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Personal control over indoor climate in office buildings in a Mediterranean climate - Amman, Jordan

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Abstract: The objective of this study is to increase understanding of personal control in office workplaces by: 1) analysing the adaptive opportunities available to the occupants, how they perceive these adaptive opportunities, as well as their desire to have these opportunities. Statistical analyses were conducted to find out the impact of available control on perceived control, and interrelations between perceived availability and desired control; 2) mapping of how often these controls were used (exercised control); 3) analysing the reasons for not exercising available adaptive opportunities; 4) analysing the effect of office types and seasons on perceived control; and 5) determining the impact of perceived control on thermal comfort perception and air quality. For this, data from longitudinal surveys which have been conducted during four seasons in three office buildings in the Mediterranean climate of Amman, Jordan were analysed. Operable windows and adjustable thermostats are the most desired adaptive opportunities. The most stated reason for not exercising available adaptive opportunities was 'No need to change'. The study found significant correlations between office types and perceived control. On the other hand, no significant correlation was found between seasons and perceived control. Perceived control correlates positively with occupants' thermal comfort perception.

Keywords:
Perceived control, adaptive opportunity, occupant behaviour, thermal comfort, air quality, mixed mode

1. Introduction

Personal control has a considerable impact on individual perception and satisfaction with the indoor climate; however, little is known about which aspects (e.g. available adaptive opportunities, reasons for not exercising adaptive opportunities, office type, season, occupants' expectations as well as the psychological issue of both the belief of having access to the adaptive opportunities and the effectiveness of having this access) are important to determine personal control (Gossauer & Wagner 2006, Boerstra et al., 2013, Hellwig 2015).

Paciuk (1990) distinguishes three levels of personal control: available, exercised, and perceived control. Available control is evident in the access to adaptive opportunities like operable windows, adjustable thermostats, adjusting clothing, etc. Exercised control is how often a building's occupant is engaged in adaptive behaviours in order to reach comfort. Recent work defines perceived control by the extent to which occupants believe they can cause desired changes of the indoor climate. Besides the objective availability of controls, their perceived availability and a person's expectation towards control, perceived control also depends on the experiences of the occupants with their indoor environment and their personality as well as social and cultural expectations (Hellwig, 2015).

This paper investigates the impact of available control, perceived availability and desired control or rather the consistency of perception of adaptive opportunities and the conformity to expectation (desire) with perception of control. Furthermore, the effect of perceived control on thermal comfort and air quality perception is investigated. The paper

aims to contribute towards a better understanding of personal control in office workplaces in different season and office type.

2. Methods

Data were collected in three office buildings during four seasons (spring, summer, autumn 2016 and winter 2017). These buildings are located in Amman which has a hot-summer Mediterranean climate (Csa) according to Köppen-Geiger climate classification (Rubel et al., 2017). Two of these buildings, building 1 and building 2, are mixed mode buildings and were awarded LEED GOLD certificate. The third building represents a naturally ventilated and passively cooled traditional building. Both mixed mode buildings are mechanically ventilated buildings with decentralized HVAC systems as the temperature can be adjusted by the occupants in each office. The built-up areas are 25,600 m2, 28,218 m2 and < 500 m2 for buildings 1,2 and 3 respectively.

Figure 1. Building 1, building 2 and building 3 respectively.

In total, a sample of 119 occupants was willing to participate in the longitudinal survey. The number of occupants differs slightly between the different seasons. During summer, 74 persons took part in the survey, followed by spring, winter and autumn with 67, 62 and 57 participants respectively. Table 1 shows the distribution of participants among the three buildings.

Table 1. Number of participants in the three buildings per season.

	season			
building	spring	summer	autumn	winter
building 1	37	39	31	28
building 2	23	29	21	28
building 3	7	6	5	6
total	67	74	57	62

The data were gathered according to the following procedure: Firstly, the researcher objectively assessed available control opportunities in the offices. Exercised control was documented while occupants were completing the set of questions. Secondly, building occupants completed a set of questions about available, perceived and desired control, as well as exercised control and the reasons why not having exercised the available adaptive controls, thermal comfort perception and air quality perception. Table 2 shows the set of questions related to this paper. The questions were available in both Arabic and English languages.

The occupants answered the set of questions twice a week for a period of two to three weeks per season. The mode of responses for each person per each question has been

calculated for each season for the nominal scales, while the median was calculated for ordinal scales.

Spearman's rank correlation (2-tailed, α=0.05) was used to analyse correlations between variables on the ordinal scale level. Spearman's rank correlation coefficient ranges between -1 and +1), in which -1 indicates a perfect negative correlation while +1 indicates a perfect positive correlation. We used Kruskal-Wallis test (α=0.05) to identify the differences of the median of perceived control in dependence on more than two different independent groups.

Table 2. Questions related to this paper.

Question	Response categories
Perceived availability Do you have these options in order to control the indoor climate? Operable window, door to interior space, door to exterior space, blinds, personal fan, personal heater and thermostat.	- yes - no
Desired control Do you prefer having the opportunity to adjust these options in order to control the indoor climate? (at the moment)? Operable window, door to interior space, door to exterior space, blinds, personal fan, personal heater and thermostat.	- yes - no
Exercised control What type of adjustment did you make to the given 'options to control indoor climate' during the last hours? Operable window, door to interior space, door to exterior space, blinds, personal fan, personal heater and thermostat.	- opened without asking others - opened after asking others - closed without asking others - closed after asking others - no adjustment - not applicable
Reasons for not exercising available controls What were the reasons you did not take the given 'options to control indoor climate'?[1)] Operable window, door to interior space, door to exterior space, blinds, personal fan, personal heater and thermostat.	- Would not have helped - Cannot adjust option any further - Was not agreeable to others in the space - Not sure if it would be OK with management - Not worth asking others' permission - Not worth disturb my work - No need-co-worker did this - Wanted to exhaust other control options first - I was comfortable enough
Perceived control How much control do you have to change 'the thermal conditions' of your office (at the moment)?	no control at all (1)… a lot of control (5) five-point ordinal scale
Thermal comfort perception How do you rate the temperature at this moment in your office?	very uncomfortable (1)… very comfortable (5). five-point ordinal scale

Air quality perception	
How do you perceive the air quality at this moment in your office?	very bad (1)… very good (5) five-point ordinal scale

[1)] Categories after Langevin (2014)

3. Results

3.1. Objective availability

The analysis of objectively available controls has been related to the office type. Only offices occupied by participants in the survey were considered. Both, building 1 and building 2 are mechanically ventilated buildings and contain three office types as follows: single offices, shared offices inhabited by two to five persons in building 2 and two to three persons in the case of building 1. The third type is an open plan office shared by up to ten persons. The third building is a relatively small free running office building which has single offices and one open plan office shared by around six persons. Figure 2 shows the distribution of office types within the three buildings.

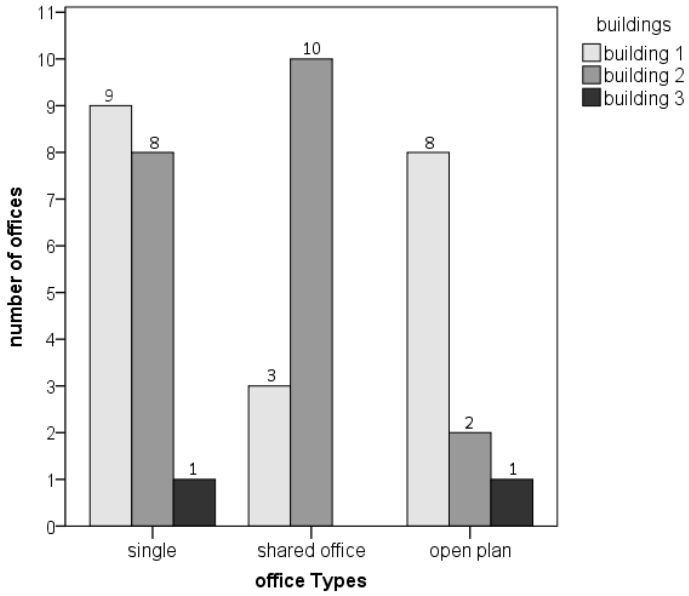

Figure 2. Prevalence of office types within the three buildings.

Figure 3 shows the available controls in offices of building 1. Building 1 has nine single offices. All offices have operable windows, interior doors, blinds and adjustable thermostats. Just one of them has an exterior door to access a terrace. The only available controls in shared offices are interior doors and adjustable thermostats. These offices were occupied by six persons. Occupants in these offices rely on mechanical ventilation to provide fresh air. In all open plan offices, adjustable thermostats are available, while two offices lack the availability of operable windows and blinds. One office doesn't have an interior door. The exterior door to a terrace was available in one office. The open plan offices were occupied by 46 persons.

