Title
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AIR MOVEMENT PREFERENCES OBSERVED IN OFFICE BUILDINGS

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ABSTRACT

Office workers' preferences for air movement have been extracted from a database of indoor environmental quality surveys performed in over 200 buildings. Dissatisfaction with the amount of air motion is very common, with too little air movement cited far more commonly than too much air movement.

Workers were also surveyed in a detailed two-season study of a single naturally ventilated building. About half the building's population wanted more air movement and only 4% wanted less. This same ratio applied when the air movement in workspaces was higher than 0.2 m/s, the de facto draft limit in the current ASHRAE and ISO thermal environment standards. Preference for "less air motion" exceeded that for "more" only at thermal sensations of -2 (cool) or colder.

These results raise questions about the consequences of the ASHRAE and ISO standards' restrictions on air movement, especially for neutral and warm conditions.

Key words

Air movement preference, Draft, Natural ventilation, Air motion

INTRODUCTION

A number of laboratory studies have found that air movement compensates for warm temperatures in making people comfortable, and have recommended high air movement levels for summer conditions (Rohles et al. 1974, Tanabe and Kimura 1989, Scheatzle et al. 1989, Fountain 1991, Fountain and Arens 1994, Mayer 1992, Arens et al. 1998). These higher levels are allowed in ASHRAE Standard 55 (2004) only when under the personal control of the occupant. Without personal control, air movement limits are determined by predictions of draft discomfort (DR), based on laboratory studies by Fanger et al. (1988) and Fanger and Christiansen (1986), and embodied in both the ASHRAE and ISO 7730 (1994) standards.

Air movement preferences in real buildings have recently been examined (Toftum 2004) using the ASHRAE field studies in the de Dear (1998) database (Table 1). Toftum examined air movement preferences for those cases in the database where occupants had registered "slightly cool" through "slightly warm" (thermal sensation – 1 through +1)—people within or close to the comfort zone. He also restricted the temperature range to between 22.5 to 23.5 ºC. He divided these data into two bins, one with air movement below the draft limit (0.15 m/s at room air temperature 23ºC), and the other above it (0.15

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to 0.25 m/s, above which there were insufficient observations). The predominant complaint in this dataset is about insufficient air movement rather than too much. A strong majority of occupants (including those who are "slightly cool") accept and request air movement *above* the limit prescribed by the draft standard. Only when occupants are both "slightly cool" *and* in the high air movement bin does the percentage of occupants requesting less air movement approach 17%. This value is less than the 20% DR (discomfort due to draft) that the standard is designed to protect, and even then, the percentage wanting more air movement is more than twice as large. When occupants' sensations are "neutral" or "slightly warm", the percentage wanting less air movement is far below 20% even when air movement is at or above the draft limit, and the percentages wanting more air movement are high.

Table 1. Air movement preference as observed in the four ASHRAE field studies

Adapted from Toftum (2004), who developed it from data from studies by Schiller et al. (1988), de Dear & Fountain (1994), Donini et al. (1997), and Cena and de Dear (1999)

Thermal sensation	Air velocity range (m/s)	Percentage of occupants preferring:			(N)
		Want less	No change	Want more	
Slightly cool	0 – 0.15	13.6	46.3	40.1	147
	0.15 – 0.25	16.7	41.7	41.6	48
Neutral	0 – 0.15	2	46	52	150
	0.15 – 0.25	2	68.6	29.4	51
Slightly warm	0 – 0.15	2.7	21.9	75.4	73
	0.15 – 0.25	8.4	33.3	58.3	24

Toftum concludes that people who feel cold prefer less air movement, and those who feel hot prefer more air movement, and that the dividing line is 22-23ºC. This is true even though the occupants in the database buildings rarely had personal control over air movement.

It is worth examining other sources of data on air movement effects in real buildings, with or without personal control, because air movement limits may impose inherent energy costs and may not be providing occupants environments that they prefer.

METHODS

This paper provides air movement preference data drawn from two datasets. One is a widely-used indoor environmental quality (IEQ) survey containing some questions relevant to air movement, and the other is from a detailed study of a single building.

1) General Indoor Environmental Quality Survey

Since 1999, the Center for the Built Environment (CBE) has been conducting an IEQ survey in a large number of buildings. The survey is web-based and interactive, oriented toward managing facilities and diagnosing operational problems. It contains questions about the occupants' satisfaction with the thermal environment and about the sources of dissatisfaction with air movement and other factors. It has the advantage of its very widespread use, which might allow it to be viewed as somewhat representative of the building population. Its disadvantage is that its information on air movement is indirect, obtained only from subjects dissatisfied with the thermal environment.

The survey measures occupant *satisfaction* with respect to nine environmental categories: office layout, office furnishings, temperature, air quality, lighting, acoustics, cleaning and maintenance, overall satisfaction with building and with workspace (Zagreus et al. 2004). We ask the occupants to consider their experience over the previous 12 months in responding to the survey.

The satisfaction questions use a 7-point semantic differential scale with endpoints "very dissatisfied" and "very satisfied". We assume the scale is linear, and assign ordinal values to each of the points along the scale, from -3 (very dissatisfied) to +3 (very satisfied) with 0 as the neutral midpoint. Figure 1 shows an example of the satisfaction scale question regarding temperature.

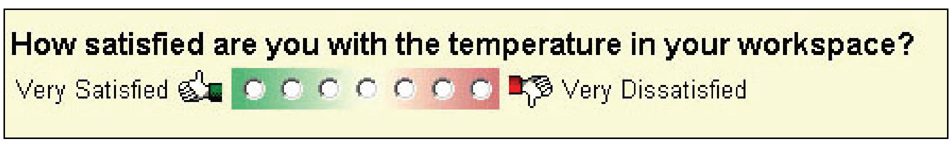


Figure 1. Typical 7-point satisfaction scale in survey

In the event that respondents vote "dissatisfied" (less than or equal to -1 on the scale) to any of the nine satisfaction scales, they are taken to a follow-up 'branching' page containing further questions aimed at locating the sources of their dissatisfaction. In the case of the temperature scale, dissatisfaction will lead them to several checkbox questions related to the nature of the air movement causing the problem.

