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Linking Indoor Environment Conditions to Job Satisfaction: A Field Study

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Linking Indoor Environment Conditions to Job Satisfaction: A Field Study

Abstract

Physical and questionnaire data were collected from 95 workstations at an open-plan office building in Michigan, USA. The physical measurements encompassed thermal, lighting, and acoustic variables, furniture dimensions, and an assessment of potential exterior view. Occupants answered a detailed questionnaire concerning their environmental and job satisfaction, and aspects of well-being. These data were used to test, via mediated regression, a model linking the physical environment, through environmental satisfaction, to job satisfaction and other, related, measures. In particular, we demonstrated a significant link between overall environmental satisfaction and job satisfaction, mediated by satisfaction with management and with compensation. Analysis of physical data was limited to the lighting domain. Results confirmed the important role of window access at the desk in satisfaction with lighting, particularly through its effect on satisfaction with outside view.

Keywords: Environmental satisfaction; Job satisfaction; Open-plan offices; Cubicles; Field study; Lighting; Well-being; View

Total manuscript words: 6,180 (excluding abstract, acknowledgement, references, tables, figure labels, and appendix)

1. Introduction

The literature is replete with studies that have examined isolated direct relationships between physical variables and occupant comfort, satisfaction and behaviour. Examples are studies of temperature on thermal comfort (e.g., Fanger, 1970), luminance levels on glare evaluations (e.g., Eble-Hankins and Waters, 2004), and sound level on acoustic satisfaction (e.g., Belojevic *et al.*, 2001). De Croon *et al.* (2005) compared general office design options (e.g. open, closed, teleworking, desk sharing) and found effects on privacy, job satisfaction, and cognitive workload. Sick building syndrome (SBS) research has examined relationships between the physical environment and self-reported health symptoms (e.g., Burge, 2004). The relevance of this kind of work is often justified with statements such as “... a better environment means a happier worker, and happier workers make for a more productive workplace”. However, only a few studies have attempted to establish this linkage formally. Several SBS studies have included environmental satisfaction and job satisfaction as predictors of symptoms (Brasche *et al.*, 2001; Chao *et al.*, 2003; Ooi *et al.*, 1998; Skov *et al.*, 1989; Zweers *et al.*, 1990), but with little consideration that the direction of the relationship could be reversed, or that one set of relationships mediates others. In other words, multi-stage analysis in such studies has been limited.

On the other hand, researchers have devoted a lot of effort to developing multi-stage models of workplace behaviours and organizational performance. For example, links between concepts such as: satisfaction with management, job structure, job satisfaction, turnover, well-being, organizational citizenship, and customer satisfaction have all been studied in detail (Carlopio, 1996; Cotton, 2003; Dalal, 2005; Katzell *et al.*, 1992; Lambert *et al.*, 2001; Roznowski and Hulin, 1992; Schneider *et al.*, 2003).

To truly understand how physical workplace environments affect job satisfaction and other variables related to organizational productivity, it would be desirable to link these areas of research

into larger models to be tested with empirical data. The present study makes some progress in this direction. The general structure of the larger model we tested was developed from the existing literature, as described below, and is shown in Figure 1.

1.1 Environmental satisfaction

The Cost-effective Open-Plan Environments (COPE) project, using survey data from 779 participants in 9 buildings, generated a statistically significant overall model linking satisfaction with lighting, ventilation, and privacy & acoustics to overall environmental satisfaction. Overall environmental satisfaction in turn predicted job satisfaction in a positive relationship (Veitch *et al.*, 2007) (see Figure 2). Other aspects of the COPE research elucidated relationships between the physical environment and satisfaction with lighting, ventilation, and privacy & acoustics (Veitch *et al.*, 2002; Veitch *et al.*, 2003; Veitch *et al.*, 2005; Newsham *et al.*, 2008). Several other studies have shown a significant positive link between the indoor environment, environmental satisfaction and aspects of job satisfaction (e.g. Carlopio, 1996; De Croon *et al.*, 2005; Oldham and Fried, 1987; Wells, 2000). However, Lee and Brand (2005) failed to find a predicted relationship between environmental satisfaction and job satisfaction, and proposed that this was because of unaccounted-for mediating relationships.