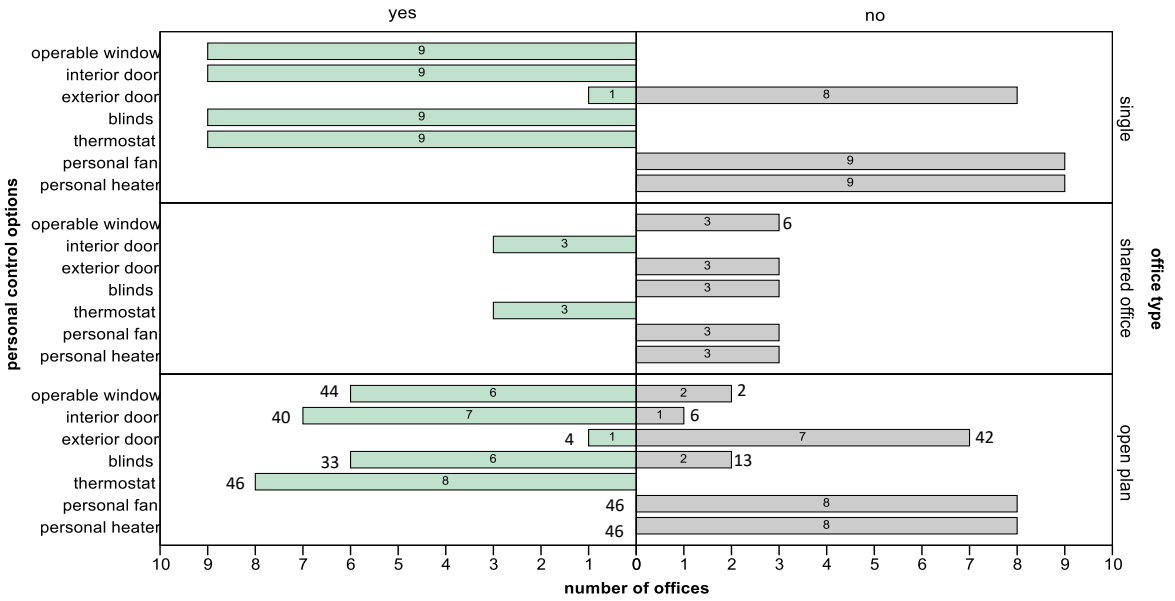

Figure 3. Available controls in offices of building 1. Numbers outside the boxes refer to the number of persons.

Figure 4 shows the available controls in offices of building 2. Building 2 has eight single offices. All of them have interior doors and adjustable thermostats. One office lacks operable windows, two offices do not have blinds. None of the single offices has access to a terrace. Personal fans and heaters were not found in any of the offices. The single offices were occupied by nine different persons (instead of eight) because the occupancy of one office changed during the longitudinal survey. All shared offices have interior doors and thermostats. Three offices lack operable windows as well as blinds. Two offices have access to a terrace. A personal fan was found in one of these offices. Personal heaters were not available. There were 32 people in these offices. Open plan offices have operable windows, interior and exterior doors in addition to thermostats. They lack blinds, personal fans and heaters. Open plan offices were shared between nine persons.

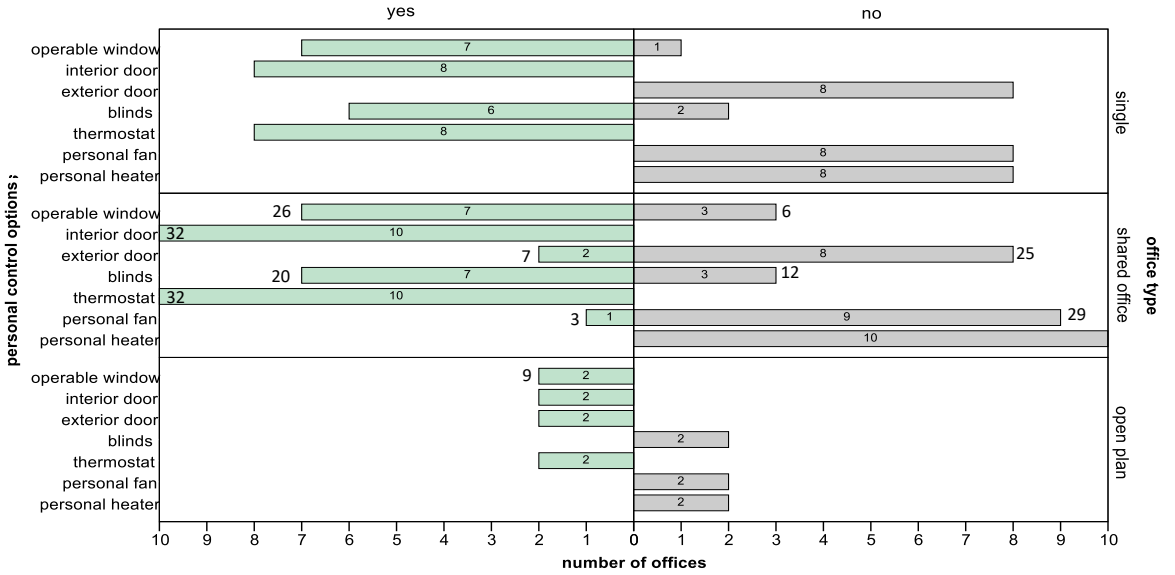

Figure 4. Available controls in offices of building 2. Numbers outside the boxes refer to the number of persons.

Figure 5 shows the available controls in offices of the third building. The single office in building 3 has operable windows, an exterior door, blinds, a personal fan and a personal

heater. The open plan office which was shared by six persons has operable windows, interior door, blinds and personal heaters.

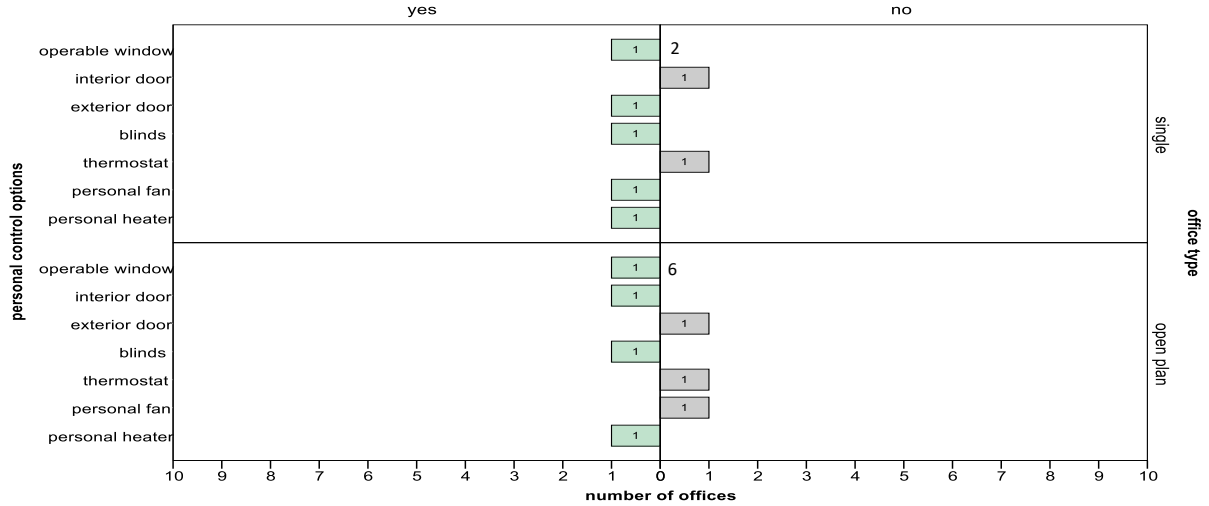

Figure 5. Available controls in offices of building 3. Numbers outside the boxes refer to the number of persons.

3.2. Perceived availability

Perceived availability in this study is defined as the subjective perception of availability of certain controls. It relates to the subjective opinion or belief of having or not having adaptive control options available.

Figure 6 shows the perceived availability of controls in building 1. All nine occupants of the single offices believe that they have access to operable windows, interior doors, blinds and adjustable thermostats. Three occupants reported perceived availability to control exterior doors. All six occupants of the shared offices stated having the availability to control interior doors and adjustable thermostats. Two of them declared the absence of operable windows and blinds. One occupant believed he/she was able to control exterior doors. The occupants of the open plan offices reported differing perceptions on the access operable windows, interior doors, blinds and adjustable thermostats. Twelve persons out of 46 stated perceived availability of exterior doors. In none of the offices, did occupants believe that they have control over personal fans and heaters.

