed sense of taste and smell	0	100	0	0	0	0	0	0

Of those symptoms, which were present every week, itching/burning/irritated eyes were not occurring because of an illness as reported by 83.3 %. Moreover, 66.8 % of the office workers were not assuming that their dry/irritated/redskin hands were appearing due to an illness. Half of the study sample assumed that fatigue and feeling heavy headed was also not present every week in the last three months due to a pre-existing illness.

However, more than a half of the respondents did not know whether cough, scaling/itching scalp or ears, fatigue, feeling heavy headed or having concentration difficulties were present because of an illness like a chronical disease, cold or allergy (Table 18).

Table 18: Percentage prevalence of SBS symptoms not occurring due to an illness

SBS symptoms	**Symptom occurring every week**		**Symptom due to an illness**					
			Yes		No		Don't know	
	n	%	n	%	n	%	n	%
Itching/burning/irritated eyes	6	100	0	0	5	83.3	1	16.7
Irritated/stuffy/runny nose	3	100	1	33.3	1	33.3	1	33.3
Hoarse/dry throat	1	100	0	0	0	0	1	100
Cough	2	100	1	50.0	0	0	1	50.0
Dry/flushed facial skin	5	100	2	40.0	2	40.0	1	20.0
Scaling/itching scalp or ears	6	100	1	16.7	0	0	5	83.3
Dry/itching/redskin hands	6	100	1	16.6	4	66.8	1	16.6
Fatigue	11	100	0	0	5	45.5	6	54.5
Feeling heavy headed	2	100	0	0	1	50.0	1	50.0
Headache	1	100	0	0	0	0	1	100
Difficulties concentrating	5	100	0	0	2	40.0	3	60.0
Nausea/dizziness	0	100	0	0	0	0	0	0
Changed sense of taste and smell	0	100	0	0	0	0	0	0

As already mentioned, the respondents were considered as having SBS when they reported to suffer from at least one symptom every week, which was not caused by a pre-existing illness and which, however, disappeared or improved after the exit of the workplace building (Takigawa et al., 2010). Of 36 respondents, 19.4 % had suffered from the SBS and 80.6 % had no SBS.

5.6. Association between the Sick Building Syndrome and Thermal Comfort

Fisher's exact test was used to compare the frequency of the SBS among satisfied and unsatisfied office workers according to thermal comfort.

Of 29 respondents having not the SBS, 69.0 % were satisfied with the thermal comfort at their office and 31.0 % were unsatisfied. Of the seven office workers having the SBS, 14.3 % were satisfied with the overall comfort and 85.7 % were unsatisfied with the thermal conditions (Table 19).

Table 19: Crosstabulation table for SBS and overall thermal comfort perception among office workers

	No SBS	SBS	Total
Satisfied with thermal comfort	20	1	21
Unsatisfied with thermal comfort	9	6	15
Total	29	7	36

Unsatisfied office workers due thermal comfort were 13 times (OR=13.3, 95 % CI (1.39-127.57), p=0.13) more likely to have SBS than satisfied office workers. However, thermal comfort was not significantly (p = 0.13) related to having SBS (Table 20).

Table 20: Odds ratio (OR) and 95 % confidence interval (CI) for the association between overall thermal comfort perception and SBS by Fisher's exact test

	OR	***95 % CI***	***p***	***Phi***
Unsatisfied with Thermal comfort	13.3	1.39 – 127.57	0.13	0.44

5.7. Association between SBS and other Risk Factors

Other potential risk factors for SBS were examined with chi square tests (Table 21). Fisher's exact test was performed to assess the association between SBS and other risk factors with only two categories.

Unadjusted with other potential risk factors, female sex (OR=1.97, 95 % CI (0.36-10.82), p=0.65), wearing no contact lenses (OR=0.96, 95 % CI (0.09-10.22), p=1), being non-smoker (OR=1.30, 95 % CI (1.07-1.59), p=0.32) and seldom use of natural ventilation (OR=0.37, 95 % CI (0.04 – 3.54), p=0.65) showed no significant association with SBS.

The analysis of Pearson's chi square test showed no significant association between SBS and age. Moreover, no significant association was found for SBS and educational level, office building, duration of employment at current office building, employment position, working hours per week, VDU use per day, type of office, geographical location of the office and presence of HVAC systems.

Furthermore, SBS was not significantly related to interesting and stimulating work, excessive work demands, environmental control and support from colleagues. It was not possible to calculate the association between SBS and the possibility for natural ventilation, since this factor was a constant factor, where all respondents (n=36) answered, that they had the possibility. For all potential risk factors calculated with the Pearson's chi square test, assumptions were violated.

Table 21: Odds ratio (OR) and 95 % confidence interval (CI) for potential risk factors of SBS by chi square tests

	OR	***95 % CI***	***p***	***Phi/Cramer's V***	***x²***	***df***
Female sex[a]	1.97	0.36 – 10.82	0.65	0.13		
Age[b]	–	–	0.25	0.29	2.75*	2
Wearing no contact lenses[a]	0.96	0.09 – 10.22	1	-0.01		
Non-smoker[a]	1.30	1.07 – 1.59	0.32	0.22		
Education level[b]	–	–	0.25	0.34	4.01*	3
Office building[b]	–	–	0.74	0.31	3.55*	6
Employment position[b]	–	–	0.15	0.51	9.34*	6
Duration of employment at current office building	–	–	0.81	0.21	1.57*	4
Working hours/week[b]	–	–	0.65	0.16	0.86*	2
VDU/day[b]	–	–	0.53	0.11	0.40*	1
Office type[b]	–	–	0.09	0.37	4.87*	2
Geographical location of office[b]	–	–	0.56	0.29	2.07*	3
Presence of HVAC[b]	–	–	0.62	0.17	0.97*	2
Possibility for natural ventilation[b]	–	–	—	—	—	—
Seldom use of naturally ventilation[a]	0.37	0.04 – 3.54	0.65	-0.15		
Interesting and stimulating work[b]	–	–	0.63	0.16	0.92*	2
Excessive work demands[b]	–	–	0.09	0.37	4.81*	2
Environmental control[b]	–	–	0.52	0.19	1.33*	2
Help from colleagues[b]	–	–	0.38	0.23	1.92*	2

– the factor had more than two categories
— the factor was a constant
a tested by Fisher's exact test
b tested by Pearson's chi square test
* violated assumption: more than 20 % cells have expected count less than 5.