1.2 Job satisfaction

To quote Roznowski and Hulin (1992, p.158): "... job satisfaction [scores] are the most useful information organizational psychologists or organizational managers could have ... in predicting a variety of behaviours of organizational members". Numerous studies have examined the importance of different organizational factors on job satisfaction, including job control, leadership style, social support, work demands, pay and benefits, and organizational culture. For example, De Jonge *et al.* (2001) found that lower job demands and higher workplace social support

at work predicted higher job satisfaction over time. Soonhee (2002) found that the use of participative management styles and decision-making processes were positively related to job satisfaction. Similarly, Lok and Crawford (2004) found that supportive organizational cultures and considerate leadership styles were positively related to job satisfaction in a sample of managers. In three surveys of public service employees, Mansell *et al.* (2006) found lower workplace “hassles”, higher recognition and reward, higher job control, and higher supervisory support were significantly correlated with higher job satisfaction across three timepoints. By comparison, Sparks *et al.* (2005) found increased pay, staffing levels, and benefits to be the most important factors related to higher job satisfaction.

Brill *et al.* (2001) claimed that all aspects of the physical workplace environment together could, on average, account for 24% of job satisfaction responses. However, this study did not include other aspects of the work experience as contributors to job satisfaction (nor have detailed results been published in a peer-reviewed outlet). In contrast, Ellickson and Logson (2002) investigated 14 factors as potential predictors of job satisfaction, and found the following 10 to be important (in order of relationship strength): departmental “*esprit de corps*”, promotional opportunities, pay, performance appraisal, benefits, supervision, equipment and resources, training, workload equality, and job level, explaining a total of 52% of the variance in job satisfaction; all relationships were positive, except job level. A single-item rating of satisfaction with the amount of physical space was not a significant predictor.

Several studies have demonstrated that job satisfaction is an antecedent to several aspects of organizational productivity. Judge *et al.* (2001) found a significant positive correlation between individual job satisfaction and manager-assessed job performance, a correlation that was stronger among high-complexity jobs. Katzell *et al.* (1992) also found a significant positive correlation between job satisfaction and manager-assessed job performance, and confirmed that organizational issues such as rewards, equity of treatment, and challenging and clear goals, were all positively

associated with job satisfaction. Many studies have found job satisfaction and organizational commitment to be positively related to each other (Gaertner, 1999; Mathieu and Zajac, 1990; Meyer, 1997; Williams and Hazer, 1986; Yousef, 2002). Organizational citizenship behaviour (support and promotion of one's organization's goals) has been shown to be positively related to both job satisfaction and organizational commitment, and to work quality and productivity (e.g., Podsakoff and MacKenzie, 1997; Podsakoff *et al.*, 2000). Counterproductive work behaviour has been shown to have a significant negative association with job satisfaction (Dalal, 2005).

Wilson *et al.* (2004) found higher absenteeism and turnover intent to be significantly correlated with lower job satisfaction, lower organizational commitment, and higher job stress in retail employees. Allen *et al.* (2005) also found a significant correlation between lower job satisfaction and higher turnover. Meta-analytical studies have also indicated a significant negative relationship between job satisfaction and absenteeism (Scott and Taylor, 1985), and between both job satisfaction and organizational commitment, and staff turnover (Griffeth *et al.*, 2000). Roznowski and Hulin (1992) argued simply that any negative experience will motivate individuals to avoid that experience again in the future, and that jobs are no exception. They then linked reduced job satisfaction to various counterproductive activities and work avoidance behaviours, such as psychological and physical withdrawal, absenteeism, and turnover.

Organizations as well as individuals may benefit from higher job satisfaction among employees. Higher average job satisfaction in business units was correlated with higher customer loyalty, lower employee turnover, better safety records, and higher profitability (Harter *et al.*, 2002), and higher returns on assets and earnings per share (Schneider *et al.*, 2003). Edmans (2008) demonstrated that the "100 Best Companies to Work for in America" (a surrogate for overall job satisfaction) yielded significantly higher returns than other companies; further, there was evidence that this relationship was causal.

1.3 Job stress

Researchers have focused considerable interest on job stress (or more accurately, job strain resulting from exposure to job stressors). The dominant model is the job demand-control-support model in which the adverse health effects (strain) of job demands (e.g., pace of work, job complexity) are moderated by the degree of control (autonomy) and social support available to the individual (e.g., Ganster and Murphy, 2000; Karasek, 1979; van der Doef and Maes, 1998). In general (and as discussed above), jobs in which there are more numerous or more intense stressors are related to lower job satisfaction (e.g., Flanagan and Flanagan, 2002; Mansell *et al.* 2006), and to higher turnover and absenteeism (e.g., Dwyer and Ganster, 1991).

Vischer (2007) argued that traditional research on workplace stress has focussed on psychosocial factors, organizational aspects, and job design, and has ignored the potential effect of the physical environment. Vischer proposed that a poor fit between the physical environment and the needs of the worker may lead to job stress due to the additional effort to make accommodation.

