Draft or Breeze? Preferences for air movement in office buildings and schools from the ASHRAE database

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SUMMARY
Office workers' preferences for air movement have been extracted from the ASHRAE database of indoor environmental quality surveys, using the 48 buildings (6148 surveys) in which the surveys included an air movement preference question. Dissatisfaction with the amount of air motion is found to be very common, with too little air movement cited far more commonly than too much air movement.

When people are cool, air movement is perceived as draft. When people are warm, air movement is perceived as desirable. In this paper we examined the region where people's responses were neutral and slightly warm (with ASHRAE sensation between -0.7 and 1.5). For ASHRAE database responses within this region, 52% of occupants wanted more air movement, 45% preferred no change, and 3% wanted less.

KEYWORDS
Air movement preference, air motion, comfort standards, thermal sensation, draft

INTRODUCTION
Air movement can be an effective and energy-efficient way to provide comfort in warm environments. The focus of HVAC design, however, has been on the strict control of temperature and humidity, while air movement has been regarded as undesirable.

Draft limits in comfort standards (ASHRAE Std 55-2004, ISO Std 7730) restrict air movement in ambient temperatures up to 26ºC. The limits range between 0.15m/s and 0.2 m/s, as temperature increases. Air speed levels exceeding the draft limit are allowed only when air movement is under the personal control of the occupant. In this paper we test the real-world relevance of these limits against data from field studies of occupants of actual buildings, in neutral and warm environments. If relaxation of these limits were justified on comfort grounds, a variety of energy-efficient building control strategies might be devised to take advantage of air movement as a method of cooling.

Zhang et al. (2007) analyzed a field study for a naturally ventilated building (Brager et al. 2004), finding that when people felt neutral or warm, their stated preference for more air movement greatly exceeded that for less air movement (20 – 100% for more air movement vs. 0 – 7.4% for less air movement). This applied both to velocities from 0 – 0.2 m/s, and velocities greater than 0.2 m/s. Among people who were dissatisfied with air movement, far more people (95% for summer and 78% for winter) wanted more than less (1% for summer and 22% for winter). Even among people experiencing high air velocities (greater than 0.2 m/s), among the 45% dissatisfied with air movement, 71% wanted more, and 6% wanted less.

Toftum (2004) conducted air movement analyses of four studies found in the ASHRAE database, for temperatures ranging between 22.5 ºC and 23.5 ºC and velocities less than 0.25m/s. He also found that far more people want more air movement than want less, when their thermal sensation is slightly cool to warm. It is desirable to look at other field studies that addressed air movement effects in real buildings and to expand the range of conditions examined.

METHODS

In the ASHRAE database, there are 9 studies (48 building tests and 6148 surveys) that included an air movement preference question allowing the occupants' preference to be ascertained. The respondents had three choices regarding their air movement preference: (1) prefer more air movement, (2) no change, and (3) prefer less air movement. The studies were conducted in Kalgoorlie, Montreal, Townsville, Honolulu and Sydney, and the measurements were taken during both Winter and Summer conditions. All buildings are HVAC with the exception of four NV schools in Honolulu.

RESULTS

Table 1 lists air movement preference in HVAC buildings under each sensation category for low velocities (less than 0.2 m/s) as well as high velocities (greater than 0.2 m/s). For both velocity ranges, it is only when occupants feel cold, that the number of people wanting less air movement exceeds the number wanting more. Even under "cool" and "slightly cool" sensations, there are more than twice as many people who preferred more air movement than less. From "neutral" and warm sensation, the people who wanted less air movement are less than 6%, except under "hot" sensation for velocity >=0.2 m/s, under which condition there are only four responses. The percentage of people who want more air movement ranges from 34 % to 82% under neutral and warm sensations.

Table 1. Air movement preference for two velocity groups: 0 – 0.2 m/s and 0.2 – 0.95 m/s (mean velocity 0.28 m/s), HVAC buildings, n=4747

Thermal sensation	Air velocity range (m/s)	Percentage of occupants preferring:			(N)	T_{air} (SD) ºC
		Want less	No change	Want more		
Cold	0 – 0.2	32.71	46.73	20.56	107	22.68 (0.92)
	> 0.2	***63.64***	***27.27***	***9.09***	***11***	***23.84(0.82)***
Cool	0 – 0.2	13.09	59.69	27.23	573	22.89(1.00)
	> 0.2	***9.48***	***70.69***	***19.83***	***116***	***22.98(1.61)***
Slightly cool	0 – 0.2	11.15	52.35	36.5	1,085	23.0(1.12)
	> 0.2	***12.24***	***60.71***	***27.04***	***196***	***22.89(1.60)***
Neutral	0 – 0.2	2.72	49.92	47.35	1284	23.20(1.13)
	> 0.2	***5.33***	***61.07***	***33.61***	***244***	***23.12(1.37)***
Slightly warm	0 – 0.2	2.32	26.29	71.39	734	23.57(1.36)
	> 0.2	***5.17***	***31.9***	***62.93***	***116***	***23.74(1.35)***
Warm	0 – 0.2	4.48	13.45	82.06	223	23.59(1.61)
	> 0.2	***2.78***	***33.33***	***63.89***	***36***	***23.93(2.16)***
Hot	0 – 0.2	0	0	100	18	25.09(1.36)
	> 0.2	***25.0***	***25.0***	***50.0***	***4***	***24.33(2.93)***

Air movement preferences for each sensation level in NV buildings are presented in Table 2. Again, the evidence that people prefer more air movement is very obvious. Only in the "cool" or "cold" sensations did more people prefer less air movement than more air movement.