6. Discussion

6.1. Summary of the Results

A cross-sectional study was performed among office workers from five office buildings in Hamburg in the winter season in February 2017. The objective of the cross-sectional study was on the one hand, to assess the prevalence of the SBS among office workers in single- and/or multi-person offices in the tertiary sector in Hamburg and on the other hand, to study associations between thermal comfort and SBS. By pursuing these objectives, the provision of recommendations to the management of office buildings to reduce the prevalence of SBS among would be possible. Instruments, which were applied in this study were a self-administered online questionnaire and environmental measurement. 36 office workers answered the survey. Environmental measurements were done in ten office rooms in five office buildings.

This study found out that 19.4 % of the office workers from single- and/or multi-person offices in the tertiary sector in Hamburg have the SBS. The percentage prevalence of the SBS varied in other studies. Wang et al. assessed that 15.5 % of 296 inhabitants of dwellings in Japan suffered from the SBS (2007). Rohizan and Abidin determined that 9.7 % of the 175 occupants from a public university had the SBS. In the study by Norhidayah et al. the SBS prevalence ranged between 20.0 % and 55.5 %. These disagreements are caused by different SBS definitions, assessment tools and the target group. Moreover, the mentioned studies are coming from different countries, which vary in their climate and might have not the same occupational safety regulations.

The thesis also showed that 41.7 % of the office were overall unsatisfied with the thermal conditions. However, slightly more office workers were satisfied with the overall thermal comfort at their office. Sakellaris et al. came to similar results. The workers from the European OFFICAIR study were neither satisfied or dissatisfied with their thermal comfort (mean: 4.48).

A Fisher's exact test was performed to examine the association between SBS and the perception of overall thermal comfort. Unsatisfied office workers with overall thermal comfort were 13 times more likely to have SBS than satisfied office workers. But this association was not significant ($p = 0.13$). Therefore, H_1 of the first hypothesis has to be rejected. Nevertheless, this result should be regarded with caution, because of the wide CI and the low power of 45 %. Wide CI for estimates of association such as the OR indicate low precision (Carlson & Morrison, 2009). The power should be minimally an 80 % chance of identifying an effect (Field, 2011). Also, Marmot et al. (2006) and Rohizan and Abidin (2015) investigated the association between SBS and thermal comfort. However, they compared data on SBS obtained from a survey with data on thermal comfort assessed by environmental measurements, which is another approach then applied in this thesis. Marmot et al. found no significant association between SBS and air velocity, relative air humidity and air temperature. Rohizan and Abidin concluded that SBS was associated to relative air humidity, but not to air temperature. Unfortunately, they did not investigate the relationship between air velocity and SBS.

The second hypothesis dealt with the association between individual factors and SBS. Chi square tests showed that unadjusted with other potential risk factors, sex, using contact lenses, smoking status, age and educational level, respectively, were not significantly association with SBS. However, assumptions of the Pearson's chi square test were violated, which made these results inaccurate. Furthermore, other researchers came to different results. Hedge et al. found out, that individual factors such as sex directly influence the presence of SBS symptoms (1989). Rohizan and Abidin (2015) also assessed that female sex contributed significantly to reporting of SBS (OR=5.12, 95 % CI (1.50-17.3), $p \leq 0.05$). Other individual factors like age are associated with the psycho-social factors like job stress and the perception of ambient conditions, which in turn lead to more SBS symptoms (Hedge et al., 1989). But Wang et al. (2007) did not find any associations between SBS and smoking status as well as sex, respectively. However, a relation between SBS and allergy was assessed.

Besides, the Pearson's chi square test showed that psycho-social factors such as interesting and stimulating work, excessive work demands, environmental control and support from colleagues were not significantly related to SBS. Again, the expected frequencies in each cell of the 2x2 contingency table was not greater than five. This violation caused an inaccurate result, so that no statement can be made towards rejecting or accepting of the third H_1. According to Hedge et al. (1989), psycho-social factors such as the perceived environmental control affects the environmental satisfaction, which in turn, affects SBS symptoms. Shahzad et al. came to similar results. They found out that there is an significant association between the overall environmental control preference and SBS symptoms (2016). Moreover, the higher the level of thermal control was, the less occupants showed SBS symptoms.

Fisher's exact test and Pearson's chi square test were also applied to test whether there is an association between workplace conditions' factors and SBS. Seldom use of natural ventilation showed no association with SBS. So, did also the office building, duration of employment at current office building, employment position, working hours per week, VDU use per day, type of office, geographical location of the office and presence of HVAC systems. Same violation as stated above doesn't allow to conclude about the fourth hypothesis. Work conditions like the presence of a ventilation system had a direct path to SBS symptoms according to Hedge et al. (1989). SBS was also caused indirectly by the employment position. Workers in management positions had a higher job stress than workers in clerical jobs or technical/professional positions. The amount of VDU use per day as another work condition influenced job stress, which was directly related to SBS. The years being occupied at an office building influences environmental satisfaction, which again is associated with SBS (Hedge et al., 1989). Kubo et al. also found significant associations between the duration of VDU and SBS among 2.161 Japanese office workers (2006). According to Rohizan and Abidin (2015), weekly working hours and years of working in a particular building were not associated with SBS.

