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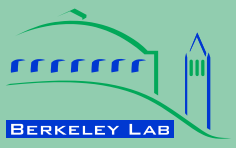
Title
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VENTILATION RATES PER PERSON AND PER UNIT FLOOR AREA AFFECT DECISION MAKING

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INTRODUCTION

Many minimum ventilation rate (VR) standards specify a minimum rate of outdoor air supply per person and per unit floor area. Changes in VR per person affect exposures to pollutants emitted by people, including carbon dioxide. Changes in VR per unit floor area affect exposures to pollutants emitted by the building and its furnishings and equipment. Little is known about the relative importance of VR per person and VR per unit floor area. The objectives of this study were to independently assess the effects of VR per person and VR per unit floor area on perceived air quality, acute health symptoms, and cognitive performance.

METHODOLOGIES

Two experiments were performed in a unique two-room laboratory facility that enabled independent control of VR per person and VR per unit floor area. Adult male and female subjects resided in room 1 with minimal sources of pollutants other than the people, while room 2 was filled with building materials, furnishings, and a laser printer. The air supplied to room 1 was a variable mixture of filtered outdoor air, recirculated air from room 1, and air from room 2. Sixteen subjects, in groups of four, worked in room 1 for four hours with a high VR of 8.5 L/s per person and for four hours on the same day with a low VR of 2.6 L/s per person, always with 5.6 L/s/m^2. Another 16 subjects, also in groups of four, resided in room 1, but with VRs of both 5.5 and 0.8 L/s/m^2, while always maintaining 8.4 L/s per person. Order of exposure (high versus low VR) and time of exposure (day of week and morning versus afternoon) were balanced. Temperature, humidity, ventilation system air flow rates, and concentrations of carbon dioxide and particles were measured continuously. Short-term integrated measurements of volatile organic compounds were collected during each session. During each session, subjects reported intensity of sick building syndrome health symptoms and perceived air quality via web-based questionnaires. Decision-making performance was evaluated with a computer-based tool called the strategic management simulation (SMS), described in greater detail in Satish et al. 2012. The resulting data were analyzed with statistical models with $p \leq 0.05$ or 95% confidence interval excluding unity as the criterion for a statistically significant finding. Protocols were approved by the Institutional Review Board of Lawrence Berkeley National Laboratory. More details are in Maddalena et al. (2013).

Participants were exposed to scenarios designed to match real-world challenges. Several parallel scenarios are available, allowing retesting of individuals without bias due to experience and learning effects. Participants are given instructions via text messages on a

computer interface, and respond to the messages using a drop-down menu of possible decisions. All participants receive the same quantity of information at fixed time points in simulated time, but participants have flexibility to take actions and make decisions at any time, as in the real world. The SMS generates scores that reflect decision-making capacities. Percentile ranks relative to the norms are calculated through a comparison of scores to the overall distribution of scores from a reference population of more than 20,000 U.S. adults.

RESULTS AND DISCUSSION

Temperature and RH were consistent across all test conditions at 22.5 °C (± 0.1) and 40.4% (± 1.0%), respectively. Carbon dioxide concentrations averaged approximately 800 ppm when the VR per person was high and 1750 ppm when the VR per person was low. The total volatile organic compound concentration, defined as the total ion current for the sample chromatogram between hexane and hexadecane reported as toluene equivalents, was 30 to 50 $\mu g/m^3$ when both VR per person and VR per floor area were high, 120 $\mu g/m^3$ when VR per person was low and VR per unit floor area was high, and 175 $\mu g/m^3$ when VR per person was high but VR per unit floor area was low. Perceived air quality and intensity of acute health symptoms were not significantly affected by either VR per person or VR per floor area.

There were statistically significant decreases of moderate magnitude in seven of eight metrics of decision-making performance with a diminished VR per person, and also with a diminished VR per unit floor area. The percentile scores are shown in Figures 1 and 2. Although there is considerable overlap of the error bars when the results are plotted as the average rank percentiles for the groups, nearly all of the differences are highly statistically significant. For the comparison of high and low VR per person, p values were less than 0.04 except for information management (p=0.30). For the comparison of high and low VR per floor area, all p values were less than 0.04.

