### Title
Implementation of desk fans in open office: Lessons learned and guidelines from a field study

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**Title**: Implementation of Desk Fans in Open Office: Lessons Learned and Guidelines from a Field Study

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## Highlights

- Fans increased thermal satisfaction by 20%
- 80% occupants considered 1 °C higher air temperature comfortable with fans
- Setpoint temperature increment must be gradual
- 90th pre-intervention temperature percentile suggested to limit setpoint increment

## Abstract

Desk fans allow individual thermal adjustment in shared spaces which increases occupants' thermal satisfaction. When associated with the increase of room conditioning system setpoint temperature, they can also reduce energy use. In comparison to other Personal Comfort Systems (PCS), low-power desk fans can be very efficient for cooling. Nevertheless, previous studies identify some barriers to their implementation and show no clear guidelines on how to overcome them. Therefore, this study presents the results of a field implementation of desk fans in an open office in Brazil. The intervention consisted of providing one desk fan for each occupant and progressively increasing the setpoint temperature. Indoor thermal conditions were recorded simultaneously with occupants' thermal perception using sensors and surveys. Results show fans increased thermal satisfaction by 20 %. And, when fans were available, the preferred indoor air temperature increased by 1 °C. However, many constraints affect the results. Based on this experience, we propose guidelines for future implementation. We emphasize the need to understand the HVAC system, engage building operators, and apply gradual temperature modification. As occupants' expectations had a great impact on the potential temperature extension, we suggest a way to limit temperature extension in future implementations.

**Keywords**: desk fans, personal comfort system, thermal comfort, setpoint, field study, intervention

## 1. Introduction

Personal Comfort System (PCS) according to ASHRAE 55 [1] is "a device, under the control of the occupant, to heat and/or cool individual occupants directly, or heat and/or cool the immediate thermal environment of an individual occupant, without affecting the thermal environment of other occupants". Desk fans are small equipment that increase the air movement around an occupant producing a cooling effect of up to 3K, depending on several environmental and personal parameters [2]. Desk Fans can be especially efficient in warm environments when enabling high and controllable airspeed with low power demand [3]. Local control in shared spaces can address interpersonal preference variations, enhancing occupants' satisfaction [4–9]. Simultaneously, local control generates a microclimate that can meet occupants' demands while the room temperature is extended. This extension could be applied to setpoint temperature offset, generating substantial energy savings [10–12].

Despite these benefits and the extensive research on the topic in recent years [13], there are still many gaps related to PCS implementation [14]. The main challenge in shared spaces with a central HVAC system is finding a common setpoint and controlling it throughout the year to satisfy multiple occupants' demands. For instance, if the most sensitive occupants are the reference for central system control, the potential energy savings are reduced [15]. On the other hand, an acceptable temperature can produce more savings but may not match the preferred temperature [16] and that could, in the long term, affect occupants' satisfaction. To account for the known interpersonal preference variation [17], many studies propose predictive personal comfort models [18] to control HVAC. However, few present a solution for how to combine individual models' responses into a single temperature setpoint [19,20]. As these solutions are tested in small settings or controlled environments, their applicability could be questioned from a practical point of view as being too complex and time-consuming for a real building.

Previous studies indicate that the optimal cooling and heating setpoint vary according to weather conditions. However, the dead band does not vary, the broader the values, the bigger the energy savings [12]. Personal comfort systems allow the extension of the dead band. Therefore, in cooling-dominated buildings without heating systems, like the ones found in Brazil, a simpler setpoint change may be proposed – to increase the cooling setpoint as much as possible within occupants' thermal comfort limits. For warm conditions, low-power desk fans can be one of the most efficient PCS as they produce a high cooling effect with 2-3W [3,21]. Climate chamber experiments indicate acceptable temperature limits of up to 30 °C with these types of fans [3]. However, field experiments show lower acceptable limits in real-world conditioned office spaces – between 26 °C and 27 °C [22–24]. Additionally, occupants used to cool environments may prefer to lower the setpoint instead of using a fan [15]. The 'Coolbiz' campaign in Japan, was successful in promoting a long-term use of 28 °C setpoint temperature with adaptive opportunities, like the use of fans. Nevertheless, the analysis of data from this initiative also shows the comfort temperature is 27 °C [25], which highlights the low applicability of the 30 °C limit found in chamber experiments.

Usually, to find the limit, researchers provide fans and increase the setpoint until complaints increase. However, the magnitude and interval of change vary among studies. Shetty et al. [24] provided desk fans and changed the setpoint in two office areas by 1 °C every two days starting from 24 °C and 25 °C, and found 27 °C not to be acceptable. Lipczynska et al. [22] tested to change the setpoint from 23 °C without fans to 26 °C and 27 °C with fans. Both temperatures were expected to be tested during two weeks each but occupants did not tolerate 27 °C for 2 weeks and the experiment was shortened. Based on this result, Kent et al. [10] tried increasing it to 26.5 °C with fans for 3 weeks and found a positive result, most occupants were satisfied. Although desk fans are available in many countries, there are few intervention field studies including them [26]. There are even fewer field studies with other PCS, and most of them do not promote temperature change [27,28] or were applied in spaces with control of individual setpoint [29,30], which do not present the same challenges. A field study by Zhang et al. [31] to test foot warmers applied a similar method, decreasing the heating setpoint by 0.6 °C for 1 or 2 weeks from 21.1 °C to 18.9 °C.

In addition to the challenges of defining the temperature limit and addressing occupants' reluctance to change, the fan's design can also become a barrier and impair its usability [32,33]. This highlights the lack of information on how to overcome these barriers to successfully implement desk fans in offices. Therefore, this paper has two goals. The first is to present the results of an intervention field study on the implementation of desk fans and extended setpoint temperature. The second is to present guidelines for implementing desk fans based on the lessons learned from this study and the literature. These guidelines could be used by practitioners and researchers interested in implementing this strategy.

## 2. Method

### 2.1. Experiment Location and Building Characteristics

The method consists of monitoring indoor thermal conditions and occupants' perception before and after the implementation of desk fans in an open office space. After providing desk fans, setpoint temperature was increased daily, and responses were monitored closely to identify the acceptable limits.

The discussion is organized around the main questions practitioners and researchers might have for applying this intervention. The answers to those questions were based on the lessons learned and literature review. The conclusion summarizes the discussion in challenges and guidelines for this intervention.

The implementation took place in part of an open plan office of a utility company in Florianopolis, in the southeast of Brazil. The local climate is subtropical hot humid, Cfa [34] and 2A [35]. The study area was on the second floor of this three-floor building. The envelope is made of reinforced concrete and single-glazed panels shaded by horizontal external louvres. The building's HVAC is a chilled water-cooling system that includes four fan-coil units (FCU) per floor. Figure 1a shows the location of the two FCUs that supply the selected areas. Both areas and other nearby occupied spaces are open or separated by low partitions, allowing air exchange. Two water chillers supply all the building's FCUs. Outdoor air is constantly supplied directly to each FCU room (without pre-cooling or heat recovery systems).

Figure 1a shows the location (red dots) of the data loggers used during the experiment to record indoor air temperature ($T_a$) and relative humidity (RH) every 5 minutes (HOBO® MX1101, Onset, USA). The data loggers have a temperature accuracy and range of ±0.21 °C from 0 °C to 50 °C, and of RH ±2 % from 20 % to 80 % and ±6 % for other ranges. HOBOs were placed in the center of occupants' locations and attached to the side of tables, at 60-70 cm from the ground. We tried to distribute them evenly to capture the spatial diversity. The studied spaces had low exposure to outdoor conditions as the included occupants were sitting far from the facades or being shaded by the balcony. Nevertheless, the measurement of the mean radiant temperature occurred in two days at two locations (indicated by red crosses) to check the variation, using a black globe and air temperature probes (Testo® 400, Testo SE, Germany), which have a measurement range of 1 °C to 120 °C and ±0.3 °C error for the measured interval. The results of those measurements indicated a median difference between air temperature and mean radiant temperature (calculated according to ASHRAE 55 [1]) of 0.4 °C in one day and 0 °C in the other. The difference between the air temperature and the mean radiant temperature during the period is common in conditioned office spaces [36] and therefore, can be ignored. The measurement of overall airspeed also occurred in two representative spots with a hot-wire probe attached to the Testo® 400 with a measurement range of 0 m/s to 5 m/s and accuracy of ±0.03 m/s + 4 % of the measured values. The results showed that 95 % of the time, on both days, the airspeed was lower than 0.2 m/s, showing that air conditioning produced a low airspeed. Additionally, a portable Testo® anemometer (405i, range from -20 °C to 60 °C, accuracy ± 0.5 °C) was used to check airspeed close to all participants' seats during the first days, and the air movement was lower than 0.1 m/s in all points.

