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Workplace Characteristics Associated with Health and Comfort Concerns in Three Office Buildings in Washington, DC

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ABSTRACT

Nearly 4,000 employees of a federal agency in Washington, DC, were surveyed in March 1989 to determine their health symptoms, comfort concerns, and reports of odor during the previous year. Their personal characteristics and perceptions of workplace conditions were also determined. A multivariate regression analysis indicated that the workplace variable affecting the largest number of health symptoms and comfort/odor concerns was dust. Perceptions of hot, stuffy air and the odor of paint and carpet cleaning and other chemicals were also associated with a number of health symptoms. Other workplace variables associated with comfort and odor concerns included glare, noise, and nearby water leaks. In most cases, individual air-handling units could not be associated with health symptoms. Areas with new carpet reported a higher frequency of throat problems. It was concluded that improved maintenance, better recirculation and filtration of air, and glare screens were desirable to improve employee health and productivity.

INTRODUCTION

In 1988–89, the U.S. Environmental Protection Agency (EPA), together with the National Institute for Occupational Safety and Health (NIOSH), sponsored a study of indoor air quality and employee health and comfort at two federal agencies. Employees at both agencies had been reporting health symptoms and comfort concerns that might be associated with their workplace. This paper summarizes results from one of the agencies, which occupies three buildings in the Washington, DC, area.

STUDY DESIGN

The study objective was to identify those personal and workplace characteristics that may be associated with reported health symptoms and indoor air quality in the three buildings. The approach was to administer a questionnaire to all employees on their health and comfort concerns, personal characteristics, and perceived workplace conditions. The questionnaire was designed by a team with expertise in medicine, epidemiology, industrial psychology, ventilation engineering, and indoor air studies.

The questionnaire included 32 health symptoms (e.g., headache), 10 comfort conditions (e.g., stuffy air), and 15 types of odors (e.g., paint). People were asked to report on the frequency of the symptoms or comfort/odor conditions over the past year on a five-point scale running from "never" to "always." Personal characteristics that might affect health (age, sex, smoking status, etc.) were also included, as were psychological or social characteristics such as heavy workload and job satisfaction. Employees' perceptions of workplace characteristics (dusty offices, presence of glare, etc.) were also explored. A final open-ended essay question was included to allow respondents to identify any additional concerns or issues they wished to raise regarding their health, comfort, or perceptions of the workplace.

Because of reported health effects in connection with the installation of new carpet about a year previous to administering the questionnaire, the locations where the new carpet were installed were determined and added to the data base. In an effort to determine the possible health effects of location or ventilation, the air-handling units serving each area were identified and used as indicators of spatial location to search for possible "hot spots."

STATISTICAL METHODS

Multiple regression analysis was used to investigate the effects of personal and workplace factors on self-reported health, comfort, and odor concerns occurring during the year prior to administering the questionnaire.

To reduce the large number of questions on health symptoms, comfort concerns, and odors noticed to a manageable number of factors, a principal components analysis (PCA) was carried out. The PCA reduced the 32 health symptoms to 12 factors: headache/nausea, eye, nose, throat, or chest symptoms, fatigue, dizziness, dry skin, chills/fever, bodily aches and pains, contact lens problems, and mental symptoms such as difficulty concentrating and depression. In a similar fashion, the 10 ques-

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tions on indoor air quality were reduced to four comfort factors (hot, stuffy air; dry air; cold, drafty air; and humid air), and the 15 questions on odors were reduced to six odor factors (paint and other chemicals, cosmetics, tobacco smoke, photocopying/printing processes, new carpet, and musty/damp odors). These 22 health, comfort, and odor factors became the dependent variables used in all regressions.

The independent variables included 25 personal and psychosocial factors and 29 workplace factors included in the questionnaire. Additional independent variables included new carpet and ventilation. Two measures of spatial variation were employed: a "coarse-grained" location variable, consisting of the two smaller buildings (each with about 500 respondents) and six architecturally homogeneous "sectors" in the larger building containing about 3,000 respondents, and a "fine-grained" variable consisting of 66 air-handling unit/floor locations in the three buildings.

Three sets of linear regressions were then run on each of the 22 health, comfort, and odor factors. The first set was designed to test for differences between the three buildings or between the six "sectors" in the largest building. The second set of linear regressions employed the "fine-grained" spatial variable, consisting of the areas served by different air-handling units (AHU) or, if an AHU served more than one floor, different floors served by one AHU. The third set of regressions tested for a possible effect of the design supply air capacity associated with the AHUs. All three sets of regressions also included all of the other personal and workplace characteristics.