The CBE IEQsurvey database as of October 1, 2005 was used for the present analysis. The data consists of responses from 34,169 occupants in 215 buildings throughout North America and Finland. The average response rate was 46%. Of the 215 buildings surveyed, 90% are located in the United States, the remainder in Canada and Finland. The percentage of surveyed buildings providing user-controlled ventilation is very small, but this is representative of current practice in North America.

2) Naturally Ventilated Building Study

The second dataset is from a detailed study of a single naturally ventilated building in California (the Berkeley Civic Center, Brager et al. 2004), which includes three components: an expanded version of the CBE IEQ survey for obtaining background information (entitled "background survey" here), a repeated "right now" survey about current sensations, opinions, and actions taken in response to the environment, and concurrent physical measurements of air movement, temperature, and humidity. Because the building has operable windows but is an open plan office, it provides most but not all of its occupants with a measure of personal control.

The study was done to test concepts of personal control and the adaptive comfort model (Brager and de Dear 2001). The office is a 7,700 m^2 office building with no mechanical cooling, using instead ventilation through open windows (Figure 2a) and interior overhead fans to provide air movement. Perimeter radiators are used for heat. Brager estimated that there were three times as many occupants with access to the windows as without. She also noted that the actual effectiveness of both the windows and ceiling fans was modest. When the window blinds were lowered, they interfered with access to the casement windows or rattled in the wind, causing these windows to be often closed. The hopper windows below them were often open, but produced an upward airflow pattern that traveled over the heads of the occupants. The ceiling fans were located above interior hallways, and so produced little air movement at the workstations.

Surveys and physical measurements were conducted over two-week periods in warm and cool seasons, whose mean outdoor temperatures were 17ºC and 12ºC respectively. The background survey was administered once at the beginning of each season for the entire population of the building (approximately 100 workers in each season). A more detailed survey was also used, that asked "right now" questions about thermal sensation (ASHRAE 7-point scale), air movement preference, indoor air quality, etc. The detailed survey was administered several times per day to 38 volunteers. Over 1,000 survey responses were collected each season (total 2,067 surveys). Physical measurements were taken continuously at these 38 volunteers' workstations over the entire two weeks each season. Measurements were done with small desktop weather stations (Figure 2b) of air temperature, globe temperature, relative humidity, and air velocity.

Figure 2a. An office in the naturally ventilated building (Berkeley Civic Center, California)

Figure 2b. Desktop weather station with (from left to right) shielded dry bulb sensor, anemometer, and globe temperature sensor

RESULTS

1) General Indoor Environmental Quality Survey

1.1) Temperature satisfaction

Temperature and air quality have the second (-0.15) and third (+0.17) lowest mean ratings of the nine environmental quality categories (acoustics has the lowest mean of -0.2). The mean scores of satisfaction for the remaining 6 categories are all near 1.0 (people have generally positive impressions of their buildings).

Figure 3 shows the distribution of temperature satisfaction votes. A total of 13,804 respondents (42% of all respondents) were dissatisfied (i.e. voted less than or equal to -1 on the satisfaction scale for temperature).

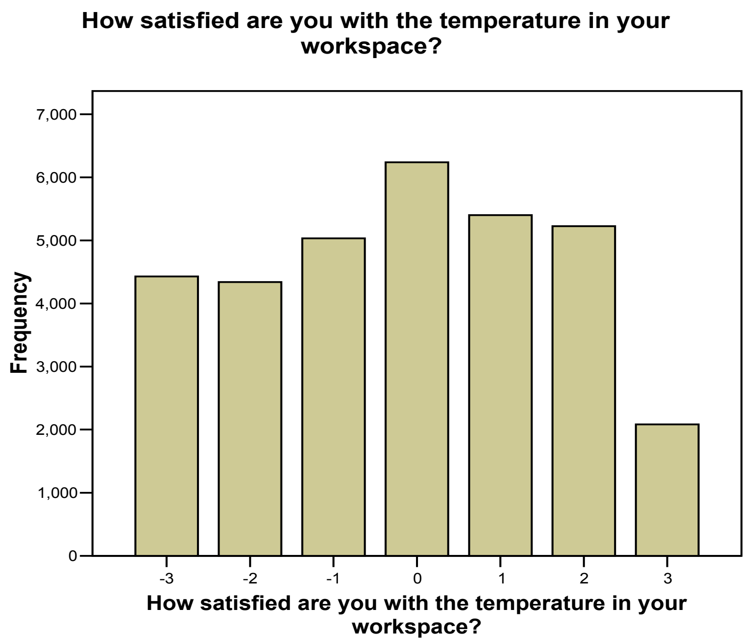


Figure 3. Thermal satisfaction votes in CBE database (total number of respondents to this question=32,750)

This is a surprisingly large number of people expressing dissatisfaction. It exceeds the goal of the ASHRAE standard, to have no more than 20% dissatisfied. It raises questions about how thermal satisfaction is perceived over time, and where to draw the boundaries of dissatisfaction. These questions are beyond the scope of this present paper. However, the large number of dissatisfied occupants gives us a large pool to assess the nature of associated air movement complaints, because only the occupants that vote dissatisfied on the temperature scale receive the follow-up questions about air movement.

1.2) Air movement complaints

The 'branching' page for temperature satisfaction asks a range of questions intended to identify the sources of their dissatisfaction. All questions are in the form of check boxes and the respondents are instructed to "check all that apply".

Figure 4 shows the distribution of thermal complaints among all respondents in the CBE database who were dissatisfied with the temperature in their workspace. The three most common complaints were all related to lack of access to temperature controls, which underscores the importance of personal control. "Air movement too low" was the 4th most common thermal complaint with 11% of all complaint votes (N=3,502). The number of votes is twice as high as "air movement too high", which was the 7th most common with 5% (N=1,507).