Regarding the subjective perception of overall thermal comfort, 41.7 % were every week dissatisfied with at least one parameter of the thermal condition in the last three months. But 58.3 % were never disturbed physically or mentally by a single thermal comfort parameter, like draught, too low or too high air temperature and changing air temperature in the last three months. Only 2.8 % were feeling disturbed every week by changing air temperature, 8.3 % by draught and 11.1 % by too high air temperature. For too low air temperature and dry air, the proportion of every week affected office workers was almost one fifth, which might be very likely related to the winter season. Taking the measurements by 'testo 480' in the office rooms into account, almost all office buildings were within the acceptable range for thermal conditions, except for relative air humidity. Here, one of five buildings did not meet the required minimum value of 30 % of relative air humidity. Moreover, almost all office rooms had a PMV between +0.5 and -0.5 and a PPD between 5 – 10 %, which predicts that office workers perceived the thermal climate as neutral and therefore comfortable and that only 5 - 10 % were dissatisfied according the thermal comfort. The PMV and PPD from only one office room from building B predicted that office workers felt the thermal condition in their office as slightly cool and thus, are up to 16 % dissatisfied. Although, no statistical test was applied here, it is possible to reach the conclusion, that H_1 of the fifth hypothesis has to be rejected and the H_0 that the subjective perception of thermal comfort is not different from the objective accepted. Also, it would be interesting to look at the perceptions of thermal comfort in particular for the five office buildings and office rooms, but because of the small sample per building, the statements from the few would have no significance.

The mixed or other findings may be related to the study design (sample, season or period, SBS definition, survey instrument used) as well as the study population (building and office workers' characteristics).

6.2. Limitations of the Study

The primary limitation in this study is the cross-sectional study design. The exposure (thermal comfort) and outcome (SBS) are simultaneously assessed and therefore no evidence of a temporal relationship between these variables can be proven. Since the study cannot show that the exposure causes the outcome, internal validity is not fulfilled (Carlson & Morrison, 2009). Moreover, the study lacks external validity, because the sample is not representative employing a small sample obtained from a single geographic location or facility (Carlson & Morrison, 2009). The sample in this study is recruited from five office buildings from a single geographical location namely Hamburg city. The results cannot be applied in other facilities or geographic locations.

Another limitation of the present study is, that the investigated office buildings and the office workers were not randomly chosen. Study participants are consisted out of a convenience sample showing an unequal distribution and leading to a selection bias. Men for example were over-represented in this study. Therefore, this study sample is not considered to be representative of the population being studied. A probability sampling would prevent this.

The study has also a very low response rate and a sample size of 36 participants not achieving the required calculated sample size. A high response rate is of great importance for internal validity (Engvall et al., 2004). One possible reason for that could be the distribution technique, applied in this study. Office workers got the self-administered online questionnaire from a contact person from the office buildings, to whom the questionnaire was sent. This person had might not use the email distribution list of the company/institution or was not allowed to. Therefore, maybe the majority of office workers did not get the survey. This is especially assumed in Office building A (95 employees) and E (600 employees), where in each case just four office workers answered the self-administered online questionnaire. One thought to improve the response rate is for example to distribute the questionnaires not online but rather individually via a paper version. Hedge et al. (1989) distributed their questionnaire individually to each worker and collected the questionnaires on the same day. In this time, the questionnaires were also checked for completeness. The response rate was very high (mean return rate 92 %). Another thought for the improvement of the response rate is to get permission for the usage of the email distribution list of the company, although this would take time resources because of administrative burden especially in office buildings like government authorities.

Caution when interpreting the results is also needed not just because of the small sample size and low power, but also because of the self-reported data on symptoms and perception of thermal comfort in the last three months. Hereby, a recall bias cannot be excluded.

An additional limitation was the collection of data with an unvalidated questionnaire. Although a reduction of variables after the pre-test was not aimed, the leaving-out of the item and factor analysis leaded to a lack of validity. Instrument validity means that the survey measures what it says it is measuring. This is an important key criterion (Moosbrugger & Kelava, 2012).

Moreover, the reliability of the questionnaire was not evaluated due to limited resources. Reliability would be given if the respondents would give the same information when the survey is applied repeated times (Engvall et al., 2004).

Also, social desirability is possible, even if the questionnaire was promising anonymity. Items asking about psycho-social factors and symptoms can lead to self-deceptive enhancement or non-disclosure because of fear of the employer (Moosbrugger and Kelava 2012). Here, respondents could think that understating for example symptoms or excessive work demands correspond to the social values and norms of the office building's leader.

Another important limitation was that the informed consent was only partly in accordance with the requirements of the European Commission (2013).

Furthermore, the SBS definition was based on Takigawa et al. (2010) and therefore, the results are not comparable with other studies using other definitions. Wang et al. hypothesize that the respective definition of symptoms influences the diagnosis of SBS (2007). Additionally, the type of questioning influences the result. Therefore, studies using different questionnaires are not comparable (Wiesmüller & Bischof, 2006).

Engvall et al. recommend starting with questions on environmental conditions instead of background questions, in order to focus on the subject matter and to get the respondent motivated. Moreover, demographic questions can be threatening if the respondent cannot see the logical reason for asking them. The theory behind this "construction of the questionnaire is that it should work like a structured dialogue on conditions of indoor living, rather than a diagnostic checklist" (Engvall et al., 2004).

There are also limitations according to the environmental measurements of air temperature, air velocity and air humidity. For random measurements, single measurements at different daytimes should be done (Röddecke & Tannenhauer, 2011). However, in this study only measurements of thermal comfort parameters were performed on one day for 30 minutes per office room.

6.3. Strengths of the Study

Despite the disadvantages of cross-sectional studies, these are "most appropriate for screening hypotheses because they require a relatively shorter time commitment and fewer resources to conduct" (Carlson & Morrison, 2009, pp. 77–78). Although they cannot show causality, but rather associations between outcome and exposure, it is an efficient way for needs assessment (Carlson & Morrison, 2009), which can lead to further research.

