INDOOR CLIMATE AND PRODUCTIVITY

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INTRODUCTION

There is increasing evidence that indoor environmental conditions substantially influence health and performance. Macro-economic estimates show that the potential benefits from indoor environmental improvements for the society are high. Some calculations show that the estimated cost of poor indoor environment is higher than energy costs of heating and ventilation of the same buildings. A few sample calculations have also shown that many measures to improve indoor air environment are cost-effective when the health and productivity benefits resulting from an improved indoor climate are included into the calculations. There is an obvious need to develop tools and models so that economic outcomes of health and performance can be integrated in cost benefit calculations with initial, energy and maintenance costs. The use of such models would be expected to lead to improved indoor environments, health and productivity. This paper presents estimates of some quantitative linkages for cost benefit calculations namely between ventilation rate and sick leave, ventilation rate and performance, perceived air quality and performance, temperature and performance. The paper also suggests that a link between SBS symptoms and performance exists. This summary is based on papers by Seppänen & Fisk 2005a,b and Seppänen et al. 2005.

VENTILATION RATES AND SHORT TERM SICK LEAVE

Earlier summaries show that the prevalence of some types of communicable respiratory diseases is higher under conditions with lower ventilation rates. Fisk et al. 2003 present a quantitative relationship between ventilation rate and sick leave based on published field data and a theoretical model of airborne transmission of respiratory infections. The model (Figure 1) accounts for the effects of ventilation, filtration, and particle deposition on airborne concentrations of infectious particles and for the feedback process by which more disease transmission in a building leads to more sick occupants who are sources of infectious particles. The theoretical model is calibrated, i.e., fit to several sets of empirical data, resulting in different curves relating ventilation rates with illness prevalence.

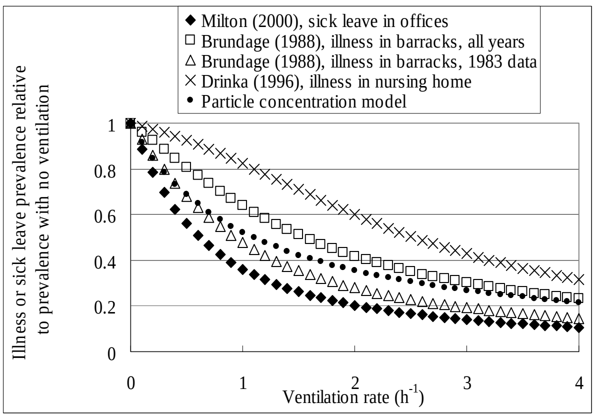

Figure 1. *Predicted trends in illness of sick leave versus ventilation rate. Sick leave relative to the prevalence with no ventilation (from Fisk et al. 2003)*

To illustrate how the illness or absence rate is predicted to vary with ventilation rate per person in an office building, Figure 2 provides a re-plot of two of the curves in Figure 1, assuming an occupant density of 83 m^3 per person, which was derived using data from a survey of 100 U.S. office buildings.

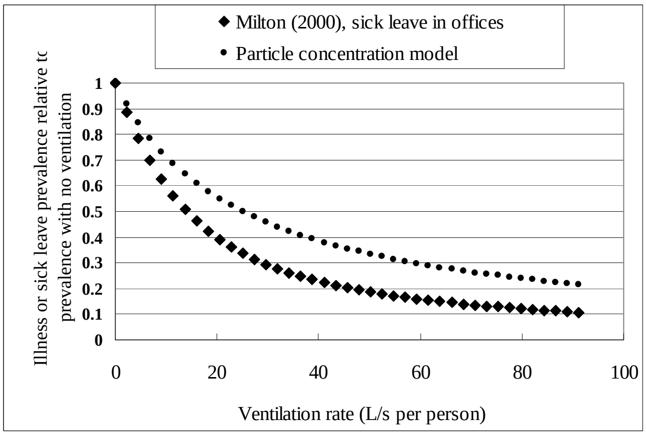

***Figure 2**. Predicted trends in illness or sick leave versus ventilation rate per person. Sick leave relative to the prevalence with no ventilation (from Fisk et al. 2003).*

VENTILATION RATES AND PERFORMANCE

Ventilation affects productivity indirectly through its impact on short-term sick leave due to infectious diseases, but also directly. To establish the relation between ventilation rate and performance relevant workplace studies and studies with data collected in controlled laboratory environment were identified. Normalised data from the studies (the change in performance is related to ventilation increase of 10 L/s-person) are presented in Figure 3.