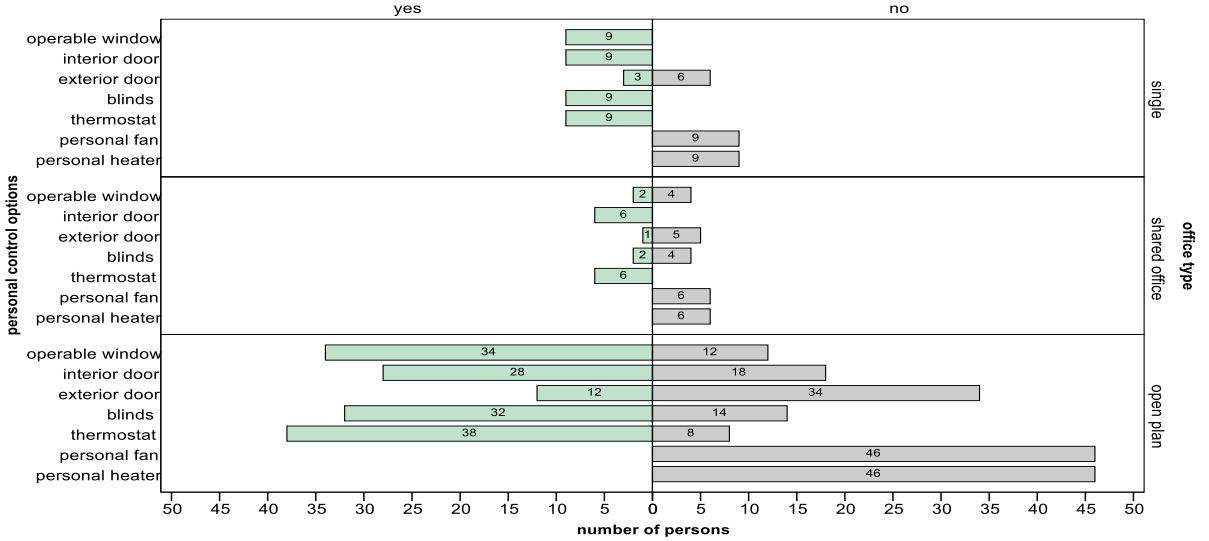

Figure 6. Occupants' perceived availability of controls in building 1.

Figure 7 shows the perceived availability of each person in building 2. Almost all occupants in all three office types reported having control over windows and interior doors.

Occupants in open plan offices perceived availability to control exterior doors. However, approximately half of the occupants of other office types did. Five persons in single offices stated having control over blinds, compared to only two in open plan offices. However, only five occupants declared not having control over blinds in shared offices. Thermostats were perceived to be available by all except for one in the shared offices. Concerning personal fans and heaters, no occupants of the single and open plan offices stated having this control option. In the shared office, less than 5% reported having these options.

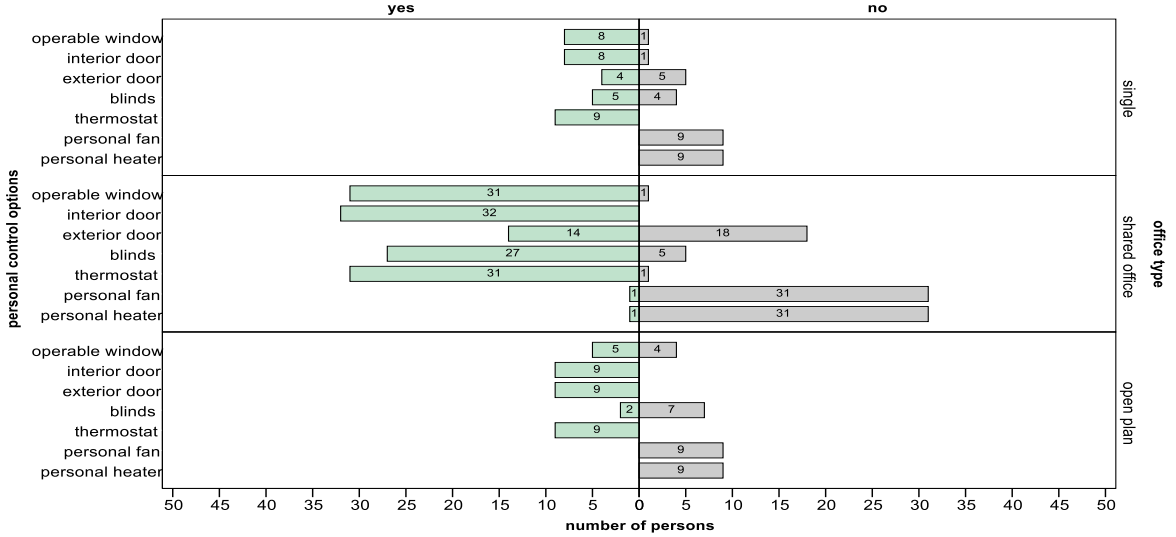

Figure 7. Occupants' perceived availability of controls in building 2.

Figure 8 shows the perceived availability of each person in building 3. All occupants in single and open plan offices stated they have control over operable windows and blinds. Six occupants of the open plan offices stated having control over the interior doors, while the two in the single offices did not. This can be explained by the fact that the single office only had access to an exterior door. None of the occupants in the open plan office perceived availability to control exterior doors. Only one person in both, single and open plan offices, stated having control over a personal heater. Concerning the personal fan control option, one person in the single office answered yes, but no one had such control in the open plan office.

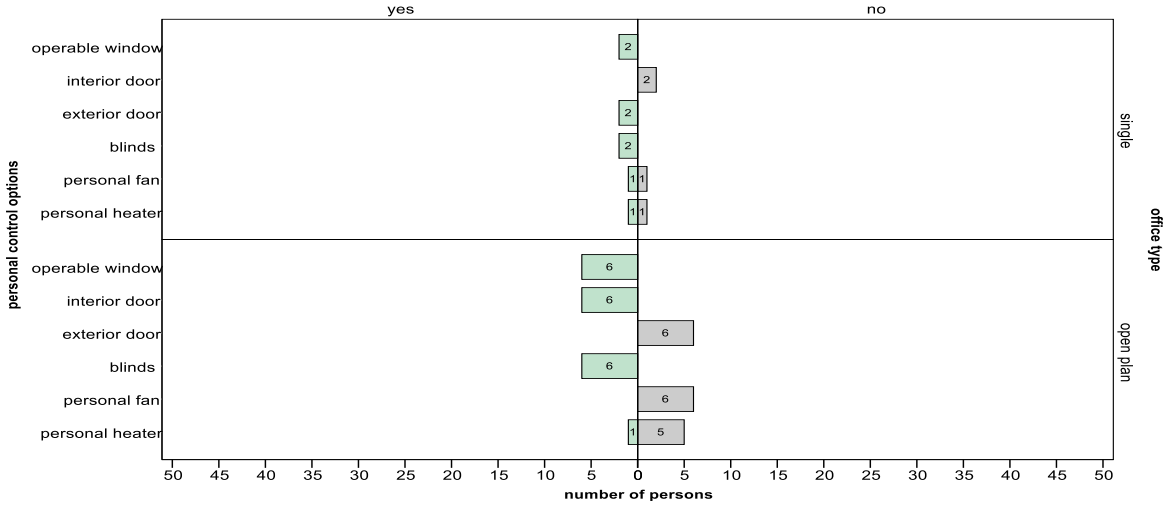

Figure 8. Occupants' perceived availability of controls in building 3.

3.3. Desired controls

This study defines desired controls as the wish for control options to adjust the indoor climate. The referred question to this part is: Do you prefer having the opportunity to adjust these options in order to control the indoor climate?

Figure 9 shows the desired controls responses of building 1. None of the occupants in shared offices wished to have control over personal fans and heaters, while some of the single and open plan occupants did. Operable windows and adjustable thermostat were the most desired control options in all office types.