Another strength is the combination of subjective and objective measurements of thermal comfort parameters to have a look on both perspectives. On the one side occupants are seen to be the "best source of information as regards their needs and comfort requirements" (Sakellaris et al. 2016: 2). On the other side, subjective opinions can be divergent from the actual thermal comfort conditions. Therefore, both sides were considered.

Subjective information was collected with a self-administered online questionnaire and not with interviews because it is a rapid and cost-efficient way to collect information from employees (Engvall et al., 2004).

Although validity and reliability were not statistically tested, the self-administered online questionnaire defines in its questions precisely the SBS and asks for the association between SBS and thermal comfort parameters and assesses as well SBS confounders. According to Engvall et al. (2004), there is also a way to get good validity, when developing the questions in different steps and to give them a good structure. In this study process, the first step was to identify important items for SBS and thermal comfort in office buildings, based on information from literature research. This led to the development of a questionnaire with mainly closed questions. Content validity was assured by identifying expressions in colloquial language describing characteristics of the work environment, symptoms of the SBS and psychosocial factors from the occupant's perspective, also through discussions with two experts. Therefore, this questionnaire could be useful as a practical screening tool when analysing the role of thermal comfort and SBS. Due to feedback of several respondents it was reasonable to complete the survey within ten minutes. The layout is simple and clearly arranged. In the beginning of the questionnaire anonymity is guaranteed and respondents are invited to answer faithfully (Moosbrugger and Kelava, 2012). Moreover, objectivity of application was fulfilled, because of the online character of the questionnaire. There was no interaction between the office worker and the test leader during the completion of the survey. As the survey uses in the most cases verbal rating scale items and item specific answer formats, which are constructed as multiple-choice items, it excluded possibilities of interpretation according to analysis, leading to an objectivity of analysis according to Moosbrugger and Kelava (2012). The online questionnaire required no material costs. The temporal expenditure for application of the survey, including development, distribution and analysis of the questionnaire, took a period of six months. Due to low financial costs for survey material and temporal expenditure for application of the survey, the economy of application was fulfilled (Moosbrugger and Kelava, 2012).

The environmental measurements of thermal comfort parameters met the requirements according to the suggested procedures of DGUV (2013), Röddecke & Tannenhauer (2011), ASR A3.5 (2010) and ASR A3.6 (2012). The measurements were done with adequate distance to staff during the working hours and the usual occupancy rate. The measurement of air temperature, air velocity, air humidity and PMV and PPD was applied on a tripod at a height of 0.6 m above the ground. Especially, the measurement of the PMV and PPD values as thermal comfort measures is a strength. These were missing in the mentioned studies (Chapter 2.3) and therefore, metabolic rate and the clothing insulation as important factors for thermal comfort were not regarded. According to Rohizan and Abidin (2015), this should be ideally taken into account in order to give a comprehensive overview of thermal comfort.

The thermal comfort parameters were measured by the multifunctional device ‘testo 480’, which contained the comfort probe, the IAQ probe and the globe thermometer. The measurement accuracy for testo 480 probes corresponds with the recommendations from ASR A3.5 (2010).

6.4. Recommendations for a Healthy Indoor Environment

According to the German Working Conditions Act, it is the duty of the employer to assess workplace exposure. This includes workplace environmental conditions such as the thermal comfort (DGUV, 2010).

Sullivan et al. indicate that an evaluation of illnesses related to indoor environment "requires a systematic approach because of the complexity of the potential causes" (2013, p. 156). The evaluation should contain assessment of the building and of signs and symptoms of those with health complaints. To determine the health status of the occupants a "health questionnaire can be useful" (Sullivan et al., 2013, p. 156). Moreover, potential causes should be located and the relation of the illness to work determined. Finally, if the cause was proven, the source should be removed or isolated. The evaluation requires a qualified environmental specialist (Sullivan et al., 2013).

In cases of complaints according to Thermal comfort conditions, the DGUV (2010) gives the following recommendations for action: When the air temperature is under 20 °C and employees feel this as too cold, then either the heating or/and the HVAC system has to be adjusted (ASR A3.5, 2010).

When the air temperature is above 26 °C and employees feel this as too warm, then if available, HVAC systems should be adjusted. If the office building has no HVAC systems, sufficient ventilation, preferably natural ventilation (window-, shaft-, roof attachment- and stack ventilation), is necessary. In summer, sharp ventilation should be done every 60 minutes for 3 -10 minutes and in winter for three minutes (ASR A3.6, 2012). According to Schild and Willems, 4-6 minutes of sharp ventilation are required for the complete exchange of air in winter seasons and 25-30 minutes are needed for a complete exchange in summer seasons (2011).

Especially for summerlike temperatures, the office building should be equipped with sun protection devices. These are for example blinds or marquees, which are fixed on the outside of the building. Second, sun reflection devices can be fixed in the interspace of the glazing. Highly reflecting or bright sun protection devised fixed inside the building can be helpful. Finally, the office building can also be equipped with sun control glazing, but glare protection and light color should be considered (ASR A3.5, 2010).

The increase of air velocity by ventilation is also helpful to reduce high indoor air temperatures. Additionally, office workers should drink sufficiently. The employer should also make the clothing regulations more flexible (ASR A3.5, 2010).

When the relative air humidity in winter season is above 50 %, then sufficient ventilation, again preferably natural ventilation and/or adjustment of air conditioning systems should be performed. When the relative air humidity is perceived as too dry, employees should drink enough. Moreover, humidifiers can be added, but these should be selected according to testing and certification (DGUV, 2010). Humidifiers can sometimes do more harm than good. They provide a place for microbes in the ventilation circuit (Burge, 2004, p. 188). As stated before, the minimum relative air humidity should be 30 % (DGUV, 2013; Röddecke & Tannenhauer, 2011). Another possibility, which however would not in itself solve the problem, is the deployment of potted plants. The water evaporation of potted plants is about 5–20 g per hour. But especially in the winter season, a great amount of potted plants must be provided to humidify the air (Bux, 2006). In winter season the minimum absolute humidity should be determined as 6 g/kg and in summer season as 12 g/kg (DGUV, 2013).