"Air movement too low", "air movement too high", "draft from windows", and "draft from vents" all refer to air movement, and the survey respondents can check all at the same time. The number of people who voted both "air movement too high" and "air movement too low" was 245. The question list is asymmetric, since three items refer to situations where air movement might be higher than preferred, and only one refers to "air movement too low". If we count the number of people who made one or any combination of the "too high" and the two draft complaints, it comes to 11%, the same percentage as the "air movement too low" complaints. Some of the draft complaints may however not be due to air movement effects. Lyons et al. (2000) found "draft due to windows" to be mainly due to radiation heat loss to the window rather than to air motion.

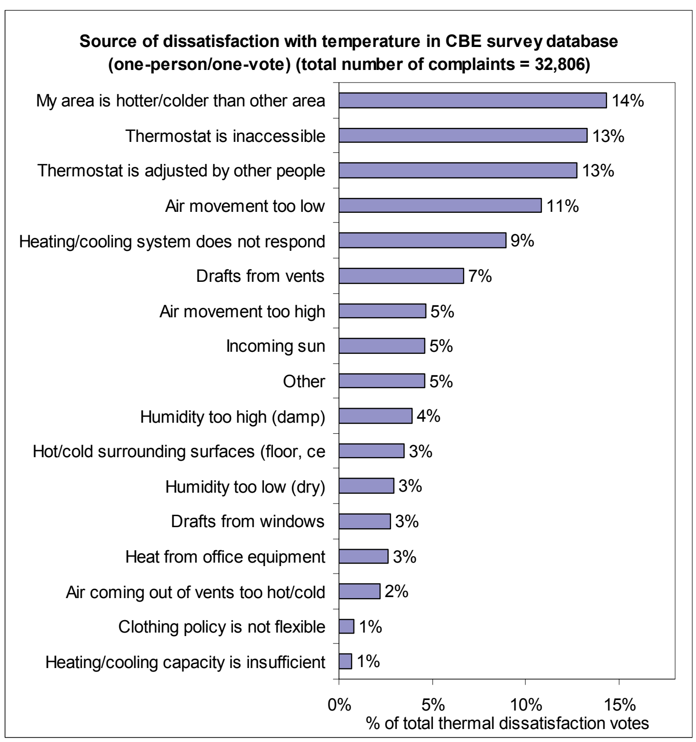


Figure 4. Sources of dissatisfaction with thermal comfort in CBE survey database

Table 2 tabulates votes on air movement complaints against the nature of temperature complaints. Of those who said they were “often too hot”, nearly half also indicated that the air motion was too low while only 1% complained that the air motion was too high. For those who complained that the temperature was “often too cool”, there were three times as many complaints of the air motion being too high compared to the air motion being too low. For those who complained that the temperature was “often too hot” *and* “often too cold” (40% of total temperature complaints), there were three times as many complaints of air motion being too low as too high.

Table 2. Air movement preferences for those who complained about temperature being often too hot, often too cold, and both

Thermal complaint	Percentage of occupants indicating:		(N)
	air motion too low	air motion too high	
often too hot	49%	1%	3,251
often too cold	6%	19%	4,553
often too hot *and* often too cold	32%	11%	5,102

1.3) Air movement preferences and occupant control over thermal environment

Of all people who had a portable fan in their workspace, 19% indicated that the air motion was often too low, as compared to 8% for people who did not have a portable fan. Occupants appear to regard personal fans as a remedial measure, needed to obtain air motion that they feel should be inherently present in a satisfactory building.

1.4) Air movement preferences and office type

In the CBE survey database, neither office type (private, shared, or open plan), workstation partition height, or perimeter-vs-core location has a significant effect on either “too high” or “too low” air movement complaints.

2) Air movement preferences in the Berkeley Civic Center building

2.1) Air movement preferences related to thermal sensations

In the Berkeley Civic Center study both the background IEQ survey and the “right now” survey were used each season, supplemented with physical measurements. The study took place over two weeks each season. In the warm season, nearly half of the votes from both surveys preferred more air movement (Table 3). Even in the cool season, about 30 to 40%

of the votes preferred more air movement. For both surveys and for both seasons, less than 5% of the votes preferred less air motion.

Table 3. Air movement preferences

Air movement preference	Warm season		Cool season	
	"right now" repeated survey for the 38 volunteers, N=1,037	background survey for the entire building population, N=104	"right now" repeated survey for the 38 volunteers, N=1,030	background survey for the entire building population, N=93
want more (%)	45	53	28	38
no change (%)	52	43	68	58
want less (%)	3	4	4	4

A) "Right now" survey results: In the "right now" survey, occupants reported their thermal sensation, using the ASHRAE seven-point scale. The distribution is shown in Figure 5. The building tended to be warm during the periods tested, with 40% of the population voting neutral, 38% on the warm side, and 22% on the cool side.

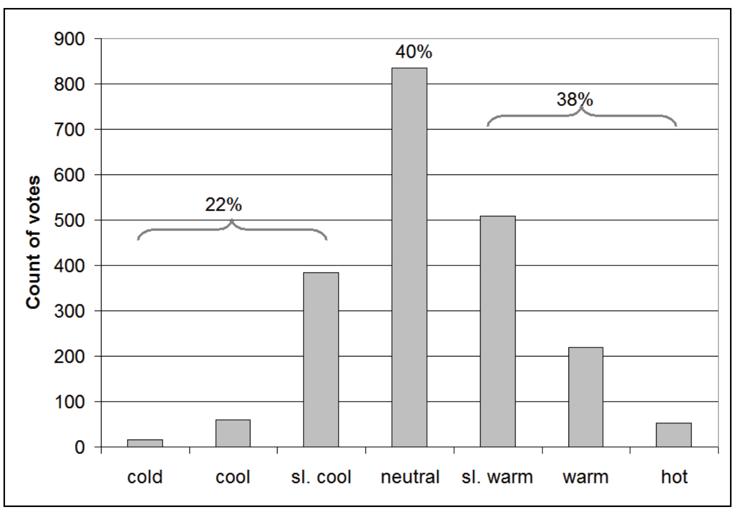


Figure 5. Thermal sensation distribution from the "right now" survey, N=2067

Figure 6 below shows the air movement preferences under each thermal sensation category, and their associated measured operative temperatures.