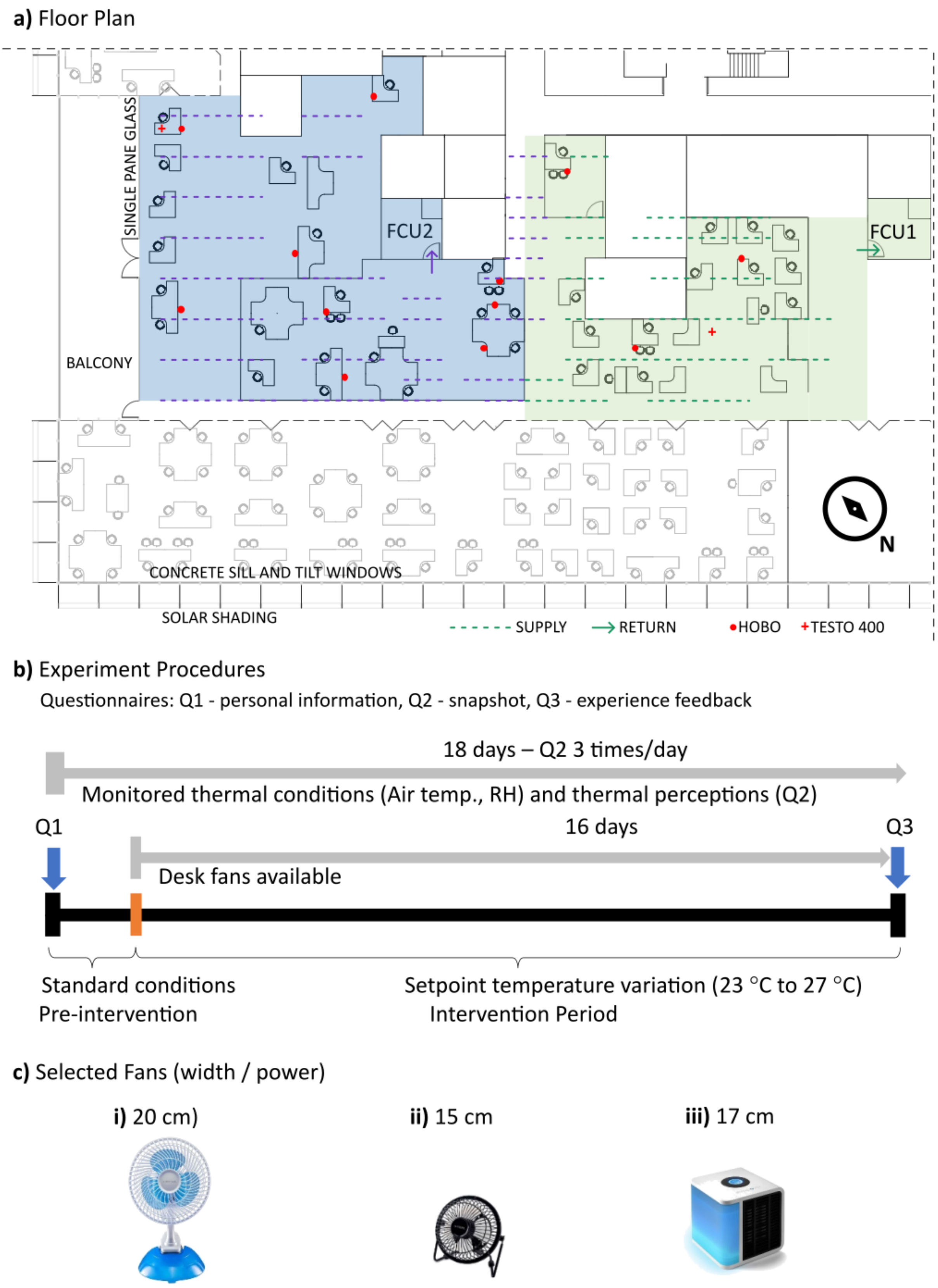

Figure 1. a) Experiment floor plan – studied areas hatched with two colors to indicate supplying fan-coil units (FCU1 and FCU2). The red dots indicate the location of measurement data loggers and the red crosses the sensors used for measuring the mean radiant temperature. The light grey layout indicates occupants not included in the study. The symbol in the bottom right indicates the north. b) Experiment procedures scheme and questionnaires. c) Selected fans with respective width sizes – characteristics described in [37].

### 2.2. Experiment Procedures

The experiment lasted 18 days from January to February 2021, which are the warmest months of the year in Florianopolis. Figure 1b shows the experiment procedures. The questionnaire Q1 had personal and background information questions and occupants answered it once. We recorded indoor air temperature and relative humidity during the whole experiment. The second questionnaire (Q2) was applied three times a day during the entire experimental period. Q2 was a snapshot questionnaire containing 5 questions about occupants' presence at their workstation, clothing, right-now thermal comfort (on a 4-level scale), right-now thermal preference (on a 3-level scale), and the status of the fan (on, off or not available). The experiment started under standard operation and the intervention started two days after, by providing a desk fan to each participant. During the intervention, participants could freely control the fans. Questionnaires Q1, Q2, and Q3 are presented in Appendix A.

Participants chose between two types of fans selected in a previous study [37] – options i and ii in Figure 1c. Option iii is an evaporative cooling fan used by only two participants – one manager and a participant who was feeling too warm during the experiment. Characteristics of the fans are detailed in [37]. One day after the fans were provided to occupants, we increased the setpoint temperature by 1 °C and monitored the responses. The strategy was to raise the setpoint temperature by 1 °C each day and monitor occupants' instantaneous responses to adjust the temperature when necessary. In case more than three "very uncomfortable" votes were identified, the setpoint would be reduced. After the complaints ceased, we tried higher setpoints again. The default setpoint was 23 °C, and the experiment ended after having at least 60 responses per setpoint temperature. Then, we applied a third questionnaire (Q3) to get feedback on the experience and help interpret the results. All questionnaires included a field for a pre-defined code to correlate answers per occupant while maintaining anonymity.

### 2.3. Data Processing and Statistical Analysis

The data from occupants and environmental variables were interconnected and analyzed using R and Rstudio with *tidyverse* [38], *Metrics* [39], *ggpubr* [40], *lme4* [41], *extrafonts* [42], *effsize* [43], *svglite* [44] and *scales* [45] packages. To test the intervention's impact on occupants' thermal perception and to answer the questions presented in the objectives, we grouped the data by different variables and applied statistical analyses. To compare the significance of differences between means, we used t-test. To evaluate the influence of environmental variables on occupants' perception, we used multiple coefficient regression analysis. The threshold for statistical significance was p-value < .05. To verify the effect size of variables over the results, the Spearman coefficient (rho) was calculated considering values as negligible (<0.2), low (0.2-0.5), moderate (0.50.8), and strong (>0.8). For the probability of no change and comfort (grouping very comfortable and just comfortable votes), Cliff's delta test was applied to assess the size of the difference, considering values as negligible (<0.15), small (0.15-0.33), medium (0.33-0.47), and large (>0.47) [46]. Participants' characteristics were analyzed to show significant differences and their influence on the results. Body mass index (BMI) was calculated based on height and weight according to [47] and clothing insulation was calculated based on [1].

## 3. Results

This section presents the main findings organized in the following sections: 1) Participants, 2) Temperature control and indoor conditions, 3) Thermal perception, and 4) Influencing factors.

### 3.1. Participants

In total, 34 people participated in the experiment, 65 % male and 35 % female. The average age was 43 years old with a standard deviation (sd.) of 11.2 and the average body mass index (BMI) was 26 – classified as pre-obese [47][48]– with sd. of 5. Mean clothing insulation was 0.5 clo. The dress code for men is stricter, they cannot wear shorts or light shoes. So, women's clothes showed greater variation (sd. 0.12 versus 0.02 for men). The absolute difference of means is small – 0.04 clo – which corresponds to underwear insulation. The average metabolic rate was estimated at 1.2 met with sd. of 0.2, indicating occupants to be in sedentary activity. The votes in which participants indicated not to be in their workstations were excluded from this analysis. BMI, age, or estimated metabolic rate showed no statistical difference between genders. Gender was asked instead of sex to account for diversity, but none of the participants indicated having other gender different from male or female. Therefore, the term sex will be used in the analysis.