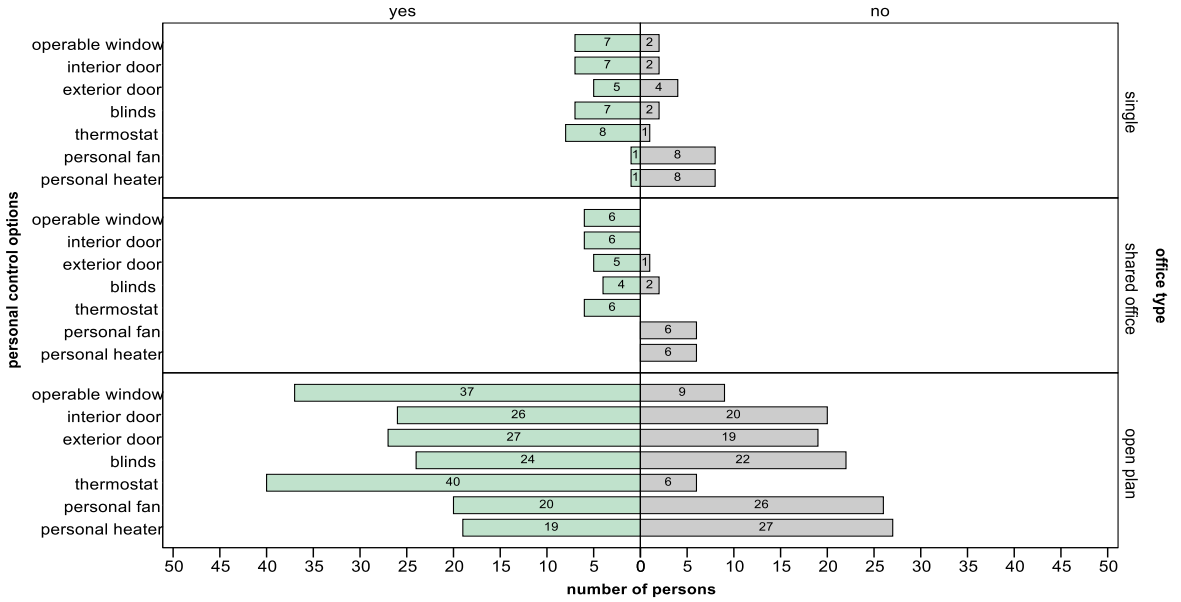

Figure 9. Occupants' desired controls in building 1.

Figure 10 shows the controls desired in building 2. Most of the occupants in both single and shared offices wished to have control over operable windows, interior doors, blinds and adjustable thermostats. Some of them wished to have control over personal fans and heaters. Interior doors and thermostats were the most desired control options in the open plan offices. The wish to have personal fans and heaters also appeared in this office type.

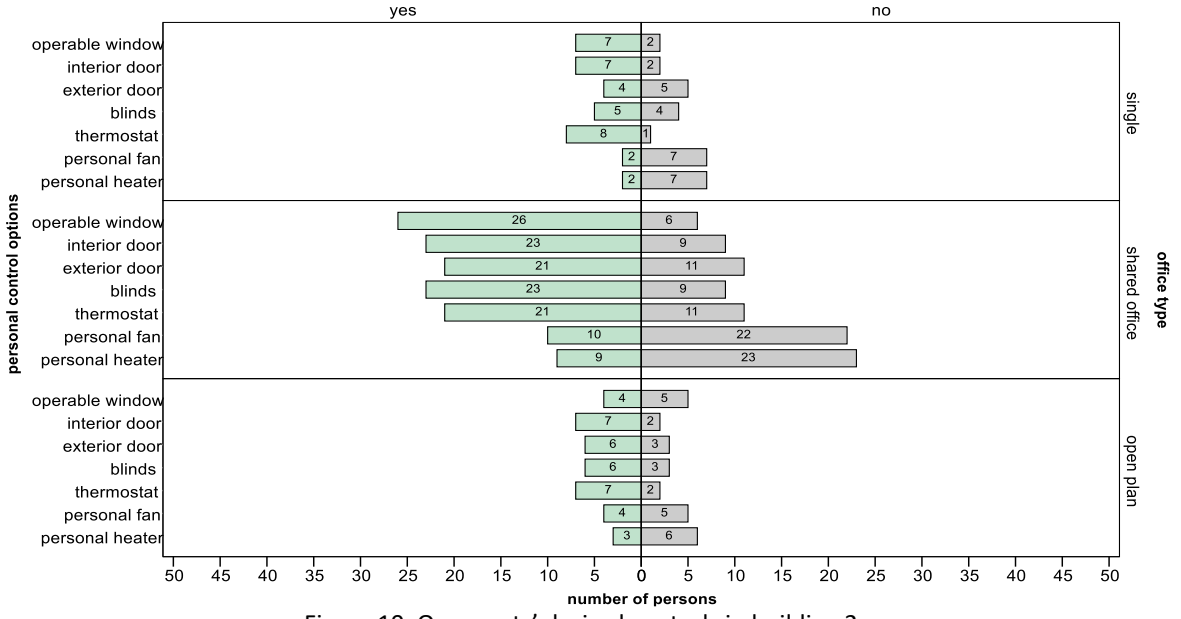

Figure 10. Occupants' desired controls in building 2.

Figure 11 shows the occupants' desired controls in building 3. In the single office, the most desired control options were interior door, exterior door, blinds, adjustable thermostat, personal fans and personal heaters, followed by operable window and interior door. While the most desired control option at the open plan office was adjustable thermostat.

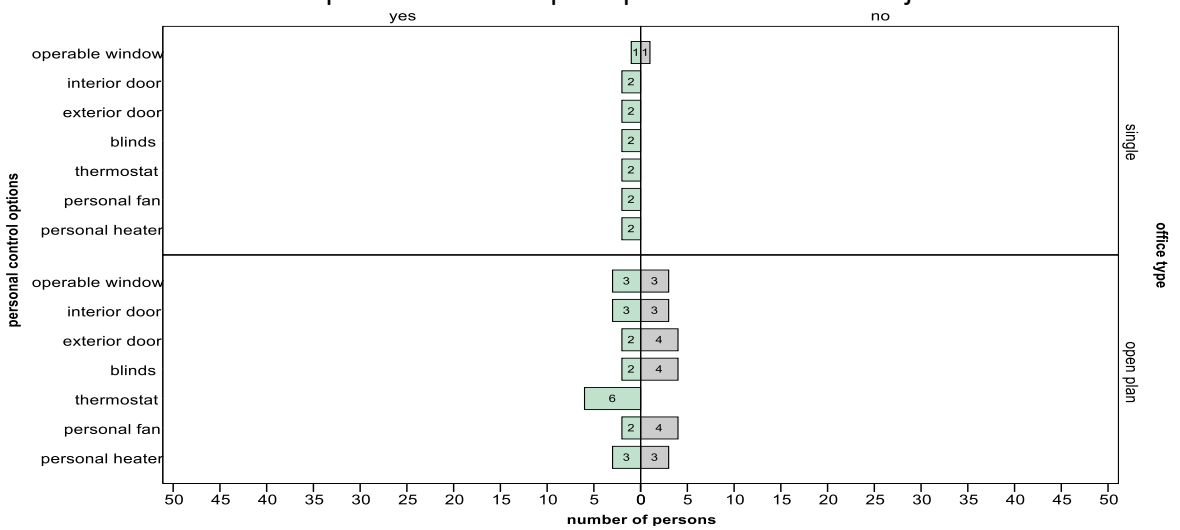

Figure 11. Occupants' desired controls in building 3.

3.4. Consistency of perceived availability and objective availability

In order to compare the perceived availability with the objective availability, in other words to provide proof of consistency between perception and reality, objective availability was subtracted from perceived availability. The answers of the related questions are binary, whereby +1 stands for 'having the control option' and '0' for 'not having the control option'. A difference of '0' means that the occupants' perception was consistent with the real conditions. An outcome of '-1', means the occupants may perceive some restrictions accessing the respective control option. A difference of '+1' indicates that they assume having this control option available although it is not objectively available in their working environment (Table 3). In this case the occupants even never tried to change the thermal environment with this control option or this control option is not important from their point of view.

Table 3. Categories of consistency between perceived availability and objective availability.

perceived availability	0	0	1	1
objective availability	1	0	1	0
difference	-1	0		+1
category	restriction	consistency		false positive assumption

Figure 12 shows the prevalence of categories of consistency between perceived availability and objective availability in the three buildings. In the case of the single offices, two persons believed they had access to outdoor space in building 1, while four persons did in building 2. The perceived availability of the other control options was consistent with the objective availability in building 1. One person believed to have access to blinds in building 2. There was the perception of restricted access to interior doors and blinds in building 2.

The perceived availability of controls in shared offices in building 1 was consistent with the objective availability for adjustable thermostats and interior doors, but not for operable

windows and blinds which two persons believed to have access to, as well as for an exterior door which one person believed to have access to. In building 2, perceived availability was in accordance with the objective availability only for interior doors. There was the perception of restricted access to exterior doors, blinds and thermostat.

In building 1, perception of restrictions appeared in open plan office type for all control options with the smallest share for access to exterior doors and the largest share for interior doors. In the case of building 2, restrictions were perceived in the open plan office type just in the case of operable windows. In building 3, the perceived availability of most of the control options was in accordance with the objective availability. Restrictions were perceived for personal fans and personal heaters in the single office and for personal heaters in the open plan office.