Following the three sets of linear regressions, a final set of logistic regressions was carried out using a reduced set of variables that had been significant at the $p < 0.05$ level in the corresponding linear regression.

All the regressions were run separately for men and women to minimize the gender-related interactions that could otherwise complicate the interpretation of the regressions. For example, women employees were less well educated, received less pay, had fewer private offices, and reported more health symptoms than men. Analyzing the genders separately eliminates these gender-related interactions. However, one drawback of the separate analyses is that the relative risks for men and women cannot be calculated. All regressions on health symptoms were run both with and without the comfort and odor factors as independent variables.

These decisions (separate regressions by sex, including and excluding the comfort and odor variables on the 12 health factors) led to a total of 68 separate regressions within each of the three sets of linear regressions and one set of logistic regressions. Since each regression included between 20 and 120 personal and workplace characteristics, many thousands of associations were investigated. When such a large number of tests are made, some associations will appear significant even though they are due to chance alone. To reduce the number of these "false positives," associations were considered significant only if there was just one chance in 100 ($p \leq 0.01$) that the association was due to chance. However, all the associations tested in the final logistic regressions appear in the final report (EPA 1991).

RESULTS

The questionnaire was administered in March 1989 to about 5,000 employees in the three buildings, of whom 3,955 (81%) returned completed questionnaires (EPA 1989). The essay question was answered by about 38% of the respondents (Selfridge 1991).

Since the three sets of linear regressions gave similar results, only the set including the "fine-grained" spatial variables was selected for comparison with the logistic regressions. All results below are based on both the linear and logistic regressions.

Of more than 100 variables tested, only 11 were associated in at least two of the eight possible linear and logistic regressions with multiple (more than three) health factors (Table 1). These 11 variables included two workplace characteristics (dust and glare), three personal characteristics (chemical sensitivity, allergy to molds, college education), two psychosocial factors (heavy workload and conflicting demands), two comfort factors (hot, stuffy air and dry air), and two odor factors (the odor of fresh paint, carpet cleaning, and chemicals; and the odor of cosmetics, body odor, and food).

About seven variables were associated with multiple (at least three) comfort and odor factors (Table 2). By far the most frequently appearing variable was dust. All four of the comfort conditions (hot, cold, dry, or humid air) and all six of the odor factors were strongly associated with dust. A considerable number (about 20%) of the employees at one of the buildings also brought up problems of maintenance (including lack of dusting or vacuuming, presence of vermin, etc.) as the first item they mentioned on the essay question. Four other workplace variables—noise, glare, nearby water leaks, and the use of a fan—were associated with a smaller number of comfort and odor factors. Two personal characteristics—chemical sensitivity and conflicting demands—were also associated with multiple comfort and odor factors.

No effect on health was noted for any of the "coarse-grained" location variables; that is, neither the building nor any of the large "sectors" within a building had any consistent association with any of the 12 health factors investigated. Among the 66 "fine-grained" locations, only 2 appeared to be related to increased frequency of some symptoms. About eight additional locations were associated with certain comfort concerns and odors.

Persons in areas where the new carpet had been installed during the year-long period covered by the survey reported increased frequency of throat symptoms (sore throat, dry throat, hoarseness). A suggestion of an effect on dizziness was also noted in some regressions but only for men.

DISCUSSION

This is the first large-scale building study to employ an objective measure (PCA) to assess the way in which health symptoms cluster together. Previous studies have subjectively grouped symptoms into clusters, which sometimes contain symptoms belonging to different factors as identified by the more objective PCA. The effect of lumping different factors would likely be to make it more difficult to detect associations.

Another unique feature of this study was the fact that it attempted a *census* (rather than a sample) of all EPA employees at the three buildings. Even though the census was not complete, the 81% coverage allowed an investigation of spatial variation within the buildings, including the effects of ventilation and carpet installation. These analyses have not been possible in preceding studies, because they have typically involved only a sample of employees from multiple buildings.

Workplace Characteristics

Dust was identified as the characteristic contributing most powerfully to a wide variety of health, comfort, and odor concerns. Dust has previously been identified as a proximate cause of health problems in offices or schools. The primary cause, presently unknown, could be physical irritation, allergens, or endotoxins (Gravesen et al. 1990). The Danish town hall study

Glare was the other workplace variable affecting a number of health factors. The influence of glare on headache and eye irritation is clear. However, the strongest effect of glare was on muscle pain, including neck and shoulder pain. This may be plausible if the presence of glare causes VDT operators to adopt and maintain uncomfortable positions to minimize glare.

Noise was associated with several comfort and odor factors, including in particular reports of cold, drafty air. Since renovation may open up areas of the building to the outdoors and is also associated with noise, the relationship is not unreasonable.