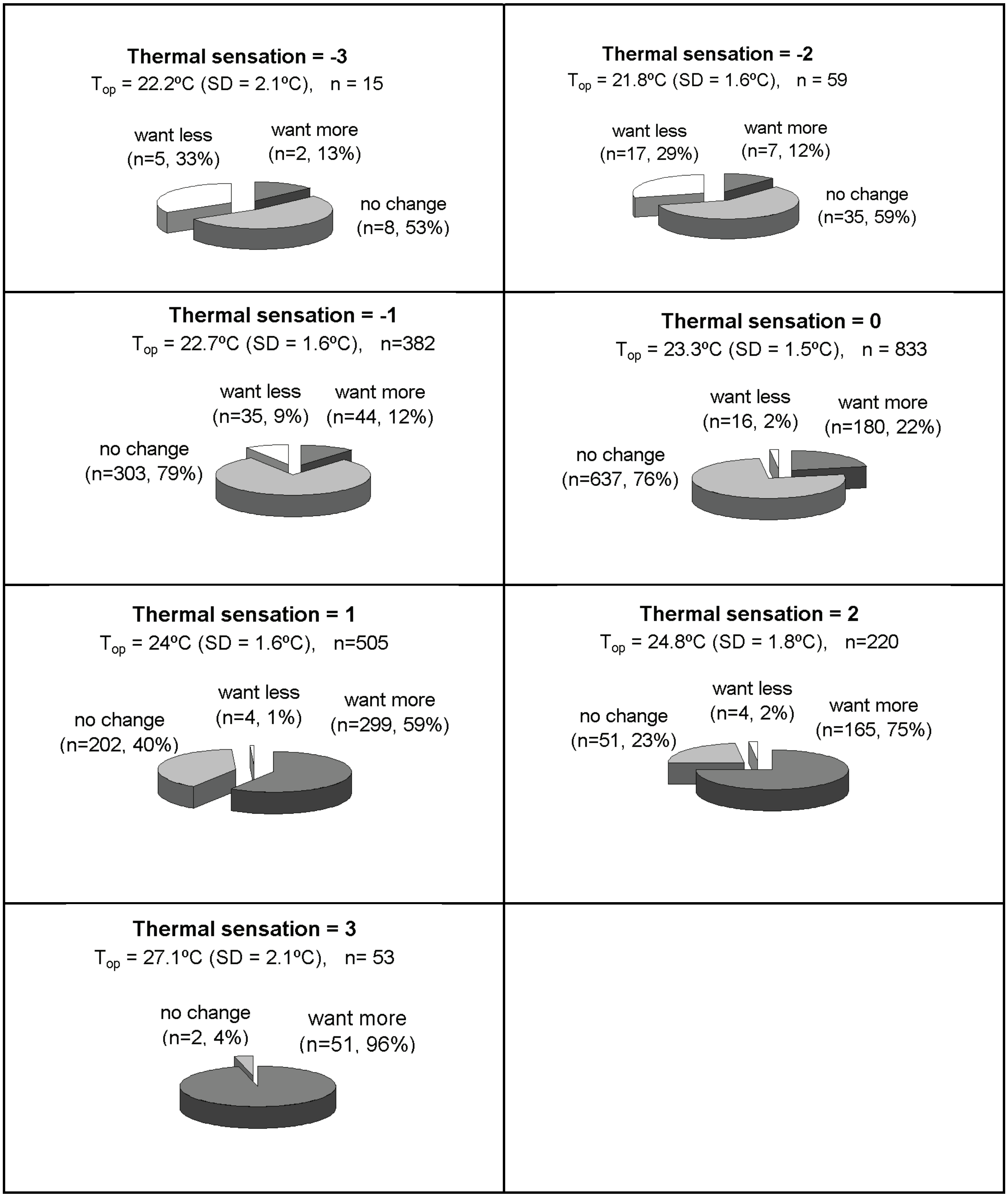


Figure 6. Air movement preference related to thermal sensation for “right now” survey

In general, when people were warmer, they preferred more air movement; when people felt cooler, they preferred less air movement. The percentages wanting more or less air movement are however not symmetrically distributed on the cool and warm sides of neutral. When sensation was *warm* (sensation = 1, 2, 3), the requirement for more air motion was strong, from 59% for the *slightly warm* sensation (sensation = 1) to 96% for the *hot* sensation (sensation = 3). The requirement for less air movement was quite small, between 0 - 2%. The turning point where an equal number of people wanted either more or less air movement happened near the *slightly cool* sensation (sensation = -1), at which 12% wanted more air motion, 9% wanted less air motion. It was only when sensation was *cool* (sensation = -2) that more people (29%) wanted less air movement than people who wanted more air movement (12%). The percentage that wanted less air movement increased to 33% when thermal sensation was *cold* (sensation = -3). The demand for less air movement under cool sensations is much smaller than the overwhelming demand for more air movement when sensation was warm. There were consistently about 12% of the people who wanted more air movement in all these cool cases.

When occupants felt neutral (833 neutral sensation votes), 22% wanted more air motion, while 2% wanted less (the 4th chart in Figure 6). Even without a cooling requirement related to thermal comfort, people appear to welcome air movement.

The above thermal sensation analysis is summarized in Figure 7.