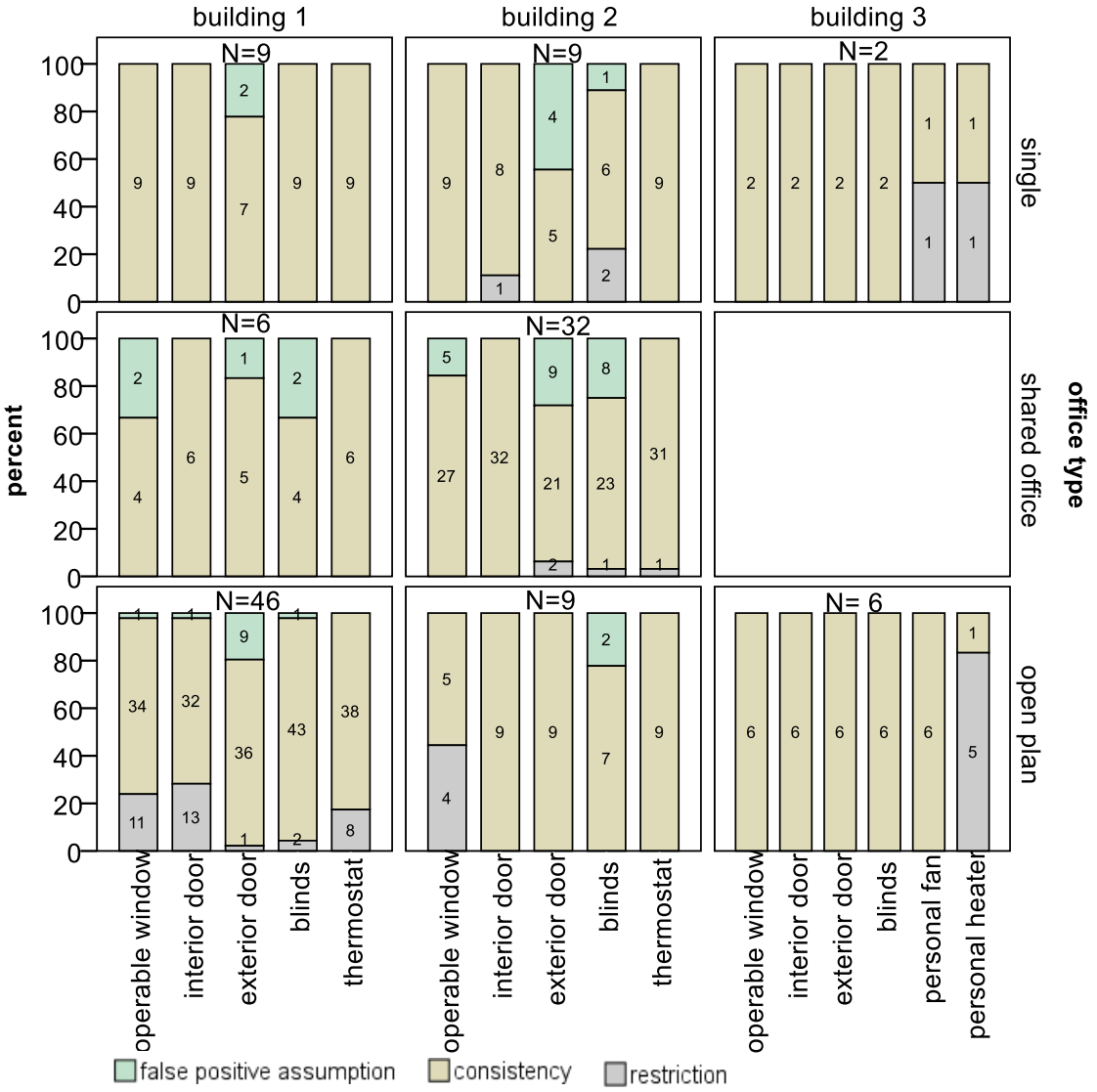

Figure 12. Categories of consistency between perceived availability and objective availability in the three buildings. Numbers in the columns represent the absolute number of occupants.

For each category of consistency between perceived availability and objective availability (Table 3) the distribution of the occupants' votes on perceived control was displayed (Figure 13) and analysed. The analysis shows no significant differences of the three categories' median of perceived control (p= 0.2). Median perceived control scores for

the categories ‘consistency’ and ‘false positive assumption’ lie at 4 while the median score for the category ‘restriction’ is 3.

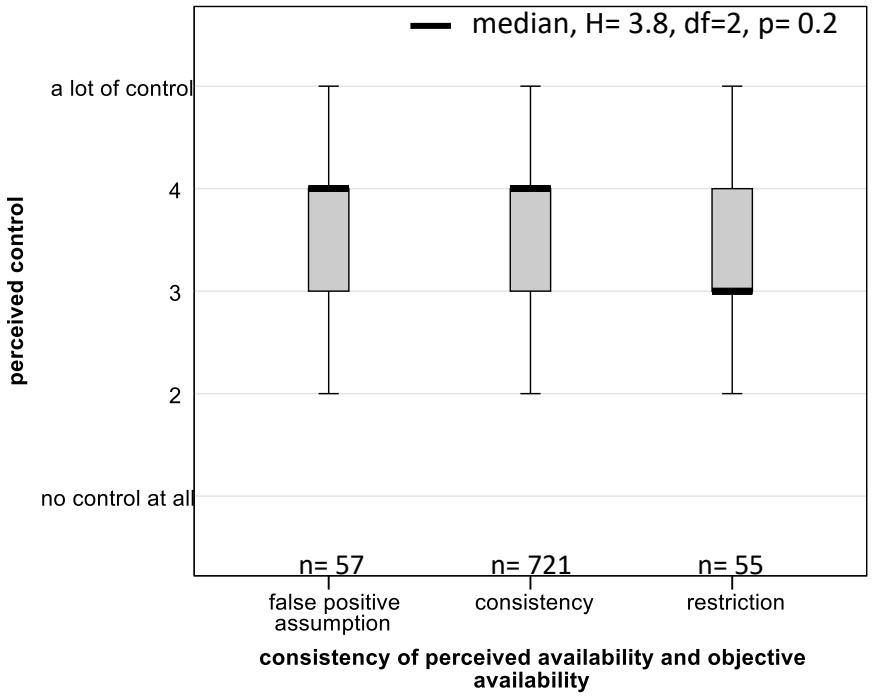

Figure 13. Perceived control for the three categories of consistency between perceived and objective availability.

3.5. Conformity between perceived availability and desired controls

The same principle as in section 3.4 was applied when investigating the level of conformity between perceived availability and desired controls. Desired controls responses were subtracted from perceived availability replies. A result of ‘0’ means, the office control options match exactly the occupant’s expectation. An outcome of ‘-1’ can be interpreted as a perception of a lack of control, hence a negative non-conformity to expectation. A value of ‘+1’ means that more control options are perceived to be available than the occupant desired, leading to a positive non-conformity to expectation (Table 4).

Table 4. Categories of conformity between perceived availability and desired controls.

perceived availability	0	0	1	1
desired controls	1	0	1	0
difference	-1	0		1
category	negative non-conformity	conformity		positive non-conformity

Figure 14 shows the frequency of the categories of conformity between perceived availability and desired controls in the three buildings. Building 1: In the case of single offices, the perceived availability of operable windows, interior doors, blinds and adjustable thermostats is in conformity with desired controls or shows positive non-conformity. Four persons desired exterior doors but did not perceive their availability. Some occupants in shared offices lacked the opportunity to control operable windows, exterior doors and blinds while few occupants in open-plan offices missed the opportunity to control operable windows, interior and exterior doors blinds, and thermostats. Building 2: In single offices,

the results were similar to those in building 1, but the category negative non-conformity appeared also for operable windows and blinds. Occupants in shared offices lack the opportunity to control operable windows, exterior doors and blinds, while in open plan offices, occupants only missed the operable windows and blinds control options. Occupants in building 3 lacked the opportunity to control interior doors in the case of the single office and the exterior door in the open plan office, as well as personal fans and personal heaters in both offices.