### 3.2. Temperature Control and Indoor Conditions

As indicated above, during the experiment, the setpoint temperature changed from 23 °C, which was the standard, to 27 °C. Both systems (FCU1 and FCU2) received the same setting, simultaneously. However, as shown in Figure 2, setpoint and indoor air temperature presented a great mismatch. The median temperature during the experiment was 25 °C although 23 °C was the setpoint on most days (40 %). This means the HVAC was not able to maintain the setpoint most of the time. In addition, Figure 2 shows this control limitation was more critical during the afternoon when indoor temperatures tended to be higher.

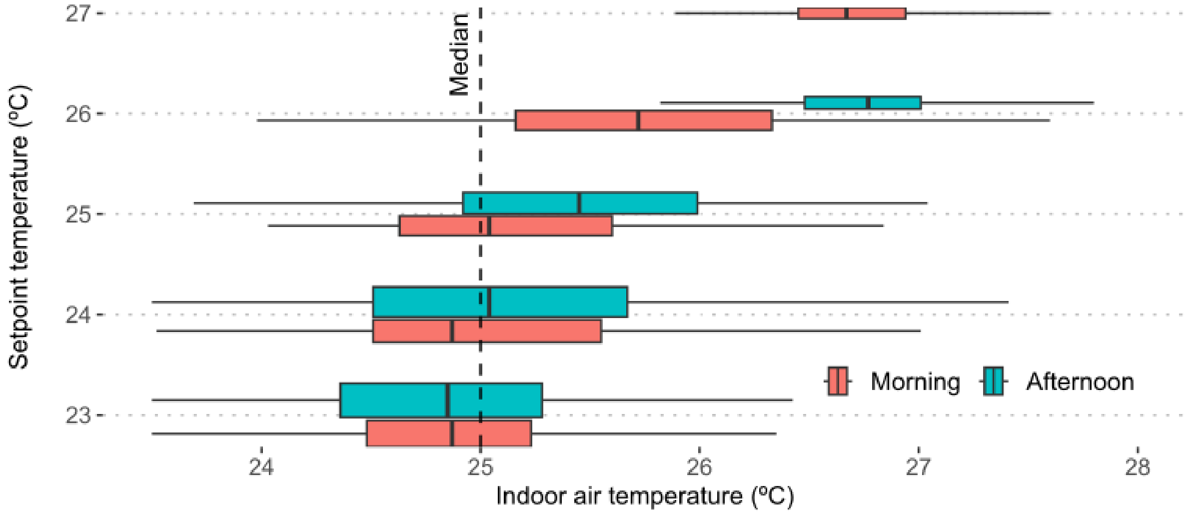

Figure 2. Setpoint temperature vs. indoor air temperature in the morning and afternoon. The thickness variation of the box plots represents sample size variation. The median of each box plot is represented by a solid line and the dashed line represents the overall median indoor air temperature.

This issue relates to the HVAC system design and control. During summer, the cooling runs from 6 am to 7 pm. Mechanical ventilation starts at the same time it is turned off later, between 9 and 10 pm to guarantee outdoor air circulation. Occupancy usually starts between 7 am and 8 am, but the HVAC starts 1h before to prepare the space for occupancy. The whole HVAC system runs with constant airflow, and to address the variable demands, each floor has 8 fan-coil units (FCU) with individual control. The duct, diffuser characteristics and pressure balance determine the airflow in each zone inlet; there are no variable air flow boxes or local reheat coils. Each FCU is installed inside a room that receives ducted outdoor air and return air from the zone through the door vents (see Figure 1a). Each FCU constantly mixes outdoor air with the return air, cools down the mix, and distributes it to each zone. The air is supplied from the ceiling via linear diffusers, as Figure 1a indicates. Usually, the chiller capacity is designed to meet a typical summer day demand with high outdoor temperatures. However, there is no dedicated air handling unit nor a heat exchange to pre-cool the outdoor air, which makes the heat load in the fan-coils vary greatly due to the variation in outdoor air conditions. During the experiment, it was not possible to change the chiller's supply temperature because it would affect other building areas not included in the experiment. The setpoint temperature change affected only one parameter – the position of the valve that controls cooled water circulation inside the FCU. These electronically controlled valves modulate the chilled water flow to each FCU to provide enough cold to maintain indoor air temperature close to the setpoint temperature based on the thermostat response.

Few buildings in Brazil have variable air volume or reheating, so this is a common design strategy for office buildings. However, results show the setpoint control precision was very low. Figure 3a shows there is a significant correlation between indoor air temperature and outdoor air temperature when outdoor air temperature surpasses 24 °C ($p < 0.01$). Despite the small effect size (rho = 0.35), Figure 3a shows that the higher the outdoor temperature, the less the setpoint corresponds to indoor air temperature. That trend is clear by observing the 23 °C setpoint in Figure 3a. On the other hand, indoor air temperature does not exceed 27 °C, even when outdoor air temperature reaches 34 °C. This means the air-conditioning presented a low control precision but was able to maintain this maximum limit. Indoor relative humidity (RH), in Figure 3b, shows a smaller variation, staying mainly between 60 % and 70 % during the experiment. This could indicate a higher humidity control capacity, but these values are higher than design standards, which are usually 55-50 % RH. Thus, the air-conditioning was able to block very hot and humid conditions to a certain extent, but its control accuracy was very low.

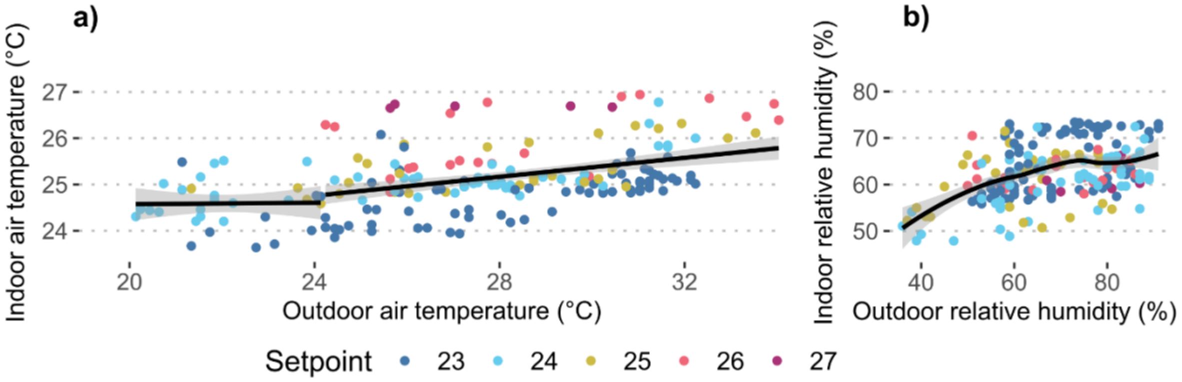

Figure 3. Indoor vs. Outdoor conditions: a) temperature, b) relative humidity. Colors indicate setpoint temperatures.

Consequently, the experiment's results were affected and the setpoint did not correspond to indoor air temperature. Because of this mismatch, the results were analyzed based on indoor air temperature.

### 3.3. Thermal Perception

Figure 4 shows the comparison of occupants' perception in pre-intervention (without fans) and post-intervention (with fans available). Figure 4a shows the availability of desk fans increased the percentage of preference for "no change" at every temperature bin. Cliff's test indicates a large difference between the probability of "no change" with and without fans (delta = -48 %). For both with and without fans, the higher percentage of no change occurs between 24 °C and 25 °C, and the availability of fans increased satisfaction by 18 % for that temperature interval. Figure 4b shows the mean preferred temperature (corresponding to "no change" votes) increased by 0.9 °C and the standard deviation reduced – from 24.1 °C (sd. 0.86) to 25 °C (sd. 0.69). The interval between the 1st and 3rd quartiles is the same but shifted up by 1 °C – from 23.6-24.6 °C without fans to 24.6-25.5 °C with fans. This means the availability of fans had a positive impact on occupants' thermal preference leading to the acceptance of a higher room temperature.