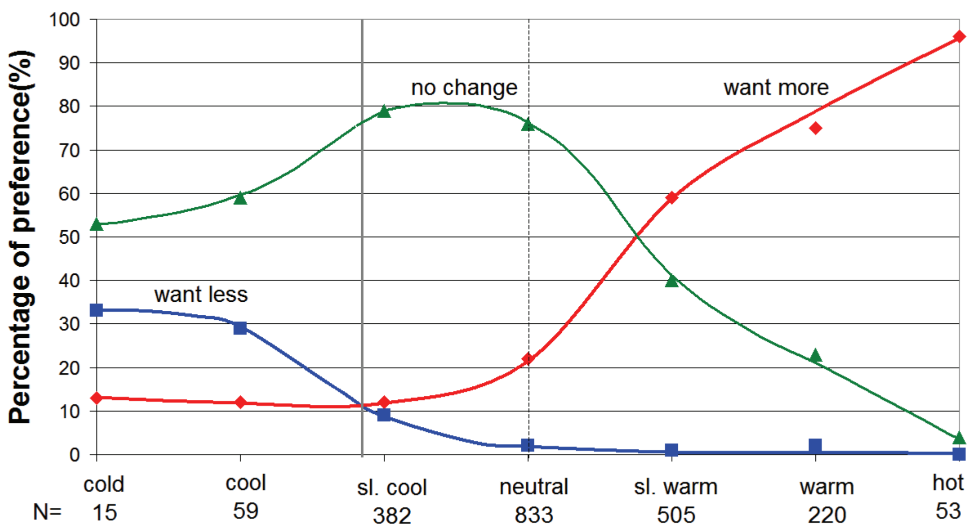
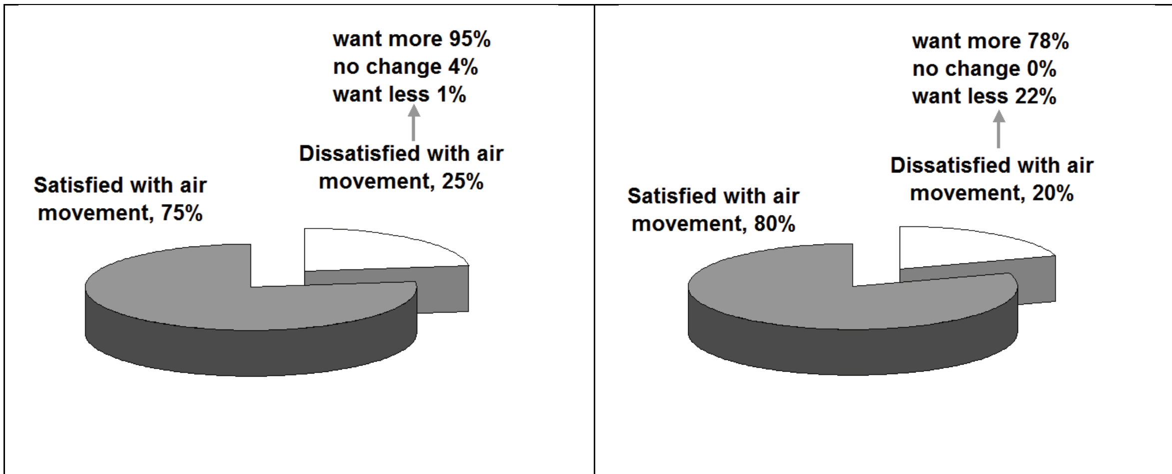


Figure 7. Air movement preference and thermal sensation for "right now" survey

B) Background IEQ survey results: Although in general the air movement in the building was low (90% of the physical measurements were less than or equal to 0.2 m/s), the air motion was perceptible to the occupants. In the background surveys for the entire building population, 88% (warm season) and 70% (cool season) voted that the air motion was "slightly perceptible" and above ("moderate" to "a lot"), with majority voting "slightly perceptible". Yet about 75% of the population was satisfied with the air movement. Among the 25% people who were not satisfied with the air movement, 95% in summer and 78% in winter wanted more air movement, and only 1% in summer and 22% in winter wanted less (Figure 8). The large majority of dissatisfaction resulted from air movement being low.



Summer, N=104	Winter, N=93

Figure 8. Air movement preferences for people who were dissatisfied with the air movement for background survey

The occupants were asked to identify from among 11 reasons why they *opened* their windows. The most common three reasons in both summer and winter were: "to feel cool", "to feel more air movement", and to "let in fresh air". Their reason for *closing* windows, in the summer, was predominantly "to reduce outdoor noises". In the winter, "to feel warmer" and "to reduce outdoor noises" were equally the main two reasons. Interestingly, in both seasons, "to reduce the air movement" was rarely selected as the reason for closing windows.

2.2) Air movement preferences related to measured velocities above the draft limit.

About 10% of the votes (N=194) in the "right now" survey corresponded to air velocities larger than 0.2 m/s. This velocity is the draft limit for the ASHRAE Standard at a temperature of 25.5ºC, if one assumes a normal indoor turbulence intensity level of 40%. (At 23ºC the limit is about 0.15 m/s). The velocity distribution of this 10% of the measured data is shown in Figure 9.

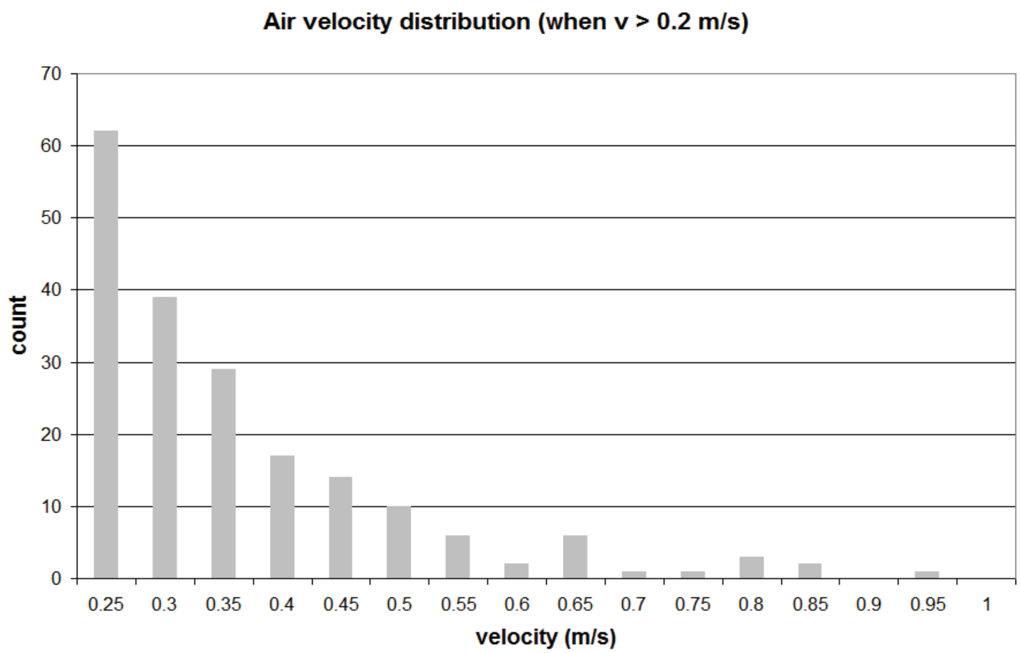


Figure 9. Air velocity distribution when measured velocity is > 0.2 m/s (N=194), for "right now" survey