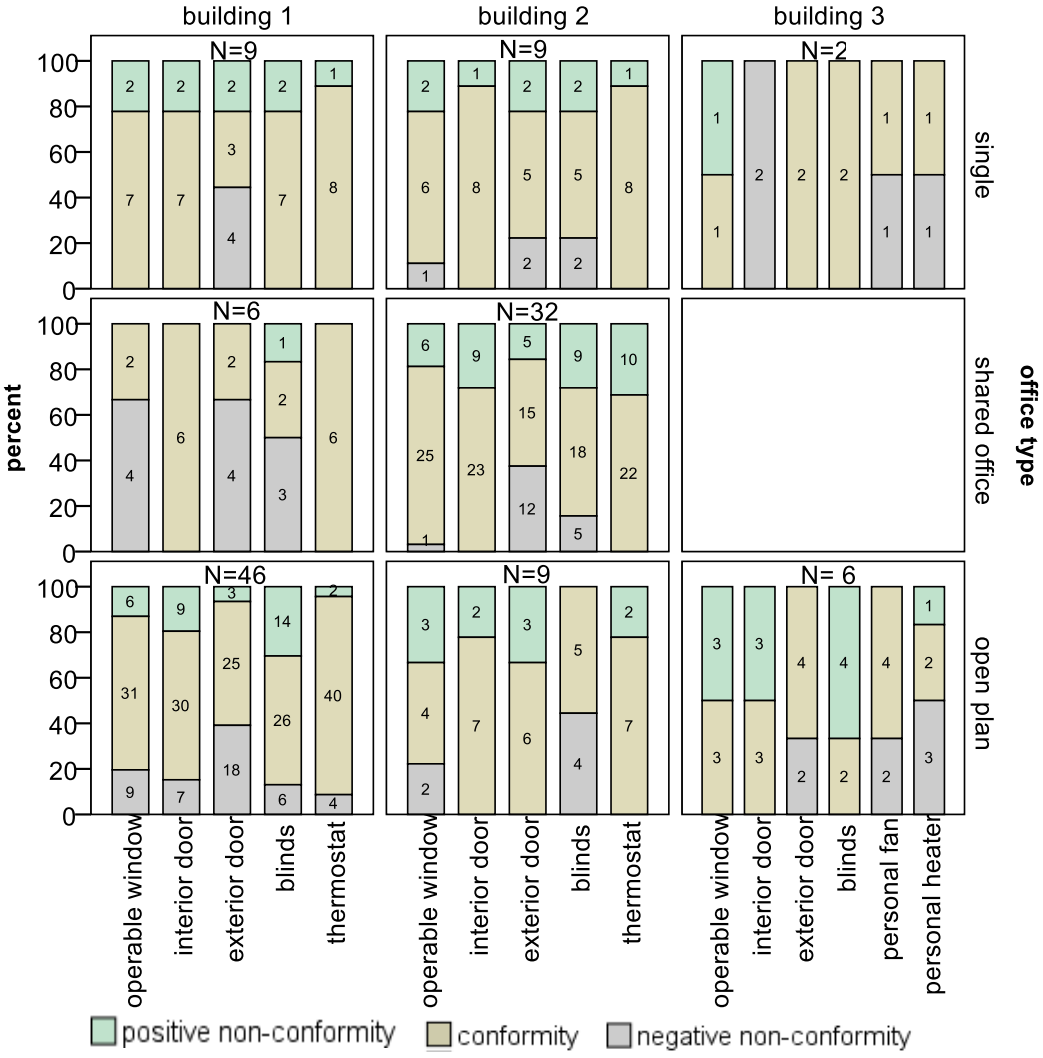

Figure 14. Categories of conformity between perceived availability and desired controls in the three buildings. Numbers in the columns represent the absolute number of occupants.

For each category of conformity between perceived availability and desired controls (Table 4) the distribution of the occupants' votes on perceived control was displayed (Figure 15) and analysed.

The analysis shows significant differences of the three categories' median of perceived control (p= 0.00). Median perceived control scores for the categories 'conformity' and 'positive non-conformity lies at 4 while the median score for the category 'negative non-conformity' is 3.

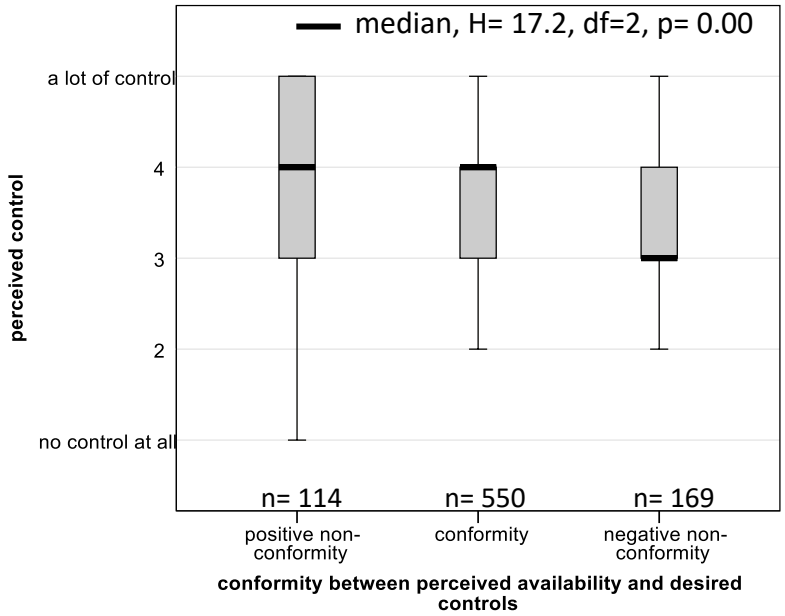

Figure 15. Frequencies of perceived control votes for the three categories of conformity between perceived availability and desired controls.

3.6. Exercised control

Exercised control was investigated as a function of the office type in all four seasons. Exercised control was calculated by percentage and with reference to the number of occupants who perceived available control. Figure 16 displays the result for exercised control in spring. In single offices, the frequencies of responses are distributed equally between 'opened without asking others' and 'no adjustment' (44%). In both, the shared offices and the open plan offices the highest prevalence is in 'no adjustment' (62%). The other responses are distributed evenly between the other control options. A similar trend as for spring was found among summer, autumn and winter: In single offices, the highest prevalence found was 'no adjustment', followed by 'opened without asking others' and 'closed without asking others'. In shared offices and open plan offices, 'no adjustment' shows the highest frequency. Followed either by opening the control options 'after asking others' or 'without asking others'. The lowest prevalence relates to closing the control options 'after asking others' or 'without asking others'.

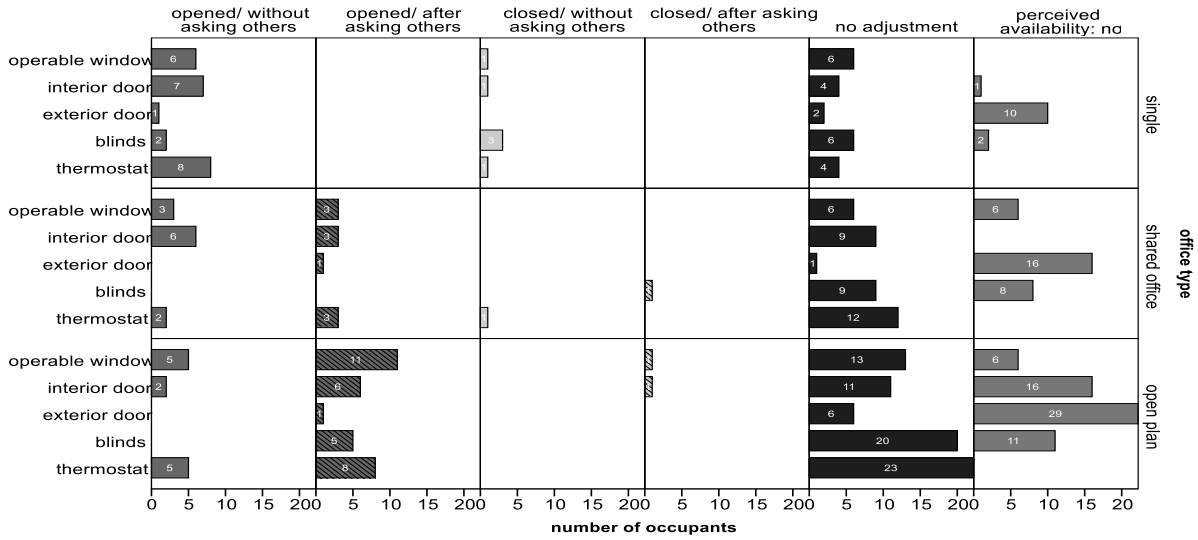

Figure 16. Exercised control in spring in all buildings.

3.7. Reasons for not exercising available adaptive controls

Results showed that the highest response rate to the question on exercised control was 'no adjustment' in all seasons. The reasons for not exercising available adaptive controls were divided into three main categories. The first one, '**no success expected**' is applied when the occupants replied: 'would not have helped', 'cannot adjust option any further', 'was not agreeable to others in the space', and 'not sure if it would be ok with management'. The second category is '**not important**' with the following reasons: 'not worth asking others' permission' and 'not worth disturbing my work'. The third category is '**no need to change**' with: 'no need co-worker did this', 'wanted to exhaust other control options first', and 'I was comfortable enough' as reasons given.