Regarding occupants' thermal comfort, Figure 4c also shows a higher percentage of very comfortable votes in the period with fans. On the other hand, the amount of just uncomfortable votes increased at 24-26 °C and this period had few very uncomfortable votes. This could indicate a decreased perception of comfort when fans were available, and the air temperature was higher than 24 °C. Nevertheless, when the comfortable (just and very comfortable) temperature ranges are compared in Figure 4d, we also observe higher quartile values when fans were available – from 23.7-24.8 °C in the pre-intervention to 24.6-25.6 °C in the post-intervention. The mean comfortable temperatures are closer than the preferred temperature, 24.4 °C (sd. 0.87) without fans and 25 °C (sd. 0.74) with fans. For this reason, Cliff's test showed the probability of a significant difference in comfortable votes with and without fans to be negligible (delta = -5 %).

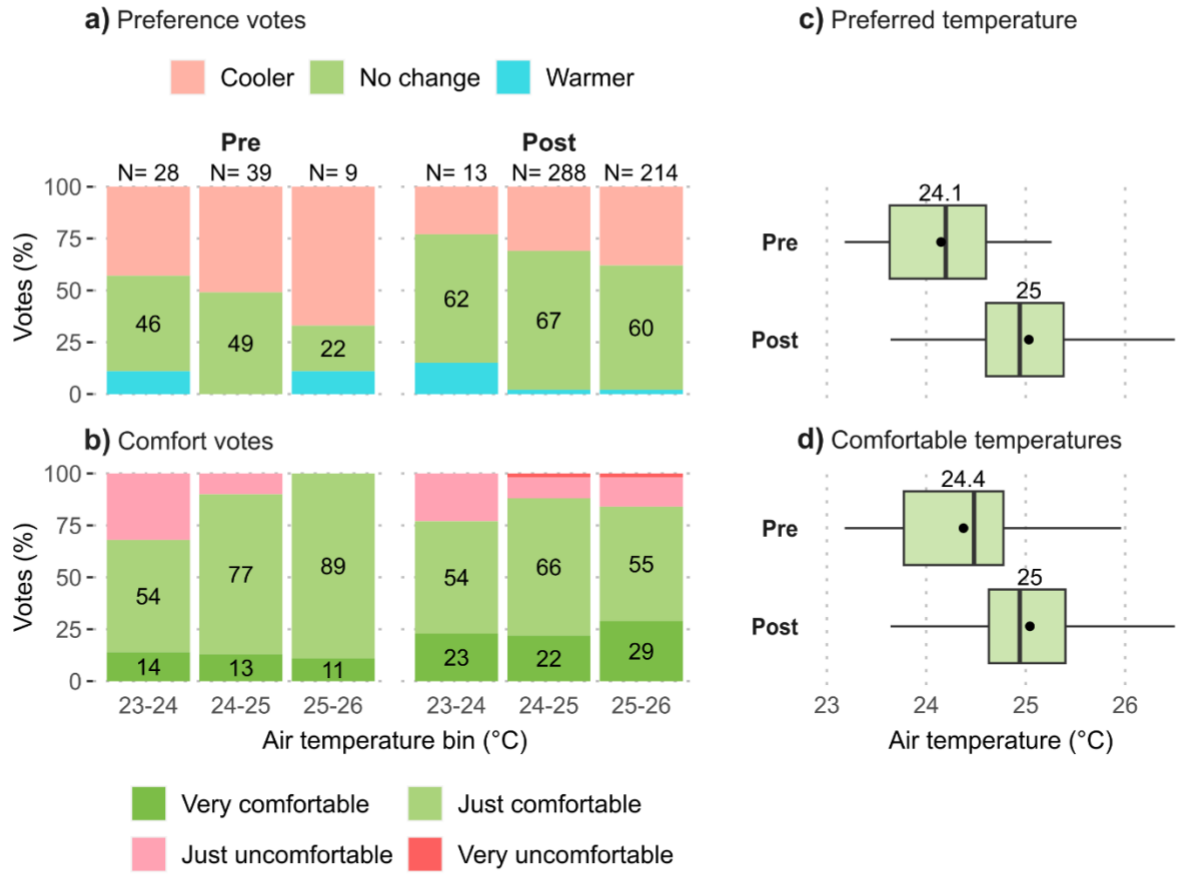

Figure 4. Thermal perception a) preference votes and b) comfort votes by temperature bin and, c) preferred temperatures (no change) and d) comfortable temperatures (just and very comfortable) in the pre (without fans) and post (with fans) periods. The numbers in figures c) and d) indicate the mean values.

This could stem from the high percentage of comfortable votes during the experiment resulting in a smaller difference between periods. The sum of just and very comfortable votes was always higher than the “no change” votes percentage – comparing Figure 4a and Figure 4b. These indicate fans met occupants’ preferences but seem not to significantly affect the less restrictive occupants’ comfort. To further understand this result, Figure 5 the daily percentage of comfort in Figure 5 (bar plot) is compared to the indoor air temperature (box plots) and mean outdoor air temperatures ($T_{out}$ in dashed line). Figure 5 also shows the setpoint of each day (triangles).

In the first week, comfortable votes increased gradually after the intervention (as of January 12) following the increase in setpoint temperature. However, in the second week, although the setpoint on January 17 was the same as January 14 (25 °C), the indoor air temperature increased a lot due to high outdoor temperatures ($T_{out}$). That abrupt increase generated very uncomfortable votes. The next day, the recording of three “very uncomfortable” votes prompted the reduction of the setpoint back to default, 23 °C. However, the “very uncomfortable” votes did not disappear, and operators received complaints. Although indoor air temperature decreased, the very uncomfortable votes lasted five working days, showing persistent discomfort was a psychological phenomenon. After one day without very uncomfortable votes, the setpoint was raised again – on January 26. Finally, in the last three days of the study (week 4), the mean indoor temperature was 1 °C higher than the pre-intervention period – 24.2 °C and 25.2 °C, respectively – and the daily percentage of comfort was similar (~ 80 %). This indicates the acceptance of a 1 °C increment by the end of the experiment.

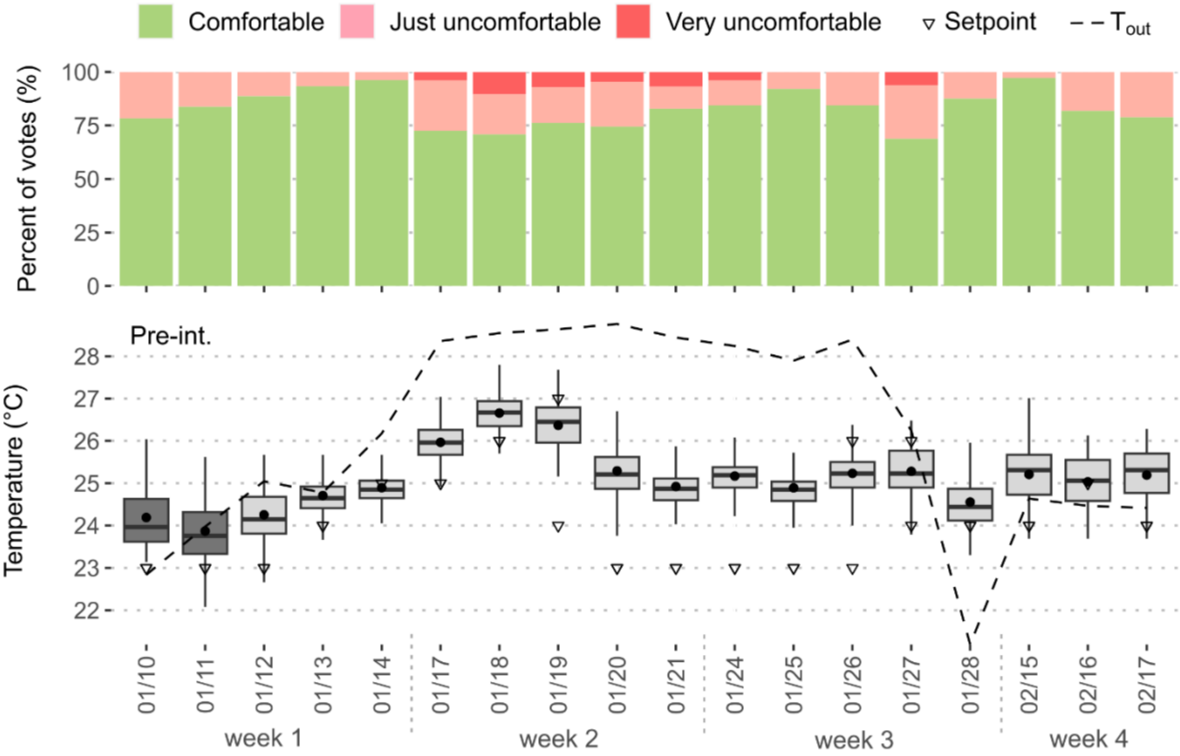

Figure 5. Percent of daily thermal comfort votes compared to daily indoor air temperature variation (box plots). Very comfortable and just comfortable votes grouped as "comfortable". The dashed line indicates the daily mean outdoor air temperature ($T_{out}$). Pre-intervention (Pre-int.) period indoor air temperature box plots are in dark grey. Dates are grouped by week.