The majority of observations when the velocity exceeded 0.2 m/s had thermal sensations of neutral or above (38% neutral, 45% warm, 17% cool; see Figure 10). 50% of the 194 votes preferred more air movement, and only 5% wanted less (Figure 11). This is consistent with the air movement preference from the entire "right now" survey database. Therefore, measured air movement higher than 0.2 m/s didn't seem to change people's preference for more air movement.

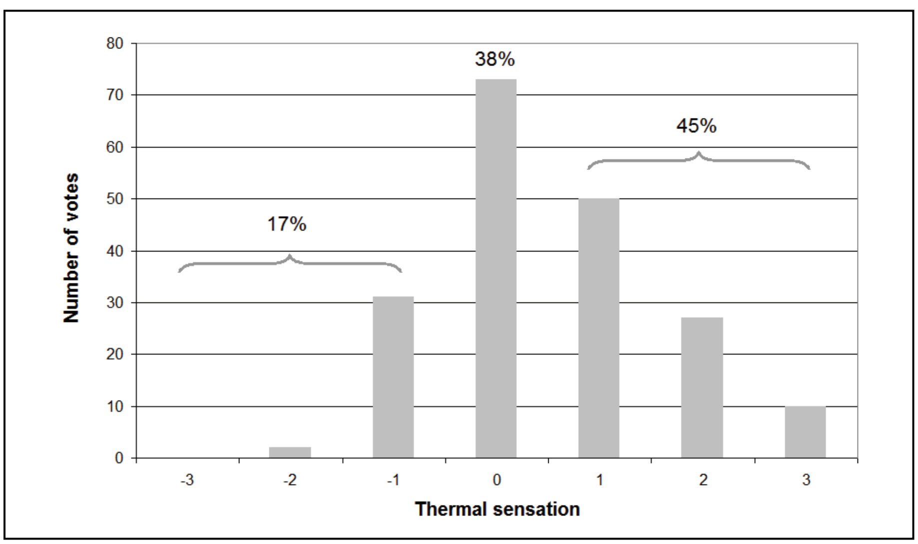


Figure 10. Thermal sensation distribution for people when measured velocity > 0.2 m/s (N=194)

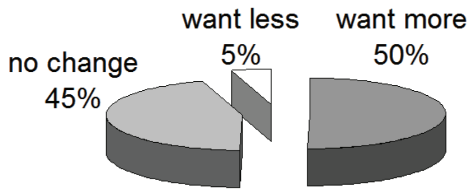


Figure 11. Air movement preferences recorded whenever measured air velocity was > 0.2, N=194, "right now" survey

Almost half of votes above 0.2 m/s rated the air motion "unacceptable". "Unacceptable" votes could be due to air movement being either too high or too low. 71% of these unacceptable votes wanted more air motion, only 6% wanted less (Figure 12).

Among the "unacceptable" votes, 42% had the access to a window, and 72% of these had adjusted the window in the past hour--81% to open it and 19% to close. The three main reasons for opening windows were identical to those of the background survey: "to feel cooler", "to feel more air movement", and "to let in fresh air". Among the 23% "no change" votes (Figure 12), the great majority (88%) had opened a window in the last hour.

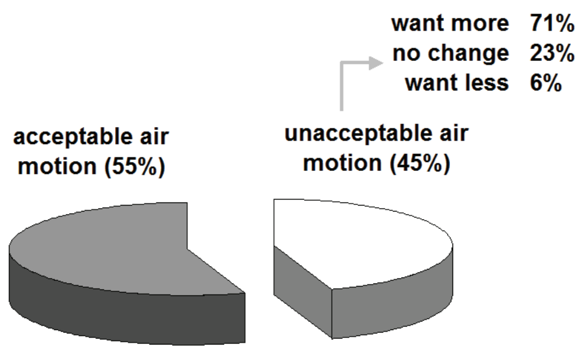


Figure 12. Air movement preference for those high-air-motion cases that were judged 'unacceptable' (measured air velocity > 0.2 m/s, N =194, "right now" survey)

Table 4 lists air movement preferences for two velocity groups: 0 – 0.2 m/s and 0.2 – 0.95 m/s, arranged by thermal sensation. It follows the format of Table 1 from Toftum, except that we use a higher threshold value for the higher velocity group, and include measured operative temperatures.

Table 4 shows that when thermal sensation was neutral or warmer, the percentages of "want more air movement" are overwhelmingly larger than the percentages of "want less". The percentages of "want less" are all below 10% for both velocity groups. Of people who were “slightly cool” in the velocity range of 0 – 0.2 m/s, roughly equal numbers wanted more (11%) or less (10%) air movement; with velocities 0.2 – 0.95 m/s, twice as many wanted less (6.7%) than more (3.3%). However, this percentage of “want less” is much smaller than the 20% probability of draft risk (DR) that forms the basis of the draft limit in the ASHRAE standard.

It is interesting to notice that within each thermal sensation category (except the cold and hot sensations since the numbers of observations are small), the operative temperatures for velocity group 0.2 – 0.95 m/s are about 1ºC higher than for velocity group 0 – 0.2 m/s. Higher velocity apparently compensates for higher room temperature providing equivalent comfort. Above 23ºC the higher air movement is acceptable. This coincides with Toftum’s conclusion that at temperature above 23ºC, sedentary people do not feel draft at high velocity (2004).