Water leaks near the respondents' office areas were associated with increased reports of damp and musty odors. Water leaks were also associated (men only) with reports of unusual fatigue and difficulty concentrating. These findings support the possibility that molds are implicated in some health symptoms, consistent with the finding that allergies to molds were broadly associated with a number of symptoms.

Although new carpet showed few relationships with health symptoms, it is of interest that people in areas where the new carpet was installed reported higher frequencies of throat symptoms (sore throat, dry throat, hoarseness). Since the period of recall was one year, which extended back to the time of installation, it is not possible to say whether the respondents were still experiencing these symptoms or whether they had simply experienced them earlier and were now recovered. Nonetheless, this finding provides some support to the hypothesis that carpet installation can result in at least this specific health symptom.

The lack of spatial variation in health effects, once other known significant variables are accounted for, provides little evidence that specific buildings, locations, or air-handling units were "hot spots" for health problems.

Personal Characteristics

The variable with the most widespread influence on health was self-reported chemical sensitivity. The questions used to define this factor included a list of possible sources of irritation (e.g., tobacco smoke, fumes from new carpets, paint, etc.) and a question on whether the respondent considered herself or himself "especially sensitive" to any of the chemical fumes. About a third of respondents at each building answered "yes." Women were more likely to report chemical sensitivity than men (37% vs. 25%).

Chemical sensitivity was also related to reports of odors, particularly odors of paint and other chemicals, tobacco smoke, and photocopier and printing processes. This is consistent with anecdotal reports of severe reactions by some persons to odors at seemingly low concentrations.

The importance of mold allergies for a number of health symptoms indicates that molds may play a part in the reported health symptoms at the buildings. Molds and dustiness may both be results of inadequate maintenance.

Certain psychosocial factors (heavy workload, conflicting duties) were associated with increased frequencies of some health symptoms, particularly the group of symptoms including difficulty concentrating and tension. However, these factors were not particularly important for a number of the other symptoms. It appears, therefore, that the bulk of the reported health problems at these buildings cannot be attributed to psychological factors.

Comfort and Odor Factors

Reports of hot, stuffy air and dry air were often associated with health symptoms. The reports of dry air were supported by the discovery that no AHUs had operable humidifiers. The resulting indoor relative humidities were in the 20% to 30% range, which is below the recommended ASHRAE standard.

Of the six odor factors, the main one with multiple associations with health symptoms was the factor composed of the odors of paint, carpet cleaning, pesticides, and other chemicals such as glues and cleansers. Most of these odors are associated with maintenance activities or with renovation.

CONCLUSIONS

Analysis of the 32 health symptoms indicated that they clustered into 12 factors, largely by single body systems, such as eye, nose, throat, chest, central nervous system, etc. This finding, if confirmed, would be useful in designing future questionnaires.

The importance of dust, mold allergies, the odor of paints and other chemicals, and nearby water leaks in affecting multiple health symptoms and comfort/odor factors points to building maintenance or renovation as a possible factor in the complaints at the three buildings. Therefore, it is recommended that attention be given to ways of improving building maintenance, particularly to reduce dust, clutter, and conditions conducive to growth of mold. The design of new buildings should allow for adequate building maintenance and should reduce the likelihood of dust buildup. This could include decisions on the optimum extent of carpeting and fabric-covered partitions vs. other, more easily cleaned surfaces; the use of walk-off mats to reduce track-in of dust and dirt; and techniques to allow for easy replacement of water-soaked carpet or cleaning and disinfecting water-stained surfaces.

Since many sources of dust are associated with essential office processes such as filing, photocopying, and the like, providing supplemental air cleaning and filtration may also be considered. Since this would also require supplemental ventilation, or at least recirculation, the same system could serve to reduce the health symptoms associated with hot, stuffy air.

A second factor of broad importance in affecting health was glare. With the increased use of computers, it appears that reducing glare has the potential of reducing complaints of headache, eye irritation, and neck and shoulder pain. Providing glare screens for all computers may be helpful, as would providing information to employees on the importance of reducing glare. An important finding of this study has been that headache is the single most common cause of absenteeism and lost work time (EPA 1989). Thus, if reducing glare resulted in reducing headache prevalence, employee absenteeism and lost work time could decrease. Inspections of workstations to improve ergonomic design could possibly reduce the complaints noted in this study regarding uncomfortable workstations. Such improvement of employee working conditions could be a cost-effective means of improving productivity.

REFERENCES

EPA. 1989. *Indoor air quality and work environment survey. Volume I: Employee survey.* Washington, DC: U.S. Environmental Protection Agency.