### 3.4. Influencing Factors

Figure 5 shows how outdoor temperature influenced indoor air temperature and occupants' thermal comfort. The multiple regression probability analysis indicated mean outdoor air temperature significantly influenced occupants' comfort but was not significant to thermal preference votes. In contrast, indoor air temperature was found to influence significantly thermal preference but not thermal comfort. The experiment period (pre- or post-intervention) and fan status (on/off) at the answering was a significant factor only for preference.

A great difference was found regarding fan activation period among occupants, some of them kept the fan on most of the time, while others indicated it to be on only in one response. Preference for a warmer environment was mostly indicated by women (17 out of 18), and 10 out of those votes were reported by the same woman. This sex difference is not related to clothing as women's clothing was not the lightest in the set and the most uncomfortable one usually wore a jacket – 0.81 clo and the mean was 0.5 clo. A multiple regression analysis showed sex significantly influenced the probability of preference but not the probability of comfort. The air temperature increment reduced the cold discomfort of women (from 16 % to 6 %) while the fans reduced the warmth discomfort of men (from 63 % to 46 %). Additionally, the temperatures corresponding to a higher percentage of "no change" votes were very different for each participant, although the temperatures were very similar per sex during the intervention period. Age and clothing were not influential factors, but BMI was. Female's average BMI was lower (23) than male's (29), showing BMI and sex are correlated.

Despite these expected personal variations, the only possible variation in temperature control would be setting a different setpoint to FCU1 and 2. The maximum air temperature difference between the experiment areas (supplied by FCU1 and FCU2) during the intervention was 1.3 °C. However, the average temperature they were exposed to was similar. Therefore, the mean preferred and comfortable temperatures between both groups were the same. Therefore, the regression analysis showed the system identifier was not significantly correlated to the probability of comfort or preference. This means that the same temperature could be set for both building areas, not demanding different adjustments despite the sex variation.

## 4. Discussion

In this section, the results are discussed based on the answers to the main questions that we believe professionals or researchers interested in implementing office fans should have. Some of these insights were also incorporated into the CBE fan guide [48]. The study limitations are also discussed at the end of the discussion.

### 4.1. Why Implementing Desk Fans in Shared Office Spaces?

As shown in this study, desk fans increased the number of occupants' "no change" votes by ~20 % and increased the very comfortable votes by ~10 %. Like in a previous study [32], some occupants did not foresee a fan as helpful equipment but that changed after the experiment. Before the intervention (in Q1), only 3 participants out of 25 – who answered Q1 and Q3 questionnaires – preferred air conditioning (AC) with fans as a conditioning mode for hot days. Most of them (13 people) preferred AC without fans. However, after the experiment, 12 people indicated preferring AC with fans. This highlights not only the effectiveness of desk fans in meeting occupants' demands but also the positive impact of increasing occupants' controllability. Moreover, this before and after comparison hints that we should provide desk fans to occupants because having the opportunity to use them exceeded their initial expectations of use. Additionally, this experiment showed desk fans can increase occupants' thermal satisfaction.

The association with setpoint extension has the potential to generate energy savings. In this study, results show indoor temperature could be extended by 1 °C. Increasing temperature setpoints saves energy as the cooling demand is reduced. The impact is greater if the HVAC system (chiller, cooling tower and supply air temperature setpoints) are tuned for it [49]. In this study, we were not able to change the HVAC setpoints because this would affect the entire building beyond the intervention area, where occupants did not have access to desk fans. Additionally, the fan coils would save energy if the fan power and air flow were not constant and/or the outdoor air was pre-cooled [22]. Unfortunately, we were not able to measure energy consumption during the experiment due to technical limitations. Nevertheless, changing the setpoint by 1 °C – from 24 °C to 25 °C – in a 2A climate location, like Florianopolis, is estimated by [12] to produce around 9 % of energy savings [12]. Fans also increase energy consumption, so a common question is if this increment would be worth it. Based on previous studies [49,50], by adding 3-10 W desk fans, like the ones used in this experiment [37], the building's annual energy consumption is expected to increase by less than 2 % provided all occupants used them all the time. Similarly, Kent et al. [10] measured 32 % energy reduction in a similar experiment where the setpoint was raised from 24 °C to 26.5 °C, and fans represented 3.5 % of energy use. Therefore, the worst-case net savings in this study could be 7 %, which is still expressive given the low cost of fans and long-term energy cost savings. The financial benefits of thermal comfort are harder to quantify, but would be positive for the cost-effectiveness of this strategy, considering the potential increment of worker retention and reduction of sick leaves.

Additionally, desk fans enhance perceived air quality and space air mixing. Fan only recirculates air, not directly cleaning the air. Although most of the studies available are based on ceiling fans, they show that increasing air movement can increase air mixture, dispersing $CO_2$ and other pollutants, reducing their concentrations in the breathing zone [51,52], and increasing ventilation effectiveness [53]. Nevertheless, in some situations, increasing air mixture may increase some occupants' exposure to pollutants, and more studies are necessary to define those boundaries. Air movement increases perceived air quality [8]. This experiment did not measure this effect because, as indicated by [51], the ambient concentration level that could be more easily measured on the field would underestimate the effect on the breathing zone.

## 4.2. How to Prepare for the Implementation?

The pre-intervention period is very important. This period should be used to collect data about the standard operation and to diagnose and understand the HVAC system design, operation, and control capability. Different from previous studies [22], in this experiment, HVAC showed poor control of indoor temperature when outdoor air temperature increased. Probably a longer pre-intervention period could have helped to identify this issue. In case of similar issues, additional tests can be proposed to understand how much and under which conditions indoor temperature can be better controlled. Unoccupied periods, on weekends, for example, can be used to perform some tests to avoid disturbing occupants and help to prepare for the intervention.

Additionally, building operators are a great source of information, as they deal with the system daily, and their experience is valuable [54]. Therefore, they can help to review and define an experiment protocol and should participate in and/or lead the intervention to avoid common mismatches between researchers' expectations and the building reality [55]. To do that, operators should be informed of the goals and benefits of the intervention, to engage in the process. Similarly, occupants should be aware of the intervention goals and benefits before any change is applied.

## 4.3. What is the Necessary Sample Size of Occupants' Votes?

For statistical analysis or generalizing the results we usually need large sample sizes. For academic purposes, a power analysis should be performed to define the sample size [56] and the possible variations along the experiment should be considered. In this experiment the pre-intervention period was too short and showed a lower variation of temperature, making it more difficult to compare to the conditions in the post-intervention. A longer pre-intervention period could have helped to increase the sample size by temperature bin and consequently the statistical relevance. Additionally, repeating the experiment in the opposite order, as in [10] would reduce the confounding effects significance and the impact of introducing a new system. Another important aspect is that, in a real-life implementation of a new system and operation strategy in an existing building, you should focus on gathering the information you need, bothering occupants as little as possible. Therefore, the survey should be short and the application frequency as low as possible. An automatic system that sends the survey only when the new data point would substantially increase the information gathered should be implemented [57]. Another option is sending surveys based on procedure changes. For example, if the pre-intervention period has a very stable temperature, occupants can be surveyed once, because the result will represent well their overall perception. Then, they can be surveyed again upon implementing an intervention, for example, after making fans available and before changing the temperature. The next survey application would be after the first temperature increment, and so on. Nevertheless, when considering an adaptation period, which will be discussed in the following sections, it is better to apply surveys by the end of a test period, so occupants are used to the new setting or condition. The size of the questionnaire derives from the next question.