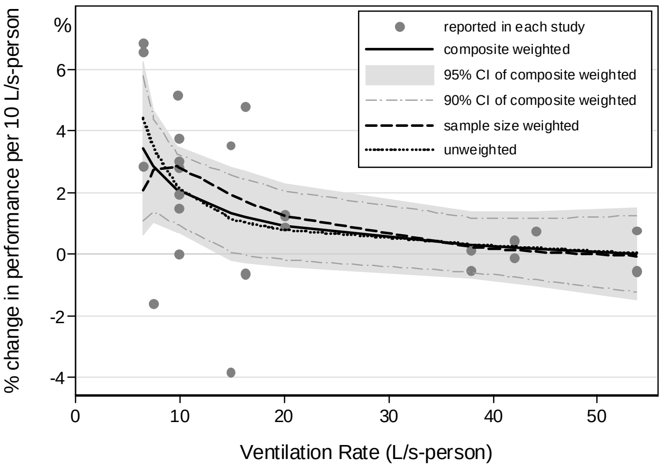

***Figure 3**. Percentage change in performance per 10 L/s-person increase in ventilation versus average ventilation rate (from Seppänen at al. 2005).*

Based on the estimated polynomial models, the performance at all ventilation rates relative to the performance at a reference ventilation rates of 6.5 L/s-person and 10 L/s-person were calculated and presented in Figure 4

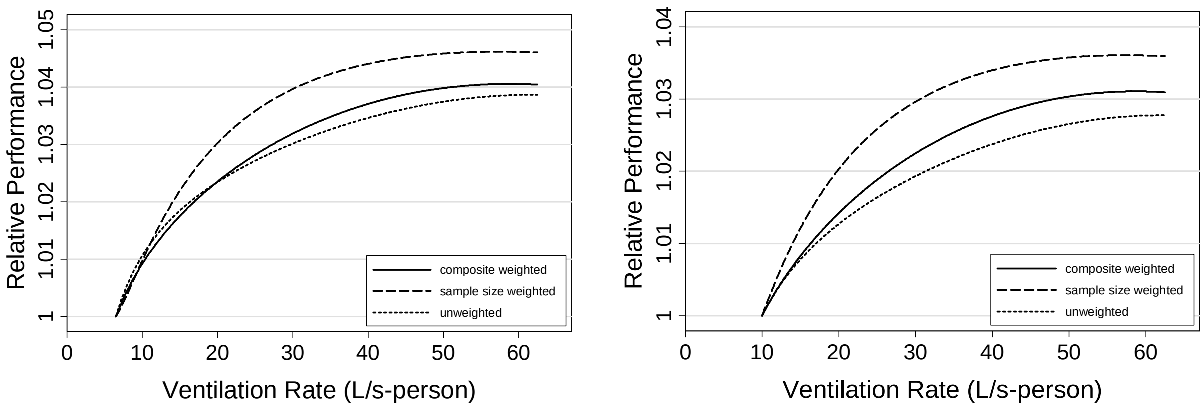

Figure 4. *Relative performance in relation to the reference value at 6.5 L/s-person (left) and 10 L/s-person (right) versus average ventilation rate (from Seppänen at al. 2005).*

PERCEIVED AIR QUALITY AND PERFORMANCE

Sensory evaluations of air quality with the olf-decipol concept have been used as indicators of air quality since 1988 when they were first introduced in 1988. Sensory evaluation is an integrated measure of air quality as sensed by human senses (olfactory and facial nerves). The studies reporting PAQ and performance have been performed mainly in Denmark. There is a consistent relationship between changes in PAQ and changes in work performance (Figure 5). The pollution sources in the experiments were a carpet removed from a sick building, pollutants from computer display terminals and from typical building materials.

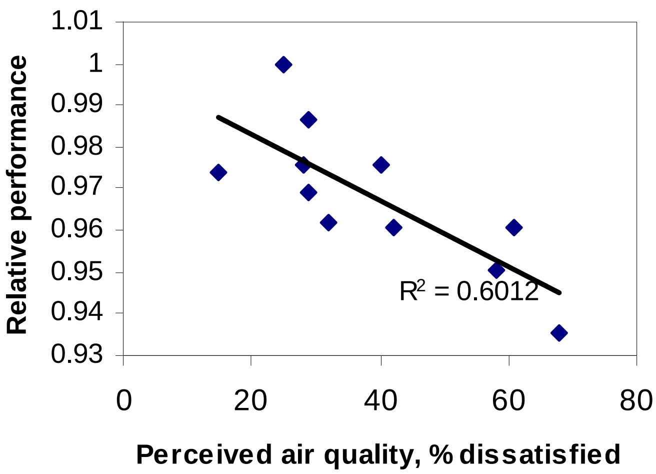

Figure 5. *Relative performance of text-typing depending on perceived air quality expressed as percentage of dissatisfied with air quality by non-adapted persons (from Bako-Biro 2004).*

TEMPERATURE AND PERFORMANCE

While the effects of temperature on comfort are broadly recognized, the effects on worker productivity have received much less attention. 150 assessments of performance from 26 studies have reported simultaneously the temperature and measured performance. From those studies the percentage performance change with an increase in temperature of each assessment was calculated and divided that by temperature range of the assessment, yielding a slope in the performance-temperature relationship. The number derived by this way indicates percentage change in performance per degree increase in temperature, positive values indicate increases in performance with increasing temperature, and negative values indicate decreases in performance with increasing temperature (Figure 6). From this relationship a curve of performance in relation to maximum performance was calcuated (Figure 7). For example, at the temperature of 30 ^{o}C the performance is 90% of the maximum performance at 21.6 ^{o}C, i.e. the reduction in performance is 10 %.