If workers complain about draught, then one possibility to avoid it is to close windows and doors and/or to adjust the air conditioning system. Moreover, if possible the workplace could be moved away from draught or rather panels could be placed in-between (DGUV, 2010).

As already noted, HVAC can be in many cases harmful if not rightly installed. It should be controlled according to the manufacturer's instructions by expert maintenance services (Sullivan et al., 2013; DGUV, 2010). Once applying mechanical ventilation systems, it is necessary to maintain the components such as filters, heat exchangers, humidifiers as well as heating and cooling batteries (Sakellaris et al., 2016). The employer must possess a technical file for the HVAC system, which contains the findings from testing, commissioning and maintenance (ASR A3.6, 2012). Shahzad et al. found out that air conditioning is not responsible for SBS symptom. When the HVAC system is functioning properly, then it does not increase symptoms. The researchers state that there "is a risk of perceiving naturally ventilated buildings as being inherently better than air-conditioned buildings – irrespective of internal layouts and working practices – and thus causing fewer building-related symptoms compared to air-conditioned buildings" (Shahzad et al., 2016, p. 17).

Despite the recommendations, workers as individuals vary in their requirements for thermal comfort, so that it is impossible to provide one environment that fits everyone in the workforce (Burge, 2004, p. 189).

7. Conclusion

The cross-sectional study, which was performed among office workers from five office buildings in Hamburg in February 2017 assessed the prevalence of the SBS among office workers and associations between thermal comfort and SBS using a survey and environmental measurements. 19.4 % of the office workers working in single- and/or multi-person offices in the service and/or information sector in Hamburg have the SBS. Moreover, 41.7 % of the office were disturbed weekly by at least one thermal comfort parameter. No association as found SBS and thermal comfort. Additionally, no association was found between SBS and risk factors such as individual factors, psycho-social factors and workplace conditions. However, this result should be regarded with caution, because of the limitations of this study. These findings are related just to the winter season and cannot be interpreted for all seasons. Moreover, these findings are not consistent with findings from other studies.

The subjective perception of thermal comfort was not different from the results of the environmental measurements. Very few office workers felt disturbed every week by changing air temperature, draught and too high air temperature. Just for too low air temperature and dry air, the proportion of every week affected office workers was almost one fifth. Regarding the environmental measurements, all office buildings met the required values, except for office building B, which had a lower relative air humidity than 30 % in both rooms and a PMV of -0.73 and a PPD of 16.3 % in the north located office. The latter predicts that office workers felt the thermal condition in their office as slightly cool and thus, are up to 16 % dissatisfied.

The SBS has a range of multifactorial causes and therefore it is difficult to understand the relation between the cause and effect (DGUV, 2013, pp. 13–14; Hedge et al., 1989). Further research is needed to explore other multifactorial etiologies of SBS such as ergonomics of the work, noise, lightning, carbon dioxide and pollutants (chemical emissions from office equipment, building material and interior furnishing, cleaning agents and disinfectants). Additionally, another building characteristics like the year of office building construction, building material or year of last renovation, floor area in m², number of workstations in each floor, size of each workstation in m² should also be considered (Shahzad et al., 2016; Norhidayah et al., 2013). There is also a need for a consensual SBS definition and assessment tool to make studies comparable and generalizable. Due to the limitations of this study, also further research is required to explore associations between SBS and thermal comfort.

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9. Appendices

Appendix A – Survey

Fragebogen zum Raumklima und gesundheitlichen Auswirkungen am Arbeitsplatz für Büroangestellte

Liebe Teilnehmerin, lieber Teilnehmer,

im Rahmen meines Praktikums und meiner Masterarbeit führe ich eine Umfrage zum Thema „Umweltfaktoren am Arbeitsplatz“ durch. Zielgruppe sind Beschäftigte, die Einzel- oder Mehrpersonenbüros als Arbeitsplatz haben.

Mit diesem Fragebogen möchte ich herausfinden, wie Sie das thermische Raumklima (Lufttemperatur, Luftfeuchtigkeit und Luftzug) in Ihrem Büro empfinden und ob daraus gesundheitliche Auswirkungen entstehen.

Für das Ausfüllen dieses Fragebogens, brauchen Sie ca. 5-10 Minuten. Bitte füllen Sie ihn möglichst vollständig aus, damit ich Aufschluss über Ihr Empfinden des thermischen Raumklimas an Ihrem Arbeitsplatz bekommen kann.

Sie bleiben bei Ihrer Teilnahme an der Befragung anonym, da ausschließlich die Gesamtergebnisse ausgewertet werden. Das heißt, dass keine direkten personenidentifizierenden Daten erhoben werden und Einzelergebnisse weder einzeln ausgewertet noch weitergeleitet werden. Eine Schließung von Rückschlüssen auf Ihre Person ist daher nicht möglich.

Mit dem Beantworten der Fragen erklären Sie sich bereit, dass wir Ihre Daten zur anonymen Auswertung verwenden dürfen.

Vielen Dank für Ihre Unterstützung!