Figure 17 shows the reasons for not exercising available adaptive opportunities in spring. The most prevalent reason for not using indoor climate controls was: 'I was comfortable', with 56% in single offices, 44% and 47% in shared and open plan offices respectively. The third category 'no need to change' was the highest stated percentage category for not using indoor climate controls with 73%, 79% and 69% in single, shared and open plan offices respectively. The second category was related to 'no success expected' with 16%, 15%, 24% in single, shared and open plan offices respectively. The category 'not important' was the least reported one with 11%, 6% and 7% in single, shared and open plan offices respectively. The results of summer, autumn and winter seasons show a tendency similar to that found in spring's results. The highest percentage for not exercising available adaptive opportunities was 'I was comfortable' for all office types among all seasons. Over all, the majority of responses fall in 'no need to change' category with the smallest percentage of 40% during winter in open plan offices. This percentage increased to 93% for single offices in summer. The second category 'no success expected' reflected the highest percentage of 54% in open offices in winter, while this percentage was 4% in single offices in autumn. Answers related to 'not important' were relatively few with a highest percentage of 14% in shared and open plan offices during autumn.

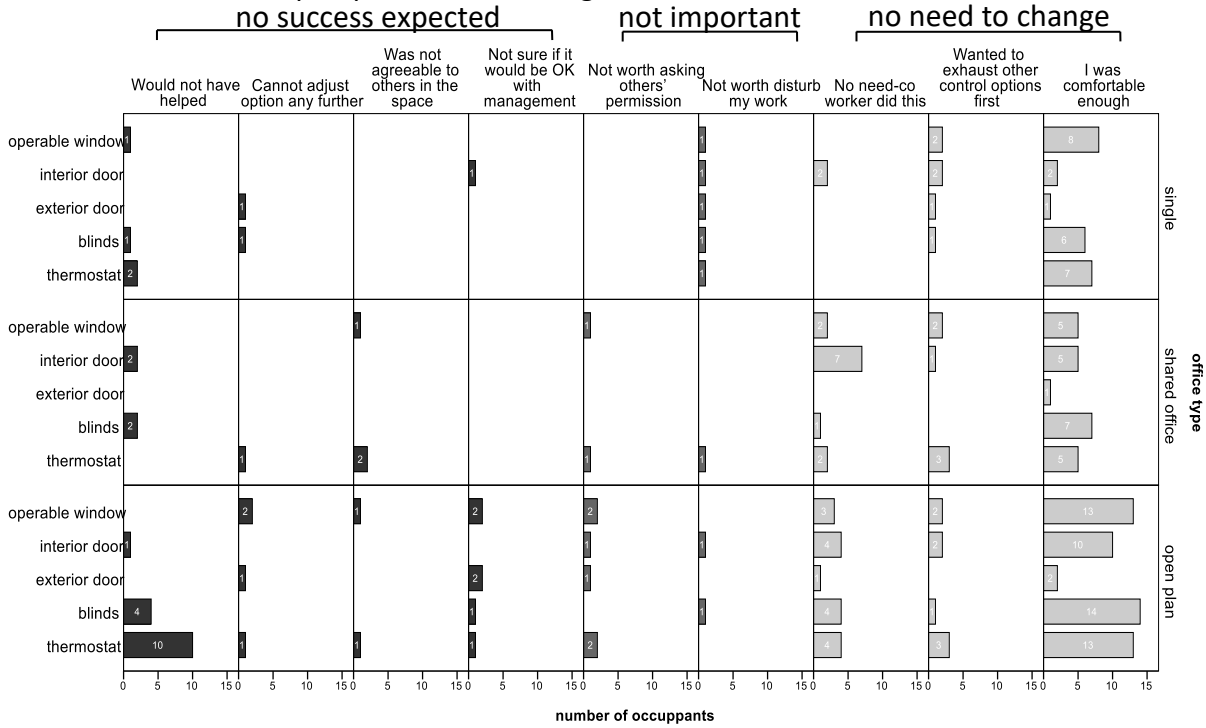

Figure 17. Reasons for not exercising available controls in spring.

3.8. Impact of office type and season on perceived control

A significant effect of the impact of office type on perceived control for each season is shown in Figure 18. Median value of perceived control for single office type is the highest in all seasons.

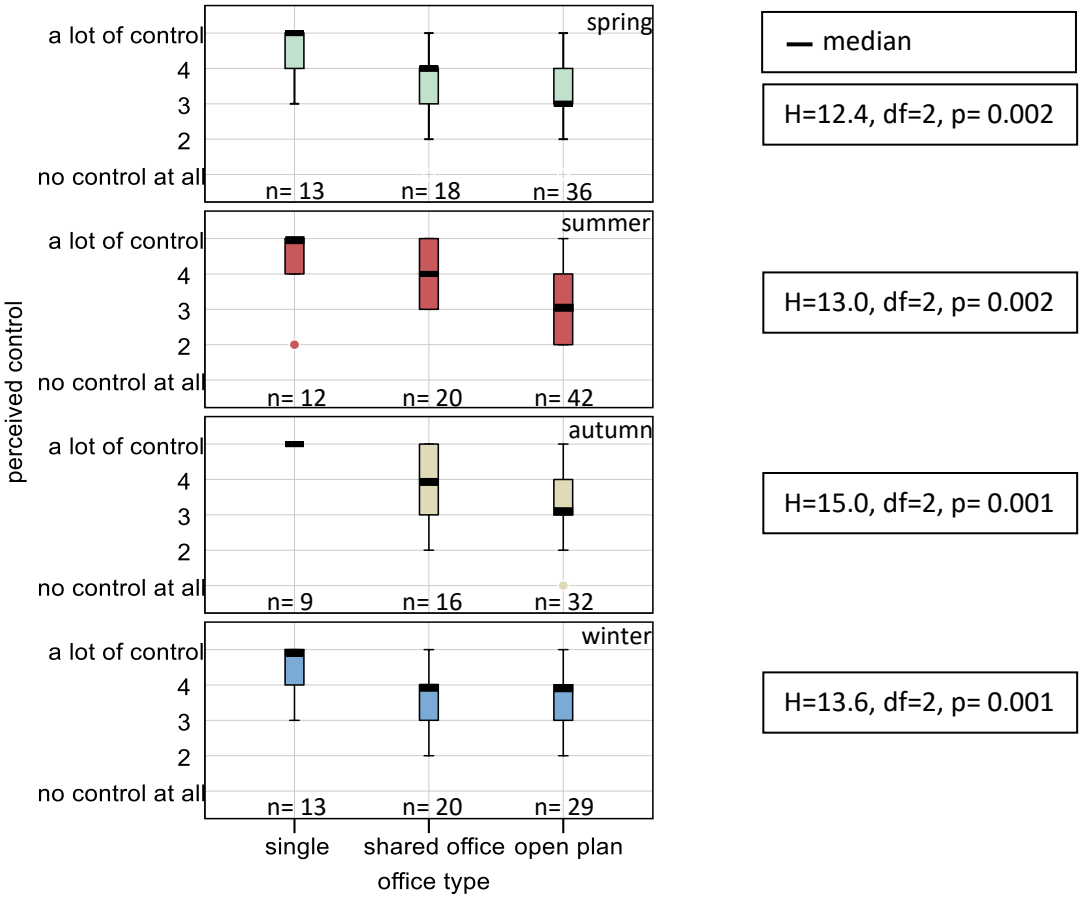

Figure 18. Perceived control versus office type in all seasons.

Concerning the impact of season on perceived control, overall scores for perceived control did not differ significantly (p=0.18) (Figure 19). The median of perceived control is 3 for spring and 4 for summer, autumn and winter.

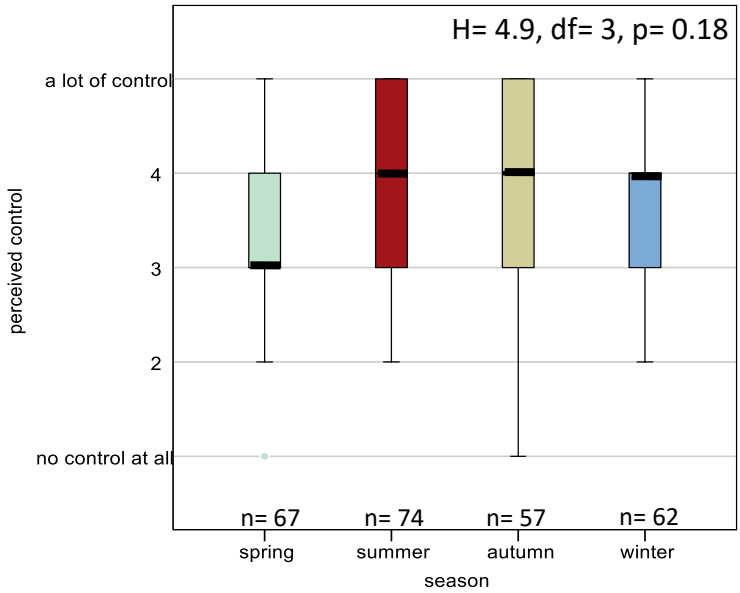

Figure 19. Perceived control versus season.