Table 4. Air movement preference for two velocity groups (“right now” survey): 0 – 0.2 m/s and 0.2 – 0.95 m/s

Thermal sensation	Air velocity range (m/s)	Percentage of occupants preferring:			(N)	T_{op} (SD) ºC
		Want less	No change	Want more		
Cold	0 – 0.2	38.0	62.0	0.0	13	22.2 (2.2)
	0.2 – 0.95	**-**	**-**	**-**	**0**	**-**
Cool	0 – 0.2	*39.8*	*59.6*	*10.6*	47	21.8 (1.6)
	0.2 – 0.95	**50.0**	**50.0**	**0.0**	**2**	**23.5 (0.8)**
Slightly cool	0 – 0.2	*10.0*	*79.0*	*11.0*	329	22.7 (1.6)
	0.2 – 0.95	**6.7**	**90.0**	**3.3**	**30**	**23.1 (1.9)**
Neutral	0 – 0.2	1.7	78.1	19.9	704	23.2 (1.5)
	0.2 – 0.95	**5.5**	**53.4**	**41.1**	**73**	**24.3 (1.6)**
Slightly warm	0 – 0.2	*0.9*	*40.8*	*57.8*	429	23.8 (1.5)
	0.2 – 0.95	**0.0**	**32.0**	**68.0**	**50**	**25.0 (2.0)**
Warm	0 – 0.2	*0.6*	*25.3*	*74.1*	158	24.5 (1.6)
	0.2 – 0.95	**7.4**	**14.8**	**77.8**	**27**	**26.3 (1.8)**
Hot	0 – 0.2	0.0	6.3	93.7	*32*	*27.1 (1.7)*
	0.2 – 0.95	**0.0**	**0.0**	**100**	**10**	**27.3 (1.8)**

2.3) Air movement and work ability

In both the general survey for the entire population of the building (197 over two seasons) and the 2,067 repeated “right now” surveys, we asked: “Overall, does the air movement in your workspace enhance or interfere with your ability to get your job done?” The results from both surveys show that about 60% voted that the air motion enhanced their work ability, while about 15% voted that the air motion interfered with their job ability. The data from the general survey is shown in Figure 13.

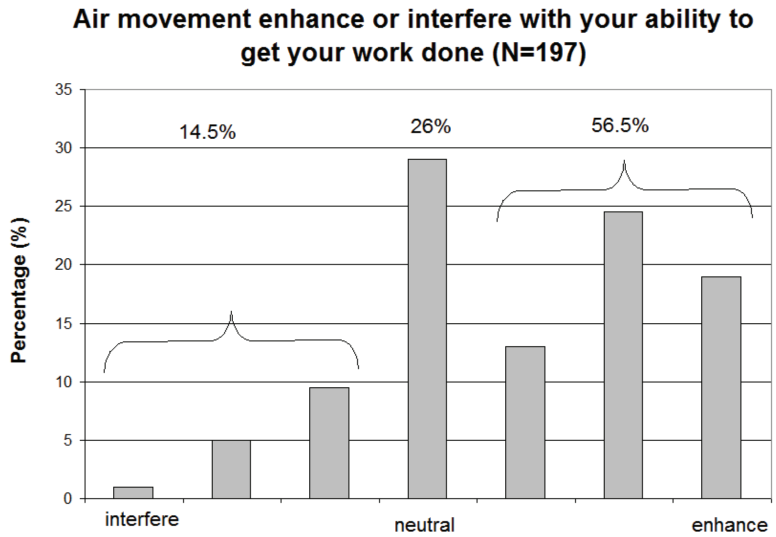


Figure 13. Air movement and ability to work, background survey, N=197

DISCUSSION

1) The extensive CBE indoor environmental quality survey database indicates that double the population would prefer more air movement than would prefer less. People citing that they are "often too warm" want more air movement, and those citing "often too cool" want less air movement.

2) The Berkeley Civic Center study shows that when people feel neutral and above on the thermal sensation scale, the request for more air movement is overwhelming. This has been found in previous field studies, as summarized in Table 1 by Toftum (2004). The Civic Center study shows that when people felt *neutral*, in velocities that exceed the draft standard (0.2 – 0.95 m/s), 41% wanted more air motion and only 5.5% wanted less. When people felt *slightly warm*, the percentage requesting more air movement was 68% and there were no requests for less. The airflow controllability in this building was basically limited to operable windows, which often did not produce much air motion even when open. Both this study and Toftum's summary of earlier field studies suggest that the ASHRAE and ISO draft limit should not apply when people feel neutral or warmer. This result does not actually conflict with the studies by Fanger et al. (1988 and 1986) which underlie the draft limit, because their experimental protocols had the subjects feeling slightly cool when the higher air velocities were tested. Figure 14 shows the overall sensation under their test conditions. In both studies, subjects felt cooler than neutral whenever the higher air velocities were tested. The draft limits in the standards are based on these results.

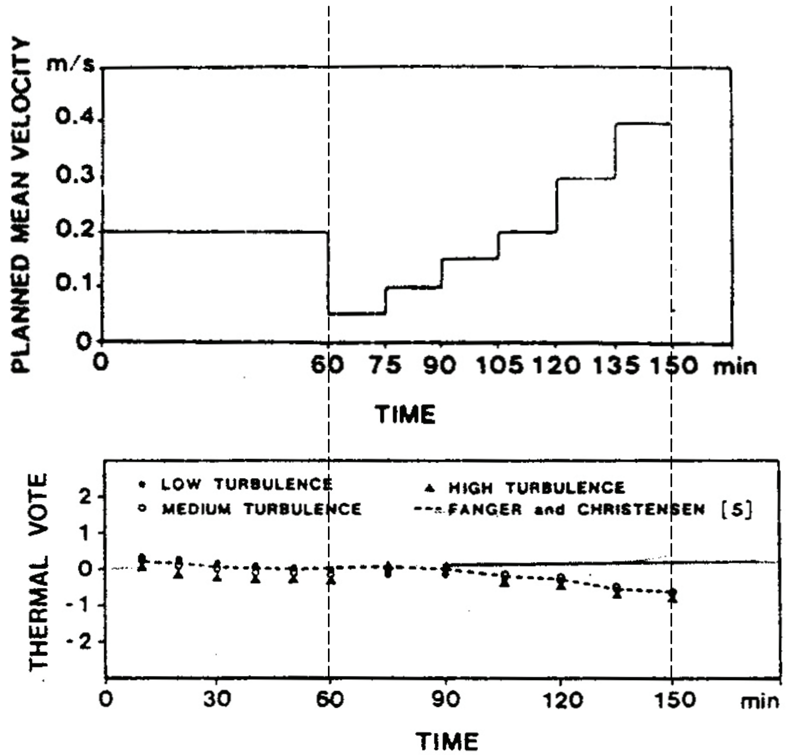


Figure 14. Thermal sensation and air movement in studies (Fanger et al. 1988 and 1986) that underlie the draft limits in the ISO and ASHRAE Standards