## 4.4. What Thermal Perception Scale to Use?

In this study, we used two thermal perception questions and scales – 3-level preference and 4-level comfort. As discussed before [14,18], there is a great variation of thermal comfort scales used among studies. The use of two scales in this experiment aimed at having complementary information as occupants could be too sensitive or too accepting, so one scale could be used to indicate the intensity of their need to change the temperature. In a way, the comfort scale fulfilled this function, as the "very discomfort" votes indicated how uncomfortable the occupants were. However, this intention was not presented to participants, so their understanding was diverse. In Q3, we asked occupants what they would expect to be used as an indicator for automatic setpoint change if the surveys had that purpose. The responses were not as expected, 40 % would expect a temperature adjustment when they indicated to prefer a cooler or warmer environment. Another 44 % indicated a preference for change associated with "just uncomfortable" votes would be a good indicator. Only three individuals expected a change based on their preferences for change and a "very uncomfortable" vote. This result is in line with previous studies that indicate the comprehension of the thermal perception scale may vary greatly among people [58]. On the other hand, the results showed participants are more restrictive when asked about their preferences, which is also in line with previous studies [16]. Therefore, using two scales increased complexity and response time without clearly adding information to the process. Therefore, the 3-level preference scale can be used as the only indicator for evaluating occupants' thermal perception. Additionally, presenting the scale to participants and how it is going to be used for control or automation is highly recommended.

### 4.5. How Much Can the Temperature Be Extended?

The results from this study indicate the potential to extend indoor air temperature by 1 °C – from 24 °C to 25 °C. This small spam limit was probably affected by the length of the experiment and the controllability limitations. Previous studies found 26 °C to be a feasible temperature when desk fans [24] or ceiling fans [10,22] are available. Therefore, 26 °C can be considered a reference for future studies, although not a universal value applies to all locations and buildings. This and previous intervention studies used a similar approach to define the temperature limit, increasing it until receiving too many complaints or occupants getting too dissatisfied [22,24]. This approach has the big disadvantage of disturbing occupants, which can generate persistent discomfort as observed in this experiment. Occupants' annoyance lasted 4 days after the setpoint was reset to the default value. This indicates discomfort caused psychological effects and negatively affected their expectations towards the building's indoor environment and HVAC control. To avoid this issue, we tried to identify some referential limit that could be established based on the results considering the hypothesis that the discomfort was triggered by expectation disruption. To do that, we tested different indicators presented in Table 1 from previous studies related to adaptation and expectation.

The adaptive model indicates indoor operative temperature accepted by occupants is mainly influenced by prevailing mean outdoor air temperature ($T_{pma}$). This correlation is stronger for naturally ventilated buildings [1,59]. However, as in this building, outdoor air temperature ($T_{out}$) showed a significant correlation to thermal perception and influenced indoor air temperature (see section 3.2), this index could apply to this study. Therefore, the number of hours indoor air temperature surpassed $T_{pma}$ was calculated and compared to the percentage of daily comfort votes and preference for no change. Other indexes tested were the proportion of time in which indoor temperature exceeded the 80th and 90th upper percentile (Q80, Q90) temperature of the pre-intervention period. This is inspired by Peixian et al. [16] who identified occupants' comfort votes as mainly correlated to the 80th percentile (Q80) of indoor operative temperature. Indicating a high occurrence of temperatures broader than the usual range (that occurs 80 % or 90 % of the time) could increase the probability of discomfort. Similarly, a moving percentile was tested. The Q80-2 and Q90-2 consider a possible adaptation along the week, causing people to be more influenced by the temperature of the 2 prior days. We also tested the influence of delta temperature (D indexes) to verify if the problem was related to the rapid increase of temperatures (Q indexes), or its variability to the previous day. Table 1 shows the linear correlation of the presented index values to the daily percentile of comfortable votes and preference for "no change" votes.

Table 1. Linear correlation to percentile of comfort and preference votes. The * indicates significant values ($p<0.05$).

| Name | Meaning | Correlation to (rho) | |
|---|---|---|---|
| | | Comfort | Preference |
| $T_{pma}$ | Freq. of $T_a$ higher than $T_{pma}$ | -0.46 | -0.20 |
| Q80 | Freq. $T_a$ higher than 80th value of pre-int. | -0.37 | -0.1 |
| Q90 | Freq. $T_a$ higher than 90th value of pre-int. | -0.74* | -0.54* |
| Q80-2 | Freq. $T_a$ higher than 80th value of 2 prev. days | -0.24 | -0.43 |
| Q90-2 | Freq. $T_a$ higher than 90th value of 2 prev. days | -0.31 | -0.56* |
| D80 | Delta 80th $T_a$ of the day before | -0.07 | -0.02 |
| $D_{mean}$ | Delta mean $T_a$ of the day before | -0.006 | -0.002 |
| $D_{max}$ | Delta maximum $T_a$ of the day before | -0.13 | -0.16 |

Unlike [16], only the 90th percentile (Q90) of the pre-intervention period was significantly correlated to both comfort and preference votes. $T_{pma}$ is almost significant for comfort with a p-value of 0.054. The Q90-2 is significantly correlated to preference, with a similar effect size than Q90. Nevertheless, the effect size of Q90 over comfort is higher than the ones related to preference (0.74 vs 0.56 and 0.54). The 90th percentile temperature was 25.2 °C, which is 1.2 °C higher than the mean pre-intervention temperature. Therefore, this result indicates that, when this usual upper limit was exceeded, occupants' thermal satisfaction decreased significantly. Although the 90th percentile of a pre-intervention period needs further validation, it could be used to limit the temperature extension to avoid occupants' discomfort in future interventions. One of the main results of the study, reinforced by this analysis is that gradual change is necessary to accommodate occupants' adaptation, which leads to the next question.

### 4.6. How Long Does It Take for Occupants to Adapt to Temperature Change?

In almost one month, occupants adapted to a 1 °C average increment, which highlights adaptation period might be long. The literature does not indicate what is the minimum adaptation period for sedentary occupants under long-term exposure. The human body can reach neutrality within 37-47 minutes when exposed to a thermal overshoot in a transitory environment [60]. For longer exposures, the literature only presents periods for participants under high-intensity exercises [61,62] which is a physiological response to an extreme condition. However, the adaptation for low metabolic rate activities and under long exposure can be expected to be longer because human thermalregulation is less in demand [63]. Therefore, this is still a literature gap. However, based on our experience and previous studies [10,22,31], at least two weeks under a stable air temperature are necessary for psychological, and behavioral adaptation.

### 4.7. Is it Possible to Automate the HVAC Temperature Control After Identifying Satisfaction Limits?

Considering temperature adjustment automation strategy, a previous study suggested occupants' preferences could be predicted based on personal comfort system operation [30]. However, as mentioned before, fan status was only significantly correlated to preference votes. The probability model based on air temperature and fan activation presented a Mean Absolute Error (MAE) of 0.68 for preference for "no change" votes and 0.28 for comfortable votes Figure 6 shows no clear trend between the percentage of activated fans and the percentage of comfort or preference votes. The same percentage of votes relates to any percentage of fan activation, from 0 % to 100 %. Therefore, including the fan status in an automation scheme would not be beneficial.

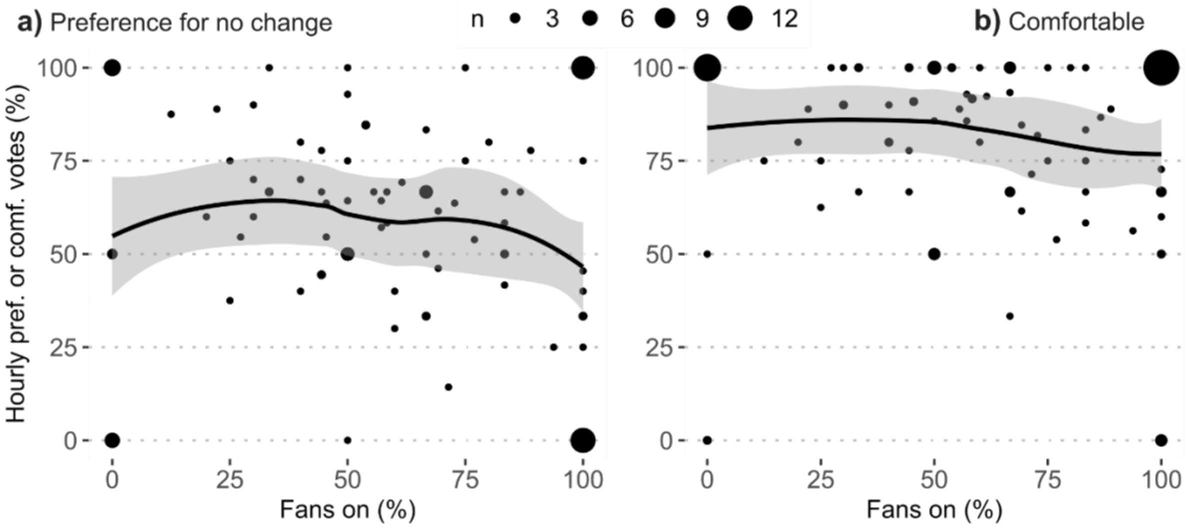

Figure 6. Percentage of fans on by a) votes of preference for no change, and b) comfortable votes (just comfort and very comfortable).