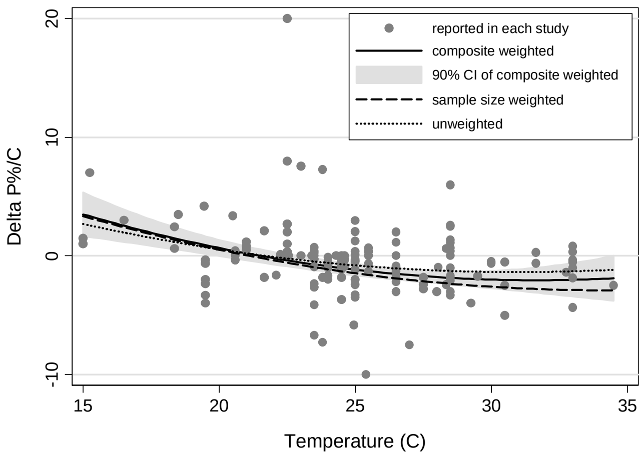

Figure 6. *Change in performance (Delta P% per ^{o}C increase in temperature) vs. temperature. Positive values indicate improved performance and negative values deteriorated performance with increased temperature. The chart has 150 data points from 26 studies (from Seppänen and Fisk 2005a).*

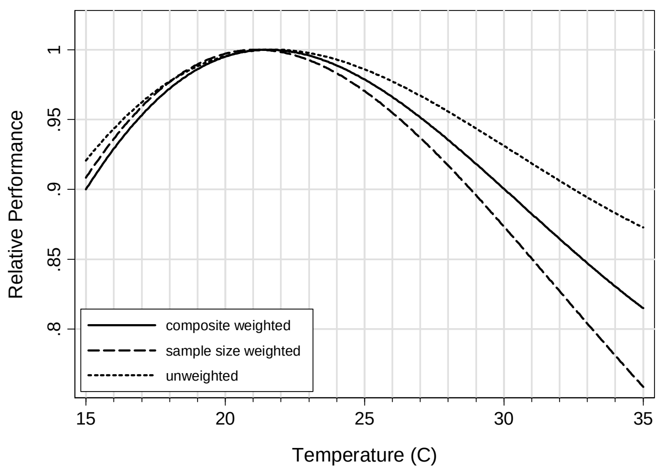

Figure 7. *Relative performance vs. temperature derived from the curve in Figure 6. Maximum performance is set equal to 1 at the temperatures where the corresponding curves in the Figure 6 cross the horizontal axis (from Seppänen and Fisk 2005a).*

SBS-SYMPTOMS AND PERFORMANCE

In many prior studies, characteristics of buildings and indoor environments have been linked to the prevalence of building-related SBS-symptoms experienced by the occupants of the building.

24 studies have simultaneously reported the association between the prevalence or intensity of SBS symptoms and a measure of work performance (Seppänen and Fisk 2005a). From those, eight were field experiments and nine were cross sectional field studies. Two of the studies with objective performance data suggest a relationship of SBS symptoms and performance. Niemelä et al. (2005) suggest, based on data form a call center, that an average reduction of 7.4 %-points in the prevalence of weekly central nervous symptoms correspond with a 1.1% increase in productivity. Tham and Willem (2004) report a linear relationship between intensity of mean score of neurobehavioral symptoms and average talk time (a measure of work speed) in a call center. The talk time improved (shortened) 5% per 10 points change in intensity of symptoms. The intensity of symptoms was measured with an analog-visual scale from 0 to 100.

CONCLUSIONS

For cost-benefit analyses leading to improved IEQ, health and productivity, it is not sufficient to have information demonstrating a statistically-significant association between an IEQ condition and health or performance, the size of that effect must be estimated quantitatively. The summaries in this paper show that it is possible, with existing data, to estimate quantitative relationships between ventilation rate and illness-caused absence, and to estimate quantitatively how work performance relates with ventilation rate, air temperature, and perceived air quality.

These resulting quantitative relationships have a high level of uncertainty; however, use of these relationships may be preferable to the current practice which ignores health and performance related productivity in decisions about building design or operation.

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