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[redacted]

1. Allgemeine Angaben zu Ihrer Person

Geschlecht ☐ männlich ☐ weiblich		
Geburtsjahr ☐☐☐☐		
Bildungsgrad		
☐ Qualifizierender Hauptschulabschluss	☐ Allgemeine bzw. Fachhochschulreife	☐ Promotion
☐ Mittlere Reife	☐ Diplom/Bachelor/Master	☐ Sonstige …………………………………...
Rauchen Sie? ☐ Ja ☐ Nein		
Tragen Sie Kontaktlinsen? ☐ Ja ☐ Nein		

2. Allgemeine Angaben zu Ihrem Arbeitsplatz

Name der betrieblichen Einrichtung, in der Sie derzeit tätig sind: ………………………………………………....	**Wie lange sind Sie schon an Ihrem heutigen Arbeitsplatz tätig?** ☐ 0-2 Jahre ☐ ab 2-5 Jahre ☐ ab 5-10 Jahre ☐ ab 10-20 Jahre ☐ mehr als 20 Jahre
Welche berufliche Stellung haben Sie innerhalb Ihrer betrieblichen Einrichtung? ☐ Angestellte/r mit einer Tätigkeit, die nach Anweisung erledigt wird (z.B. Sachbearbeiter/in, Buchhalter/in) ☐ Angestellte/r mit selbstständiger Leistung in verantwortlicher Tätigkeit bzw. mit begrenzter Verantwortung für andere (z.B. wissenschaftliche/r Mitarbeiter/in, Prokurist/in, Abteilungsleiter/in) ☐ Angestellte/r mit umfassenden Führungsaufgaben und Entscheidungsbefugnissen (z.B. Direktor/in, Geschäftsführer/in, Mitglied des Vorstandes) ☐ Beamter/Beamtin im einfachen Dienst (bis einschl. Oberamtsmeister/in) ☐ Beamter/Beamtin im mittleren Dienst (von Assistent/in bis einschl. Hauptsekretär/in, Amtsinspektor/in) ☐ Beamter/Beamtin im gehobenen Dienst (von Inspektor/in bis einschl. Oberamtsrat/rätin) ☐ Beamter/Beamtin im höheren Dienst (von Rat/Rätin aufwärts), Richter/in ☐ Sonstige ………………………………………………………………………………	
Durchschnittliche Wochenarbeitszeit (Antwort in Stunden pro Woche) ☐☐ Stunden pro Woche	**Wie viele Stunden durchschnittlich pro Tag verbringen Sie mit Bildschirmtätigkeiten?** ☐ 0-2 h ☐ 3-4 h ☐ mehr als 4 h
Art des Bürozimmers ☐ Einzelbüro ☐ Mehrpersonenbüro ☐ Sonstige …………………………………………..	
Wie ist die ungefähre geographische Richtung bzw. Lage Ihres Büros? ☐ Norden (indirekte Sonneneinstrahlung) ☐ Osten (direkte Sonneneinstrahlung am Morgen) ☐ Süden (direkte Sonneneinstrahlung am Mittag) ☐ Westen (direkte Sonneneinstrahlung am Abend) ☐ Weiß nicht	

3. Thermisches Raumklima

Haben Sie sich während der letzten 3 Monate durch eine oder mehrere der folgenden Bedingungen am Arbeitsplatz physisch oder mental beeinträchtigt gefühlt?

	Ja, oft (jede Woche)	Ja, manchmal (1 bis 3 Mal im Monat)	Nein, nie
Zugluft	☐	☐	☐
Zu hohe Raumtemperatur	☐	☐	☐
Wechselnde Raumtemperatur	☐	☐	☐
Zu niedrige Raumtemperatur	☐	☐	☐
Trockene Luft	☐	☐	☐

Gibt es in Ihrem Büro Raumlufttechnische Anlagen (z.B. Lüftungssysteme)?

Ja	Nein	Weiß nicht
☐	☐	☐

Haben Sie die Möglichkeit Ihr Büro natürlich zu belüften (z.B. durch manuelles Öffnen der Fenster)?

			Wenn ja, nutzen Sie die Möglichkeit Ihr Büro natürlich zu belüften?		
Ja	Nein	Weiß nicht	Ja, immer	Ja, selten	Nein
☐	☐	☐	☐	☐	☐

4. Psychosoziale Faktoren am Arbeitsplatz

	Ja, immer	**Ja, meistens**	**Ja, aber selten**	**Nein, nie**
Empfinden Sie Ihre Tätigkeit am Arbeitsplatz als herausfordernd und/oder anregend?		☐	☐	☐
Fühlen Sie sich zeitlich und/oder inhaltlich überfordert?		☐	☐	☐
Helfen Ihnen Ihre Arbeitskollegen, wenn Sie bei Ihrer Arbeit Probleme haben?		☐	☐	☐
Haben Sie die Möglichkeit Störfaktoren (z.B. Lärm) in Ihrer unmittelbare Umgebung im Büro zu reduzieren?		☐	☐	☐

6. Symptome

Hatten Sie während der letzten 3 Monate eine oder mehrere der folgenden Beschwerden?

				Wenn **JA, OFT**: Werden die Beschwerden gelindert bzw. gehen diese weg, nachdem Sie das Gebäude Ihres Arbeitsplatzes verlassen?			Wenn **JA, OFT**: Hatten Sie diese Beschwerden aufgrund einer Erkrankung (z.B. Erkältung, Allergien, chronische Erkrankung etc.)?		
	Ja, oft (jede Woche)	Ja, manchmal (1-3 Mal im Monat)	Nein	Ja	Nein	Weiß nicht	Ja	Nein	Weiß nicht
Jucken, Brennen und/oder Reizungen der Augen	☐	☐	☐	☐	☐	☐	☐	☐	☐
Gereizte, verstopfte und/oder laufende Nase	☐	☐	☐	☐	☐	☐	☐	☐	☐
Heiserkeit und/oder trockener Hals	☐	☐	☐	☐	☐	☐	☐	☐	☐
Husten	☐	☐	☐	☐	☐	☐	☐	☐	☐
Trockene und/oder gerötete Gesichtshaut	☐	☐	☐	☐	☐	☐	☐	☐	☐
Schuppen und/oder Jucken der Kopfhaut und/oder im Bereich der Ohren	☐	☐	☐	☐	☐	☐	☐	☐	☐
Trockene, juckende und/oder gerötete Haut im Bereich der Hände	☐	☐	☐	☐	☐	☐	☐	☐	☐
Müdigkeit	☐	☐	☐	☐	☐	☐	☐	☐	☐
Schweregefühl im Kopf	☐	☐	☐	☐	☐	☐	☐	☐	☐
Kopfschmerzen	☐	☐	☐	☐	☐	☐	☐	☐	☐
Konzentrationsschwierigkeiten	☐	☐	☐	☐	☐	☐	☐	☐	☐
Übelkeit und/oder Schwindel	☐	☐	☐	☐	☐	☐	☐	☐	☐
Verändertes Geschmacks- und/oder Geruchsempfinden	☐	☐	☐	☐	☐	☐	☐	☐	☐

8. Zusätzliche Informationen/Anmerkungen

……................ ……................