EPA. 1991. *Indoor air quality and work environment survey. Volume IV: Multivariate analysis.* Washington, DC: U.S. Environmental Protection Agency.

Gravesen, S., P. Skov, O. Valbjørn, and H. Lowenstein. 1990. "The role of potential immunogenic components of dust (MOD) in the sick building syndrome." In Walkinshaw (ed.), *Indoor Air '90: Proceedings of the 5th International Conference on Indoor Air Quality and Climate*, Vol. 1, pp. 9-13. Ottawa, Ontario: Canada Mortgage and Housing Association.

TABLE 1
Variables Associated[a] with at Least 4 of the 12 Health Factors

Workplace Characteristics	
Dust	(headache; nasal, chest, eye, throat symptoms; fatigue; chills and fever; difficulty concentrating[b]; dizziness; dry skin; contact lens problems)
Glare	(headache; eye symptoms; fatigue; difficulty concentrating; pain[c])
Personal Characteristics	
Chemical sensitivity	(headache; nasal, chest, eye, throat symptoms; fatigue; pain; difficulty concentrating; dizziness)
Mold allergies	(headache; nasal, eye, throat symptoms; fatigue; pain; dry skin)
No college	(headache, chest symptoms, fatigue, chills and fever, dizziness)
Psychosocial Characteristics	
Workload	(headache, eye symptoms, pain, difficulty concentrating, dizziness)
Conflicting demands	(nasal, chest symptoms; chills and fever, pain, difficulty concentrating, dizziness)
Comfort and Odor Characteristics[d]	
Hot stuffy air	(headache; nasal, eye, chest symptoms; fatigue; difficulty concentrating; dizziness)
Dry air	(headache; nasal, eye, throat symptoms; dry skin)
Odor of paint, chemicals	(headache; nasal, chest, throat symptoms; fatigue; chills; difficulty concentrating; dizziness)
Odor of cosmetics	(eye symptoms, chills and fever, pain, difficulty concentrating)

[a] Significant ($p < 0.01$) in at least two (of eight) linear and logistic regressions
[b] Includes difficulty concentrating, difficulty remembering, depression, tension
[c] Includes aching muscles, back pain, shoulder/neck pain, hand/wrist pain
[d] Significant at $p < 0.01$ in at least two (of four) linear and logistic regressions

TABLE 2
Variables Associated[a] with at Least 3 of 10 Comfort and Odor Factors

Workplace Characteristics	
Dust	(all four comfort concerns and all six odor factors)
Glare	(hot air, dry air, odors of paint, cosmetics, dampness)
Noise	(hot air, dry air, cold air, odors of paint and cosmetics)
Use fan	(hot air, humid air, cold air [negative], odor of cosmetics)
Water leaks	(odors of dampness, cosmetics, tobacco smoke)
Personal Characteristics	
Chemical sensitivity	(humid air, odors of paint, photocopying, new carpet, tobacco smoke)
Conflicting demands	(dry air, cold air, odors of cosmetics, photocopying, dampness, tobacco smoke)

[a] Significant ($p < 0.01$) in at least two (of four) linear and logistic regressions

(Skov et al. 1989) found dust to be the most highly correlated variable with self-reported health symptoms. A Swedish study (Norbäck and Torgen 1989) found that intensive cleaning of carpets and wet dusting reduced health symptoms in an office building for at least the following two months. A U.S. study (Hedge 1991) found that supplying increased recirculation and filtration (employing HEPA filters and charcoal) to employees on two floors of a building resulted in decreased symptom frequencies compared to employees on two untreated floors.

Dust was also the single strongest variable affecting comfort and odor factors. Since odors may be carried by particles or by gases associated with particle emissions, as in tobacco smoke, printing processes, painting, etc., the observed relationships of odors with dust may all have physical causes.

Hedge, A. 1991. Press announcement, "Effect of filtering breathing-zone air in reducing sick building syndrome complaints." Centercore, Plainfield, NJ.

Norbäck, D., and M. Torgen. 1989. "A longitudinal study relating carpeting with sick building syndrome." *Environ. Int.*, Vol. 15, pp. 129-135.

Selfridge, O.J. 1991. *Summary of responses to the essay question of the employee survey questionnaire. Supplement to volume I of the indoor air quality and work environment study.* Research Triangle Park, NC: U.S. EPA, Atmospheric Research and Exposure Assessment Laboratory.

Skov, P., O. Valbjørn, B.V. Pedersen, and the Danish Indoor Climate Study Group. 1989. "Influence of personal characteristics, job-related factors, and psychosocial factors on the sick building syndrome." *Scand. J. Work Environ. Health*, Vol. 15, pp. 286–295.