Indoor setpoint temperature could be automatically controlled based on air temperature and occupants' thermal perception. However, year-long data is necessary to weigh seasonal variations. Previous studies showed occupants forget to use desk fans [32]. Therefore, automatic activation according to occupancy would be beneficial if occupants can override settings [49]. For PCS that supply cooling or heating, integration into the central system is crucial so conflicts of activation and energy waste [54,64] are avoided. Nevertheless, desk fans do not affect cooling setpoint, therefore, this integration is not necessary, and a simpler implementation procedure can be applied. Determining cooling seasonal setpoints would be sufficient for office spaces without heating systems.

At the same time, it is important to check if different groups of people present different acceptability within the same building. In this study, a unified setpoint would be enough because the multi-regression analysis showed the system identifier was not significantly related to the probability of comfort and preferences. However, in another building the results might be different, so the survey responses should be analyzed per group of people. Also, a statistical analysis should be performed to identify if the differences are significant and, therefore, it is worth setting a different temperature for each group. In any case, the size of these groups must be determined by the HVAC zoning and be related to the HVAC system control capability.

### 4.8. Study limitations

Many constraints affected the results of this study, limiting the possibility of generalizing the outcomes. The first one was the HVAC control issues, which affected the stability of indoor air temperature and its correlation to the setpoint temperature. In other buildings, with better controls, the results would probably be different. The control issue associated with the great outdoor temperature variation between pre- and post-intervention periods affected considerably the results. Initially, the pre-intervention period was short because indoor air temperature was expected to be constant. However, that was not the case, and the sample size imbalance hindered the analysis. Extending both periods and repeating the experiment in a different order, like done in [10], would enable the assessment of the intervention impact, and the extension of sample sizes could increase statistical power. A longer study could have demonstrated acceptability to a higher indoor temperature and the 90th percentile limit could be recalculated after adaptation was verified. Nevertheless, this limit could not be extended indefinitely. In this building, the limit is expected to vary seasonally, demanding a year-round study to define a strategy for setpoint control when fans are available. A suggested strategy would be to use the setpoint identified during summer, surveying occupants at the beginning and end of each month/season depending on the expected indoor temperature variation and keeping an open communication channel in case there is a need for a daily adjustment. Another limitation relates to space restriction. Only by implementing this strategy into the whole building would it be possible to evaluate the variation among building areas and necessary local adjustments of setpoints, which might be more significantly different between floors and zones. These case-dependent variables should be considered to identify the most suitable control granularity and influencing factors. For instance, in this study, relative humidity (RH) was not an influencing factor because it presented a low mean variation, which is related to the local climate characteristics. However, in other conditions, RH could hinder fans' effectiveness [65,66].

## 5. Conclusions

This study presented the results of a practical implementation of desk fans in an open office during summer. Despite some limitations, the implementation increased occupant thermal satisfaction under slightly higher temperatures, which has the potential to save energy. Occupants' preference for no thermal change increased by 20 % with the use of fans and the preferred indoor air temperature increased by 1 °C. In this process, we identified the main challenges and suggested guidelines based on the lessons learned for the successful implementation of desk fans associated with room temperature extension.

- HVAC control:
    - Challenge: HVAC system temperature control might not be optimal. In this study, the setpoint did not equal the air temperatures in the space.
    - Guidelines: 1) Pre-intervention period should be used to understand the HVAC system design and operation. 2) Operators should be involved and validate intervention procedures. 3) Procedures should be adapted to system capability and limitations.
- Setpoint temperature adjustment:
    - Challenges: The adjustment of setpoint temperature can cause discomfort and standard limits might not be accepted. Psychological and behavioral adaptation periods are still undetermined.
    - Guidelines: 1) Modifications should be applied gradually with small temperature variations. 2) The 90th percentile temperature range of the pre-intervention period is suggested as a limit reference for initial temperature extension. 3) Two weeks is the minimum expected period for adaptation. 4) The impact of temperature changes needs to be closely monitored. Short surveys are recommended to capture occupants' perception.
- Participants engagement
    - Challenges: Occupants do not want to be disturbed and might be reluctant to try something new, accept changes and give feedback.
    - Guidelines: 1) Inform participants of the intervention benefits, disclose the procedures and what will be the follow-up of their feedback. 2) Define an action plan for discomfort and keep communication with occupants in addition to the regular surveys. 3) Make fans available for all participants and let them choose from different fan options. 4) Reduce survey questions to a minimum by assessing perception just with a 3-level thermal preference scale. 5) Limit survey application to once in the pre-intervention period for diagnosis, and 2-3 weeks after any intervention or change for comparison. 6) Analyze the responses per group based on HVAC zoning and check if the differences found are significant and variations are necessary.

## CRediT authorship contribution statement

**Maíra André**: Methodology, Formal analysis, Investigation, Writing - Original Draft, Visualization, Conceptualization, Data curation, Software. **Stefano Schiavon**: Methodology, Writing - Review & Editing, Visualization, Validation, Conceptualization. **Roberto Lamberts**: Methodology, Writing - Review & Editing, Conceptualization, Supervision, Resources, Funding acquisition.

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# APPENDIX A – QUESTIONNAIRES

The following tables present the questionnaires in two languages (LNG), English (EN) and the original language of the study, Brazilian Portuguese (PT).

Table A. 1 - Personal information (Q1)

| No. | LNG | Question | Answering options |
|---|---|---|---|
| 1 | EN | Write your initials followed by your year of birth (e.g., AR85) | Open-ended |
|  | PT | Escreva as iniciais do seu nome seguido do seu ano de nascimento (ex.: AR85) |  |
| 2 | EN | Indicate your gender | Female/Male/Other |
|  | PT | Identifique o seu gênero: | Feminino/Masculino/Outro |
| 3 | EN | What is your age? (in years, e.g., 40) | Open-ended, only numbers |
|  | PT | Qual a sua idade (em anos, ex.: 40)? |  |
| 4 | EN | What is your weight? (in kg, e.g., 70) | Open-ended, only numbers |
|  | PT | Indique seu peso aproximado (em kg, ex.: 70) |  |
| 5 | EN | What is your height? (in m, e.g., 1.70) | Open-ended, only numbers |
|  | PT | Indique sua altura aproximada (em m, ex.: 1.65) |  |
| 6 | EN | How long have you been working in this building? | "Less than 1 year", "more than 1 year", "other" |
|  | PT | Há quanto tempo você trabalha neste edifício? | "Há menos de 1 ano", "há mais de 1 ano", "outro" |
| 7 | EN | What is your regular commuting method? | "walk", "car", "bus", "bike", "other" |
|  | PT | Como você costuma vir ao trabalho? | "A pé", "de carro", "de ônibus", "de bicicleta", "outro" |
| 8 | EN | Do you exercise regularly? | "No", "Yes, once a week", "Yes, two or more days a week", "other" |
|  | PT | Você faz atividade física regularmente? | "Não", "sim, 1 vez por semana", "sim, 2 ou mais vezes por semana", "outro" |
| 9 | EN | Are you used to turning on the air-conditioning in your house or car during warm days? If yes, indicate in which places: | "Yes, in my house", "yes, in my car", "yes, in my house and car", "no, neither", "other" |
|  | PT | Você costuma utilizar ar condicionado em sua casa ou carro nos dias de calor? Marque sim ou não e se sim, o(s) local(is) de uso: | "Sim, em casa", "sim, no carro", "sim, em casa e no carro", "não, nem em casa nem no carro" |
| 10 | EN | Do you have or would like to have a fan at your workplace during warm days? | "I like and use fans", "I don't have it, but I think I would like it", "I don't have it, but I think I would not like it", "I don't have it and do not know if I would like it", "other" |

| | | | |
|---|---|---|---|
| | PT | Você possui e/ou acha que gostaria de utilizar um ventilador no seu ambiente de trabalho nos dias de calor? | “Eu gosto e uso ventilador”, “não possuo, mas acho que gostaria.”, “não possuo, mas acho que não gostaria”, “não possuo e não sei se gostaria”, “outro” |
| 11 | EN | Imagine you work in an IDEAL ENVIRONMENT. On warm days what would you prefer: | “air-conditioning”, “natural ventilation”, “natural ventilation with fan”, “air conditioning with fan” |
| | PT | Imaginando que você trabalhasse em um AMBIENTE IDEAL, nos dias quentes você preferiria utilizar: | “Ar condicionado”, “ventilação natural apenas”, “ventilação natural com ventilador”, “ar condicionado com ventilador” |
| 12 | EN | In your workspace do you usually feel: | “Always warm”, “warmer than colder”, “warm on hot days and cold on cold days”, “neither cold nor hot, usually I am comfortable”, “colder than warmer”, “always cold”, “other” |
| | PT | No seu atual ambiente de trabalho, você considera que, no geral: | “Sente sempre calor”, “sente mais calor do que frio”, “sente calor nos dias mais quentes e frio nos dias mais frios”, “não sente frio nem calor e a maior parte do tempo está confortável”, “sente mais frio do que calor”, “sente sempre frio”, “outro” |