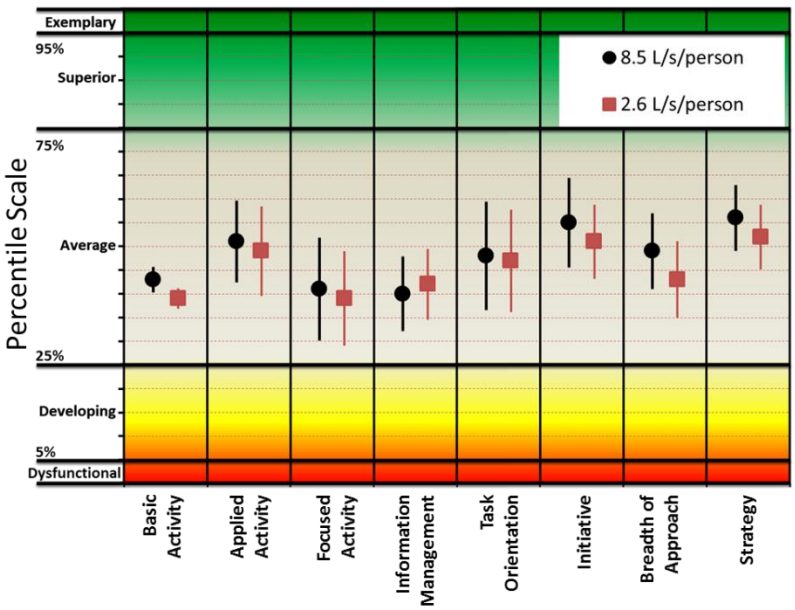


Figure 1. Average percentile ranks (± 1 standard deviation) with high and low VR per person.

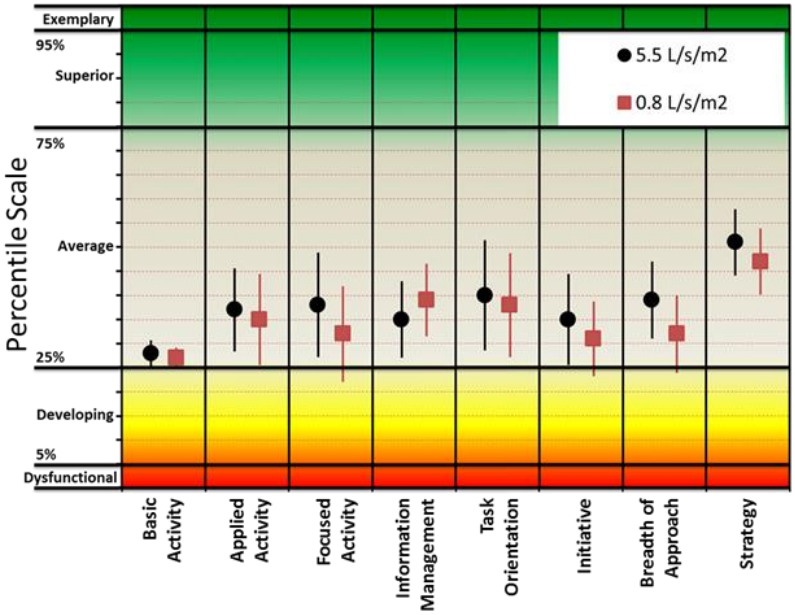


Figure 2. Average percentile ranks (± 1 standard deviation) with high and low VR per floor area.

These results provide compelling evidence that decreased VR per person and per unit floor area can diminish human performance even when perceived air quality and sick building syndrome symptoms are not affected. As discussed in Maddalena et al. (2013) a unit change in VR (L/s) per person had a larger effect on decision making that a unit change in VR (L/s) per square meter floor area. The results for VR per person are consistent with the findings of Satish et al. (2012) showing that higher carbon dioxide, with other conditions constant, degraded decision-making performance, suggesting that a lower VR per person which increases CO2 would also degrade decision making. Overall, the findings indicate that both VR per person and VR per floor area are important to maintenance of human performance.

CONCLUSIONS

In this tightly controlled laboratory study, independent reductions in VR per person and VR per unit floor area diminished decision-making performance.

ACKNOWLEDGEMENT

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