3). Even for people who are slightly cool, the ASHRAE and ISO standards' prediction of draft discomfort overestimates the dissatisfied percentage seen in these field studies by about a factor of two. A possible reason might be as follows. The laboratory studies underlying the ASHRAE draft risk standards were performed with the air movement impinging on the back of the neck. This is the worst scenario from a comfort perspective, since the side directions are known to be considerably less sensitive to air movement (Toftum 1997), and the front direction may be also (Mayer 1992). The DR in the ASHRAE and ISO standards is quantified as if any air movement in the room is directed at the back of the neck. However in the average room, the probability that a given wind comes from the back might be about 25% (if one subdivides all possible wind directions into four). That reduces the probability of draft risk from many possible air velocities. If a particular air velocity exceeds the standard's 20% DR limit when on the back of the neck but is acceptable for the other three directions, the actual probability of draft discomfort for that wind velocity would only be 5%. This number is close to what we observed for slightly cool and neutral cases with air movement over the draft limit of 0.2 m/s, and to what Toftum found for neutral cases above 0.15 m/s.

The risk of restricting air movement to achieve a very strict 5% limit for DR is that it may have the effect of causing much larger levels of discomfort due to insufficient air movement.

4) The satisfaction about air quality is relatively high in the Civic Center compared with the entire CBE IEQ database of 215 buildings. For the entire database, the average satisfaction is 0.27 on the scale: –3 (dissatisfied), 0 (neutral), +3 (satisfied). For the Civic Center, it was 0.72 in the cool season and 1.12 in warm season, ranking in the 65th and 81st percentiles of the whole database (in Figure 15, higher numbers represent better satisfaction). The indoor operative temperature in the summer was 1.4 ºC warmer than in the winter (Table 5), and the thermal sensation was also slightly warmer in summer than in winter. The Civic Center's more satisfactory summer perceived air quality contrasts with Fang et al.'s (1998) finding that perceived air quality is better in cool environments than in warm environments. This could be due to the higher air movement in summer (average 0.09 m/s, maximum 0.95 m/s) than in winter (0.04 m/s, maximum 0.75 m/s). The higher air movement could disrupt the thermal plume around an occupant's body, which transports pollutants from carpet and body surface up to the breathing zone, and thereby improve the occupant's perceived air quality. Alternatively, association with ventilation and outdoor breezes might cause people to associate perceived air movement with better air quality. In either case it may be counterproductive to associate perceived air quality with temperature alone, without considering such potential effects of air movement.

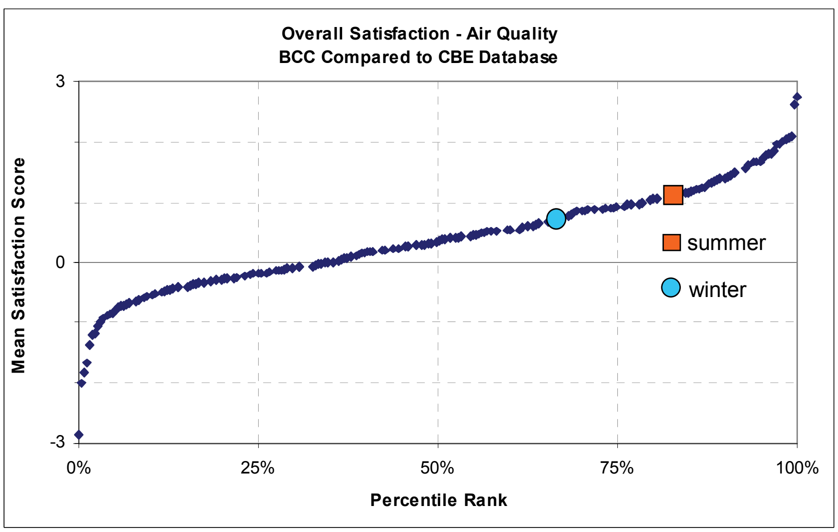


Figure 15. The ranked percentiles of perceived air quality (summer and winter) in the Civic Center (background survey) compared with the whole CBE IEQdatabase.

Table 5. Satisfaction with air quality in the Civic Center background survey, and the temperature, thermal sensation, air movement during the detailed "right now" surveys

	Satisfaction of air quality (background survey)	Mean operative temperature (ºC) ("right now" survey)	Mean thermal sensation ("right now" survey)	Mean indoor velocity (m/s) ("right now" survey)
Winter	0.72	22.8	0.1	0.04
Summer	1.12	24.2	0.4	0.09

5) In the Civic Center, higher air movements raised the operative temperatures associated with neutral-to-warm sensations by more than 1K over the operative temperatures associated with neutral-to-warm sensations at lower air movements. Using air movement to raise the neutral operative temperature during warm seasons could result in significant air-conditioning energy savings for any given level of comfort.

6) Relaxing the current draft limit for neutral-to-warm conditions (above 23 ºC) would open up opportunities for saving energy that are now restricted to personally-controlled air movement devices. It is of course desirable to give occupants personal control over air movement, but practical ways of achieving this remain limited. These field studies suggest that there may be a zone of temperatures and air velocities in which devices that move air across large areas can do so without creating an appreciable draft risk for the occupants.

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