Table A. 2 - Snapshot (Q2)

| No. | LNG | Question | Answering options |
|---|---|---|---|
| 1 | EN | Write your initials followed by your year of birth (e.g., AR85) | Open-ended |
| | PT | Escreva as iniciais do seu nome seguido do seu ano de nascimento (ex.: AR85) | |
| 2 | EN | Are you in workstation? If yes, for how long? | “Yes, more than 20 minutes”, “yes, less than or equal to 20 minutes”, “no, I am not in my workstation” |
| | PT | Você está no seu posto de trabalho? Se sim, indique há quanto tempo você está sentado: | “Sim, estou há mais de 20 minutos”, “sim, estou há 20 minutos ou menos”, “não estou no meu posto de trabalho” |
| 3 | EN | Which of the images better describes your clothing now? (consider long skirt=pants and short skirt=shorts) |  |
| | PT | Qual imagem melhor descreve sua vestimenta neste momento? (no caso de saia, longa=calça, curta=short) | |

| No. | LNG | Question | Answering options |
|---|---|---|---|
| 4 | EN | How would you rate the thermal conditions right now? | “Very comfortable”, “just comfortable”, “just uncomfortable”, “very uncomfortable” |
| | PT | Como você avalia a temperatura neste momento? | “Muito confortável”, “apenas confortável”, “apenas desconfortável”, “muito desconfortável” |
| 5 | EN | How would you prefer the temperature to be now? | “Warmer”, “no change”, “cooler” |
| | PT | Como você preferia que a temperatura do ambiente estivesse neste momento? | “Mais quente”, “como está”, “mais fria” |
| 6 | EN | Right now, your fan is: | “On”, “off”, “I don’t have a fan” |
| | PT | Neste momento, seu ventilador de mesa está: | “Ligado”, “desligado”, “eu não possuo ventilador” |

Table A. 3 - Feedback about the experiment (Q3)

| No. | LNG | Question | Answering options |
|---|---|---|---|
| 1 | EN | Write your initials followed by your year of birth (e.g., AR85) | Open-ended |
| | PT | Escreva as iniciais do seu nome seguido do seu ano de nascimento (ex.: AR85) | |
| 2 | EN | Overall rate the experience of having a personal fan on a 5-number scale: | 1= “Very interesting”, 5= “very uninteresting” |
| | PT | De forma geral avalie a experiência de ter um ventilador pessoal em uma escala de 5 números: | 1= “Muito interessante”, 5= “muito pouco interessante” |
| 3 | EN | Rate the following characteristics of your fan: aesthetics, size, noise, air flow sensation, adjustability, cooling effect | “Very good”, “good”, “neither good nor bad”, “bad”, “very bad” |
| | PT | Avalie o desempenho do ventilador que você possui nesse momento:<br>Categorias: estética, tamanho, ruído, sensação do vento, possibilidade de controle do vento, efeito de redução do calor | “Muito bom”, “bom”, “nem bom nem ruim”, “ruim”, “muito ruim” |
| 4 | EN | Would you like this fan to be better in some aspect or have any additional features? | Open-ended |
| | PT | Você gostaria que esse ventilador tivesse alguma outra funcionalidade ou algum aspecto fosse melhor? | |
| 5 | EN | Do you think the fan helped to maintain your comfort during summer? | “Yes, it helped in most of the days”, “Yes, it helped in the warmer days”, Yes, but it was not enough in the warmer days”, “It did not make much difference”, “No, I did not use it much”, “other” |

| No. | LNG | Question | Answering options |
|---|---|---|---|
| | PT | Você considera que o ventilador ajudou a manter seu conforto nesse verão? | “Sim, ajudou na maioria dos dias”, “sim, ajudou nos dias mais quentes”, “sim, mas não foi suficiente para os dias mais quentes”, “não fez muita diferença”, “não, utilizei muito pouco”, “outro” |
| 6 | EN | Did you change the fan position during the experiment? | “Yes, often”, “Yes, sometimes”, “No” |
| | PT | Você mudou a posição do seu ventilador ao longo do experimento? | “Sim, frequentemente”, “sim, algumas vezes”, “não, mantive sempre na mesma posição” |
| 7 | EN | What were the reasons for changing the position? | “To put it closer to me to increase the effect”, “to put it away from me because of excessive effect”, “putting it somewhere that would interfere less with my tasks”, “other” |
| | PT | Por favor, indique todos os motivos da(s) mudança(s): | “Deixá-lo mais perto de mim ou em um lugar que aumentasse seu efeito”, “deixá-lo mais longe pois o vento era excessivo”, “colocá-lo em um lugar que atrapalhasse menos minhas tarefas”, “outro” |
| 8 | EN | Imagine you work in an IDEAL ENVIRONMENT. On warm days what would you prefer: | “air-conditioning”, “natural ventilation”, “natural ventilation with fan”, “air conditioning with fan” |
| | PT | Imaginando que você trabalhasse em um AMBIENTE IDEAL, nos dias quentes você preferiria utilizar: | “Ar condicionado”, “ventilação natural apenas”, “ventilação natural com ventilador”, “ar condicionado com ventilador” |
| 9 | EN | Imagine the answers from the questionnaires were used to adjust the temperature of air-conditioning in this space. When would you expect a change to occur? | “When I prefer cooler or warmer”, “when I prefer cooler or warmer and to be just uncomfortable”, “when I prefer cooler or warmer and to be very uncomfortable”, “other” |
| | PT | Imagine que no ambiente atual, as respostas do questionário usado neste experimento fossem utilizadas para ajuste da temperatura do ar condicionado. Você esperaria que ocorresse alteração quando: | “Sempre que indico preferir mais frio/mais quente”, “sempre que indico preferir mais frio/mais quente e estar ‘apenas desconfortável’”, “sempre que indico preferir mais frio/mais quente e estar ‘muito desconfortável’”, “outro” |
| 10 | EN | Considering how your preference affects your colleagues, when do you think a temperature adjustment should happen? | “When most of the people (80 %) is just uncomfortable”, “when more than half (51 %) is just |

| No. | LNG | Question | Answering options |
|---|---|---|---|
| | | | uncomfortable”, “when one person is just uncomfortable”, “when most of the people (80 %) is very uncomfortable”, “when more than half (51 %) is very uncomfortable”, “when one person is very uncomfortable”, “other” |
| | PT | Pensando que a sua preferência afeta seus colegas, o que você considera que deveria ser considerado para realizar uma alteração: | “A maioria (80%) das pessoas de um mesmo espaço indicam estar “apenas desconfortáveis’”, “mais da metade (51%) das pessoas de um mesmo espaço indicam estar ‘muito desconfortáveis’”, “se uma pessoa indica estar ‘apenas desconfortável’”, “a maioria (80%) das pessoas de um mesmo espaço indicam estar “muito desconfortáveis’”, “mais da metade (51%) das pessoas de um mesmo espaço indicam estar ‘muito desconfortáveis’”, “se uma pessoa indica estar ‘muito desconfortável’” |
| 11 | EN | Would you be willing to accept the setpoint temperature rise if you had a fan? | “Yes”, “yes, if it would save energy”, “yes, if my colleagues were more comfortable”, “no”, “other” |
| | PT | Você estaria disposto a aceitar o aumento da temperatura do ar condicionado se tivesse um ventilador? | “Sim”, “sim, apenas se ajudasse a economizar energia”, “sim, apenas se meus colegas estivessem mais confortáveis”, “não”, “outro” |