Vielen Dank für Ihre Hilfe!

Appendix B – Data Sets and Syntax Files

The data sets of the survey and the environmental measurements as well as the syntax files can be find on the attached CD-ROM. A description of the variables used in the datasets also will be shown in the following:

Dataset of the environmental measurements

Variable name	Label	Value	Measure
OfficeB	Name of the office building	1 = office building A 2 = office building B 3 = office building C 4 = office building D 5 = office building E	Nominal
OfficeNo	Number of the office room	1 = office room 1 2 = office room 2 3 = office room 3 4 = office room 4 5 = office room 5 6 = office room 6 7 = office room 7 8 = office room 8 9 = office room 9 10 = office room 10	Nominal
GeoLoc	Geographical location of the office room	1 = north 2 = south	Nominal
OfficeType	Office type	1 = single office 2 = multi-person office	Nominal
T	Air temperature		Scale
RH	Relative air humidity		Scale
CO2	Carbon dioxide		Scale
Vel	Air velocity		Scale
Turb	Grade of turbulence		Scale
Draught	Draught		Scale
PMV	Predicted Mean Vote		Scale
PPD	Predicted Percentage of Dissatisfied		Scale

Dataset of the survey

Variable name	Label	Value	Measure
sex	Sex	1 = male 2 = female	Nominal
ybirth	Year of birth		Scale
education	education	1 = Secondary modern school qualification 2 = high school diploma 3 = higher education entrance qualification 4 = Postgraduate degree, bachelor's degree, master's degree 5 = doctorate/PhD	Nominal
smokingstatus	Smoking status	1 = smoker 2 = non-smoker	Nominal
contactlenses	User of contact lenses	1 = yes 2 = no	Nominal
officebuilding	Designation of office buildings	1 = office building A 2 = office building B 3 = office building C 4 = office building D 5 = office building E	Nominal
durationemployment	Duration of employment at current office building	1 = 0 - 2 2 = ≥ 2 - 5 3 = ≥ 5 – 10 Jahre 4 = ≥ 10 – 20 5 = > 20	Nominal
employposition	Employment position at the office building	1 = employee with tasks following instructions 2 = employee with tasks following self-responsibility but limited responsibility for others 3 = employee with management tasks and decision-making authority 4 = official in the lower grade of the civil service 5 = official in the middle grade of the civil service 6 = official in in the upper grade of the civil service 7 = official in the higher grade of the civil service 8 = Student trainee	Nominal

		9 = Apprentice 10 = Partly employed and self-employed	
worktimeweek	Weekly working time		Scale
VDU	Working time on screen/computer per week	1 = 0 – 2 2 = 3 – 4 3= > 4	Nominal
officetype	Type of office	1 = single office 2 = multi-person office	Nominal
geooffice	Geographical location of the office	1 = north 2 = south 3 = don't know	Nominal
draught	Being affected by draught in the last three months	1 = yes, often 2 = yes, sometime 3 = no, never	Nominal
hightemp	Being affected by high air temperature in the last three months	1 = yes, often 2 = yes, sometime 3 = no, never	Nominal
changetemp	Being affected by changing air temperature in the last three months	1 = yes, often 2 = yes, sometime 3 = no, never	Nominal
lowtemp	Being affected by low air temperature in the last three months	1 = yes, often 2 = yes, sometime 3 = no, never	Nominal
dry	Being affected by dry air in the last three months	1 = yes, often 2 = yes, sometime 3 = no, never	Nominal
HVAC	Presence of HVAC systems in the office room	1 = Yes 2 = No	Nominal
naturalvent	Possibility for natural ventilation	1 = Yes 2 = No	Nominal
usenaturalvent	Use of the possibility for naturally ventilation	1 = Yes, always 2 = Yes, but seldom 3 = No, never	Nominal
pregnancy	Pregnancy in the last three months	1 = Yes 2 = No	Nominal
interestwork	Interesting and stimulating work	1 = Yes, always 2 = Yes, mostly 3 = Yes, but seldom 4 = No, never	Nominal

excessivework	Excessive work demand in terms of content and time	1 = Yes, always 2 = Yes, mostly 3 = Yes, but seldom 4 = No, never	Nominal
envcontrol	Environmental control over	1 = Yes, always 2 = Yes, mostly 3 = Yes, but seldom 4 = No, never	Nominal
colleagues	Help from colleagues in case of problems	1 = Yes, always 2 = Yes, mostly 3 = Yes, but seldom 4 = No, never	Nominal
SympEyes	Itching/burning/irritated eyes	1= Yes, often 2 = Yes, sometimes 3 = No, never	Nominal
BuildEyes	Itching/burning/irritated eyes disappeared/improved after leaving the office building	1 = Yes 2 = No 3 = Don't know 99 = not applicable	Nominal
IllEyes	Itching/burning/irritated eyes due to an illness	1 = Yes 2 = No 3 = Don't know 99 = not applicable	Nominal
SympNose	Irritated/stuffy/runny nose	1= Yes, often 2 = Yes, sometimes 3 = No, never	Nominal
BuildNose	Irritated/stuffy/runny nose disappeared/improved after leaving the office building	1 = Yes 2 = No 3 = Don't know 99 = not applicable	Nominal
IllNose	Irritated/stuffy/runny nose due to an illness	1 = Yes 2 = No 3 = Don't know 99 = not applicable	Nominal
SympThroat	Hoarse/dry throat	1= Yes, often 2 = Yes, sometimes 3 = No, never	Nominal
BuildThroat	Hoarse/dry throat disappeared/improved after leaving the office building	1 = Yes 2 = No 3 = Don't know	Nominal