Table 2. Air movement preference for two velocity groups: 0 – 0.2 m/s and > 0.2 m/s (mean velocity 0.36 m/s), NV buildings, n=1391

Thermal sensation	Air velocity range (m/s)	Percentage of occupants preferring:			(N)	T_{air} (SD) ºC
		Want less	No change	Want more		
Cold	0 – 0.2	50	50	0.0	4	22.28 (0.85)
	> 0.2	***40***	***53.33***	***6.67***	***15***	***23.26 (1.77)***
Cool	0 – 0.2	12.5	79.17	8.33	24	23.71 (2.27)
	> 0.2	***13.33***	***74.07***	***12.59***	***135***	***25.41 (1.61)***
Slightly cool	0 – 0.2	4.41	64.71	30.88	68	23.81 (2.29)
	> 0.2	***10.69***	***63.36***	***25.95***	***262***	***25.87 (1.57)***
Neutral	0 – 0.2	1.63	67.48	30.89	123	24.30 (1.75)
	> 0.2	***4.11***	***54.55***	***41.35***	***341***	***26.1 (1.42)***
Slightly warm	0 – 0.2	2.27	39.77	57.95	88	24.35 (1.57)
	> 0.2	***2.2***	***30.22***	***67.58***	***182***	***26.57 (1.13)***
Warm	0 – 0.2	3.33	36.67	60	60	24.38 (1.32)
	> 0.2	***5.88***	***27.06***	***67.06***	***85***	***26.59 (1.46)***
Hot	0 – 0.2	25.0	0	75.0	*4*	*24.4 (1.46)*
	> 0.2	***0***	***10.0***	***90.0***	***10***	***26.58 (0.97)***

For naturally ventilated buildings (Table 2), under most sensation categories the operative temperature for high velocities is 2ºC higher than the operative temperature for low velocities at the same sensation. This shows that as an alternative to lowering the room temperature, air movement can be introduced to achieve similar thermal sensation. For HVAC buildings (Table 1), we cannot see this effect, due to the very small range of temperatures in those buildings.

Figure 1 shows the three preference curves as modeled by a probit analysis of both HVAC and NV buildings. It is at thermal sensation between cool (-2) and cold (-3) that the percentages for more and less air movement are identical. As the occupants feel less cool, their preference for more air movement increases, and at warmer sensations greatly exceeds their preference for less air movement.

Air movement preference for ASHRAE sensation from –0.7 to 1.5

Zhang et al. (2007) and Toftum (2004) suggest that the draft limit of the Standards should not apply when people feel neutral or warm. Thus, the analysis in this section focuses on the air movement preference analysis for the population whose sensation is neutral and warm. We chose a lower bound of –0.7, since it is the lower bound of the neutral thermal sensation range corresponding Class C in the ISO standard 7730. We limited the upper bound to 1.5, since sensation above 1.5 is probably undesirable in office environments.

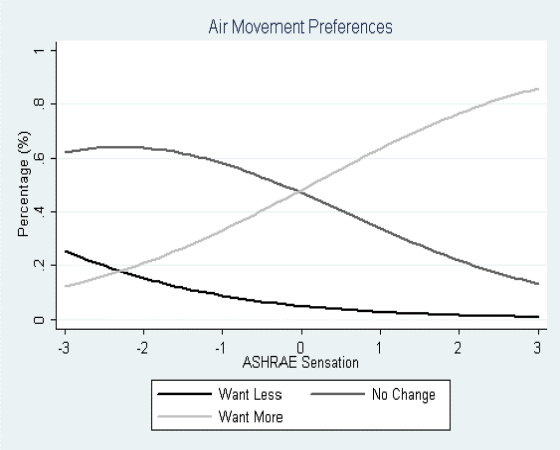

Figure 1: Air movement preference based on thermal sensation.

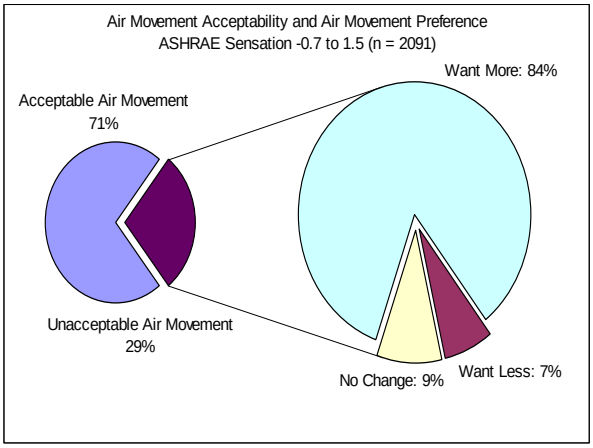

Figure 2: Air movement preference of respondents dissatisfied with air movement.

Under sensation -0.7 to 1.5, 52% of occupants wanted more air movement, 45% preferred no change, and 3% wanted less, and 29% of the population said that their velocity was not acceptable. Among those people, 84% wanted more, and 7% wanted less (Figure 2). Clearly the occupants' dissatisfaction is mostly due to too much air movement, not too little. Even at velocities greater than 0.2m/s, among the 29% of occupants that were dissatisfied with air movement, 73% wanted more and 17% wanted less.

DISCUSSION

Perceived air quality is significantly improved by air movement (Arens et al. 2008). This could be for psychological reasons or physical ones (e.g. air movement might disrupt the body's thermal plume carrying body odors and other pollutants into the breathing zone); in either case the desire for improved air quality might explain some of the observed preference for more air movement in neutral to warm conditions.

CONCLUSIONS

This study's findings are consistent with the statement presented in Zhang et al. (2007) that the draft limit should not apply to people when their thermal sensation is neutral and warm. This opens opportunities for energy-efficient air movement to be used as a method of cooling.

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