3.9. Impact of perceived control on thermal comfort and air quality perception

Concerning the thermal comfort perception, 92% of the occupants were neither comfortable nor uncomfortable to very comfortable (scale points 3 to 5) and only 8% voted for uncomfortable or very uncomfortable. Occupants also perceived a good air quality with 92% (scale points 3 to 5) and only 8% voted for bad or very bad air quality.

An analysis using Spearman rank-order correlation of perceived control versus thermal comfort perception and air quality perception respectively was carried out for all seasons (perceived control: no control at all (1)… a lot of control (5), thermal comfort: very uncomfortable (1)… very comfortable (5), air quality perception: very bad (1)… very good (5).

The strongest significant correlation was found for summer (rs =0.52; 2-tailed p= 0.00), followed by autumn, all seasons, winter and spring respectively as shown in table 5. This indicates that persons, who believe having control, are generally more thermally comfortable. Perceived control was also found to correlate positively with air quality perception among all seasons. The strongest correlation was found for all seasons (rs =0.51; 2-tailed p= 0.00) as shown in table 5. This suggests that persons, who believe having control, are more positive towards air quality.

Table 5. Spearman rank-order correlation between perceived control and both thermal comfort and air quality perception.

	perceived control versus thermal comfort perception		perceived control versus air quality perception		
	r_s	Sig. (2-tailed)	r_s	Sig. (2-tailed)	N
all seasons	**0.45****	**0.00**	**0.51****	**0.00**	119
spring	**0.34****	**0.005**	**0.32****	**0.009**	67
summer	**0.52****	**0.00**	**0.41****	**0.00**	74
autumn	**0.49****	**0.00**	**0.29***	**0.03**	57
winter	**0.42****	**0.00**	**0.41****	**0.00**	62

* correlation is significant at the 0.05 level (2-tailed)
** correlation is significant at the 0.01 level (2-tailed)

4. Discussion

In this study, a detailed longitudinal approach to analyse the impact of available control (objective and perceived) and desired controls on perceived control has been used. The mechanically ventilated buildings tended to provide bigger office units: in building 1 the majority (75%) of the participating occupants worked in open-plan office environment; in building 2 the majority (64%) worked in shared offices.

The most desired control options were operable windows (77% of the occupants) and thermostats (82%) in the three buildings. This proportion is somewhat lower but of similar magnitude as previous findings e.g. the ProKlimA - study showing that 85% of office workers wish to have control over their indoor environment (Bischof et al. 2003). The most desired control features should be provided to the occupants as these are the features the occupants are likely to use, and this will lead to a positive perception of self-efficacy (Hellwig, 2015). The less desired control options in the mechanically ventilated buildings were personal fans and heaters, while these options were desired by occupants in the free running building ‘building 3’.

As shown in Figures 3, 4 and 5, single offices of the surveyed buildings offered more objectively available control options compared to shared and open plan offices. Non-operable windows were found in three shared offices in both building 1 and 2, and in two open-plan offices. This is surprising as both buildings are LEED certified, aiming also for high occupants' comfort and satisfaction. Although availability of control has not been an evaluation criterion in most green building evaluation systems, it is known for many years and from numerous SBS studies (e.g. Bischof et al. 2003) that sealed facades/non-operable windows contribute considerably to the prevalence of the sick building syndrome.

The occupants' perceived availability of all control options was lower in shared and open plan offices compared to single offices as shown in Figures 6, 7 and 8. Some occupants stated no availability of operable windows and blinds in open plan offices in both mechanically ventilated buildings, although these opportunities were available. Furthermore, restrictions accessing the available control options obviously appeared in shared and open plan offices (Figure 12). This is related to the nature of these office types as many persons with different personalities and needs had to work close to each other. Some occupants were sitting relatively far away from the mentioned control options and stated not having exercised them for the reasons: 'would not have helped', 'cannot adjust option any further', 'was not agreeable to others in the space', and 'not sure if it would be OK with management'. Thus, they perceived restrictions from making adjustments. This is in line with Leaman and Bordass (1999) who found that when negotiations with others are needed before exercising the control options, constraints may appear.

New variables have been introduced: consistency of perceived and objective availability and conformity to expectation. Overall, the vast majority of votes (n=721) showed consistency of objective and perceived availability of control. This means that the majority was aware of the adaptive opportunities available at their workplace.

Only 55 votes expressed perceived restrictions with regard to controls. Although the Kruskal-Wallis-test for the median difference of perceived control of the categories of consistency between perceived and objective availability was not significant, votes expressing perceived restrictions in accessing controls led to a one scale point lower level of perceived control compared to all other votes (n=778, Figure 13). Restrictions may result from the objective availability of control options in the buildings or the social environment -here work- (management, negotiations, norms), leading to a lower level of perceived control in the workspace (Hellwig, 2015).

Conformity to expectation was also introduced in this study as it is seen as part of a person's evaluation system for judging the indoor environment (Hellwig, 2015). An expectation which is not met by the indoor climate or the building can also have an impact on perceived control or comfort perception. The majority of votes (n=550) demonstrated conformity to expectation. This means that the expectation of the majority towards control was met. 169 votes expressed a negative non-conformity to expectation; hence expectation was not met. The Kruskal-Wallis-test for the median difference of perceived control of conformity between perceived availability and desired controls was significant, votes expressing negative non-conformity led to a one scale point lower level of perceived control compared to all other votes (n=664) (Figure 15). A higher degree of conformity to expectation was shown to be prevalent in naturally ventilated office types compared to mechanically ventilated buildings. If offices lack some control options, occupants in these offices desired having these missed control options. Those who missed some control options scored at a lower level on the perceived control scale.

The results related to exercised control opportunities were similar among the four seasons. The highest percentage of exercised control opportunities was 'no adjustment' in all buildings among the four seasons as occupants felt comfortable. Even if 'no adjustments' were made most of the time, it would not justify reducing the availability of control opportunities, as availability is an important positive feature as such in a workspace.

Furthermore, the correlation between perceived control and both, thermal comfort and air quality perception, has been investigated. Perceived control has shown a positive significant correlation with thermal comfort and air quality perception during all seasons (Table 5). This was also shown by Boerstra (2016) who showed that perceived control acts as a mediator of the relation between indoor climate and comfort perception.

We found no significant differences in perceived control level with regard to season; although the median of perceived control in spring was 1 scale point lower compared to the other seasons. In contrast, Gossauer, Leonhart & Wagner (2006) found that the effectiveness of temperature changes was lower in summer compared to winter affecting the satisfaction with the thermal conditions in summer negatively.

Votes on perceived control showed significant differences between office types among the four seasons, as perceived control in single offices was the highest among all seasons. This was reflected on a higher level of perceived control, thermal comfort and air quality perception in single offices.

5. Conclusion

This study investigated the impact of available control on perceived control, interrelations between perceived availability and desired control, as well as the effect of perceived control on thermal comfort and air quality perception. It also analysed the exercised control that took place in offices and the reasons behind not adjusting the available control options. Another main objective of this study was to investigate whether different seasons and office types affect perceived control.

Our analysis showed that larger office units offered less control -not only objectively- but also according to occupant's perceived availability of certain controls and according to perceived control votes. Also, this study confirms that operable windows (and thermostats) are a highly desired feature of workspaces and therefore buildings should preferably be designed with operable windows if external environmental conditions are suitable for that. Windows and thermostats were also the most adjusted control options during all seasons. But the most prevalent control exercise was 'no adjustment' because the most stated reason for not exercising available controls in all buildings and among the different seasons was a positive thermal comfort perception.

Negative non-conformity between perceived and objective availability of controls could have an impact on perceived control but was not significant in our study, maybe due to the low number of votes in this category. Perceived control could be shown to be affected significantly by conformity to expectation.

Furthermore, perceived control correlates positively with both thermal comfort and air quality perception during all seasons and also in each season separately. So, improving the availability of adaptive opportunities in buildings can positively affect occupants' comfort perception.

This study contributes to a better understanding of what affects personal control and how perceived control is linked to thermal comfort and air quality. It also shows the role of office

types and seasons on perceived control. Further analysis is needed to understand the effect of different seasons on perceived control.

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