		99 = not applicable	
IllThroat	Hoarse/dry throat due to an illness	1 = Yes 2 = No 3 = Don't know 99 = not applicable	Nominal
SympCough	Cough	1= Yes, often 2 = Yes, sometimes 3 = No, never	Nominal
BuildCough	Cough disappeared/improved after leaving the office building	1 = Yes 2 = No 3 = Don't know 99 = not applicable	Nominal
IllCough	Cough due to an illness	1 = Yes 2 = No 3 = Don't know 99 = not applicable	Nominal
SympFace	Dry/flushed facial skin	1= Yes, often 2 = Yes, sometimes 3 = No, never	Nominal
BuildFace	Dry/flushed facial skin disappeared/improved after leaving the office building	1 = Yes 2 = No 3 = Don't know 99 = not applicable	Nominal
IllFace	Dry/flushed facial skin due to an illness	1 = Yes 2 = No 3 = Don't know 99 = not applicable	Nominal
SympEars	Scaling/itching scalp or ears	1= Yes, often 2 = Yes, sometimes 3 = No, never	Nominal
BuildEars	Scaling/itching scalp or ears disappeared/improved after leaving the office building	1 = Yes 2 = No 3 = Don't know 99 = not applicable	Nominal
IllEars	Scaling/itching scalp or ears due to an illness	1 = Yes 2 = No 3 = Don't know 99 = not applicable	Nominal
SympHands	Dry/itching/redskin hands	1= Yes, often 2 = Yes, sometimes	Nominal

		3 = No, never	
BuildHands	Dry/itching/redskin hands disappeared/improved after leaving the office building	1 = Yes 2 = No 3 = Don't know 99 = not applicable	Nominal
IllHands	Dry/itching/redskin hands due to an illness	1 = Yes 2 = No 3 = Don't know 99 = not applicable	Nominal
SympHeavyHead	Feeling heavy headed	1= Yes, often 2 = Yes, sometimes 3 = No, never	Nominal
BuildHeavyHead	Feeling heavy headed disappeared/improved after leaving the office building	1 = Yes 2 = No 3 = Don't know 99 = not applicable	Nominal
IllHeavyHead	Feeling heavy headed due to an illness	1 = Yes 2 = No 3 = Don't know 99 = not applicable	Nominal
SympFatigue	Fatigue	1= Yes, often 2 = Yes, sometimes 3 = No, never	Nominal
BuildFatigue	Fatigue disappeared/improved after leaving the office building	1 = Yes 2 = No 3 = Don't know 99 = not applicable	Nominal
IllFatigue	Fatigue due to an illness	1 = Yes 2 = No 3 = Don't know 99 = not applicable	Nominal
SympHeadache	Headache	1= Yes, often 2 = Yes, sometimes 3 = No, never	Nominal
BuildHeadache	Headache disappeared/improved after leaving the office building	1 = Yes 2 = No 3 = Don't know 99 = not applicable	Nominal
IllHeadache	Headache due to an illness	1 = Yes 2 = No	Nominal

		3 = Don't know 99 = not applicable	
SympConcent	Difficulties concentrating	1= Yes, often 2 = Yes, sometimes 3 = No, never	Nominal
BuildConcent	Difficulties concentrating disappeared/improved after leaving the office building	1 = Yes 2 = No 3 = Don't know 99 = not applicable	Nominal
IllConcent	Difficulties concentrating due to an illness	1 = Yes 2 = No 3 = Don't know 99 = not applicable	Nominal
SympNauDiz	Nausea/dizziness	1= Yes, often 2 = Yes, sometimes 3 = No, never	Nominal
BuildNauDiz	Nausea/dizziness disappeared/improved after leaving the office building	1 = Yes 2 = No 3 = Don't know 99 = not applicable	Nominal
IllNauDiz	Nausea/dizziness due to an illness	1 = Yes 2 = No 3 = Don't know 99 = not applicable	Nominal
SympTasteSmell	Changed sense of taste and smell	1= Yes, often 2 = Yes, sometimes 3 = No, never	Nominal
BuildTasteSmell	Changed sense of taste and smell disappeared/improved after leaving the office building	1 = Yes 2 = No 3 = Don't know 99 = not applicable	Nominal
IllTasteSmell	Changed sense of taste and smell due to an illness	1 = Yes 2 = No 3 = Don't know 99 = not applicable	Nominal
UnsatThermalComf	Perception of thermal comfort	0 = satisfied 1 = unsatisfied	Nominal
SympYesOften	Having symptom every week → respondent answered "yes, often (every week)"	0 = no symptom 1 = symptom present	Nominal

NoSympBuild	Symptom improved or disappeared after leaving the office building → respondent answered "yes"	0 = symptom stayed after leaving the building 1 = symptom disappeared after leaving the building	Nominal
SympNoIllness	Symptom occurred not because of an illness → respondent answered "no"	0 = symptom due to illness 1 = symptom without illness	Nominal

Codeplan for missing values	
2222	failed to give any answers
99	not applicable
1000	'don't know' response

Statutory Declaration

I declare that I have authored this master thesis independently, that I have not used other than the declared sources, and that I have explicitly marked all material which has been quoted either literally or by content from the used sources.

Hamburg, 7th August 2017

Anna Barabasch