1.4 Physical symptoms

Many researchers have addressed the effect of lighting, acoustics, indoor air quality, and other indoor parameters on physical symptoms such as headaches, fatigue, musculoskeletal pain, and eye, nose, throat and skin irritation. For example, Hedge *et al.* (1989), found a significantly higher symptom prevalence in air-conditioned buildings, and Stenberg *et al.* (1994) found a higher risk of SBS symptoms with lower outdoor air rates. Aaras *et al.* (2001) found that improvements to lighting and workplace design according to ergonomic principles reduced visual discomfort and shoulder and neck pain in software engineers. Wilkins *et al.* (1989) reported substantially lower levels of headaches and eyestrain when office fluorescent lighting was operated with high-frequency electronic ballasts, compared to magnetic ballast technology.

Several studies have indicated a negative relationship between symptom reports and environmental satisfaction (e.g., Broder *et al.*, 1990; Hedge *et al.*, 1989). There is also evidence that better physical health is correlated with higher job satisfaction and other factors such as lower job stress and better psychological well-being (e.g., Cass *et al.*, 2003; Ganster and Schaubroek, 1991). Poor job satisfaction has been associated with higher likelihood of SBS complaints (Brasche *et al.*, 2001) and absenteeism due to SBS (Zweers *et al.*, 1990). Some SBS studies have linked job stressors such as high workload and low levels of support with higher prevalence of physical symptoms (e.g., Eriksson *et al.*, 1996; Marmot *et al.*, 2006; Mendelson *et al.*, 2000; Stenberg *et al.*, 1994). In a review of relevant literature, Lahtinen *et al.* (1998) found higher workload, lower job control, poorer social relationships, lower job satisfaction, and higher job stress to be consistently related to higher SBS symptoms.

1.5 Psychological well-being

Donald and Siu (2001) demonstrated positive links between satisfaction with physical working conditions, job satisfaction, and employee physical and mental well-being. In addition, Wells (2000), using structural equation modelling, found that higher satisfaction with the physical environment predicted higher job satisfaction, which predicted higher employee well-being. A large meta-analysis also supported this relationship (Cass *et al.*, 2003). Other research has indicated that employees with lower job satisfaction and psychological well-being are more likely to be absent (Hardy *et al.*, 2003). Indeed, job satisfaction is sometimes construed as part of well-being (Warr, 1990). Cotton and Hart (2003) argued that overall employee well-being is comprised of distress, morale, and job satisfaction, all of which may be influenced by organizational climate (which included management practices, for example). Well-being is then an antecedent to organizational productivity outcomes such as customer satisfaction, employee sickness and turnover, and voluntary overtime (cf., Harter *et al.* 2002; Schneider *et al.*, 2003).

1.6 Physical conditions: Daylight and windows

Of the many aspects of the physical environment that can affect environmental satisfaction and comfort, the role of potential exterior view was of particular interest in this study. Windows are generally seen as favourable influences on health and well-being, providing access to views of the outside and the potential for restorative experiences (e.g., Chang and Chen, 2005; Kaplan and Kaplan, 1989; Ulrich, 1984).

Having a window in one's workspace has been associated with improved job satisfaction and interest in the job (Finnegan and Solomon, 1981). Leather *et al.* (1998) found that the size of the floor area into which direct sunlight penetrated was positively related to job satisfaction and general well-being, and negatively related to turnover intention.

Not all investigations have found universal benefits of windows. Veitch *et al.* (2005) found no effects of window proximity on job satisfaction, but did find that having access to a window immediately in one's workstation had a positive effect on satisfaction with lighting and a negative effect on overall environmental satisfaction

1.7 Exploring the conceptual model

The overall conceptual model we have drawn from the research literature is shown in Figure 1. We explored aspects of this conceptual model using archival data collected from occupants of an open-plan office building (N=95). It should be emphasized that this is only one possible conceptual model of several that could find justification in previous research. One cannot test all possible models, particularly with a sample of limited size, and one from a single organization in a single building; this sample inevitably limited the range of some variables.

Despite its limitations, this dataset represents a rare opportunity to explore a broad set of relationships among the physical workplace environment, occupant environmental and job

satisfaction, and factors important to organizational productivity. In our research we initially explored relationships between environmental satisfaction and job satisfaction, and then extended these linkages to self-reported physical symptoms, job stress and well-being. In a subsequent analysis, we explored relationships between physical descriptors of the office environment and satisfaction with lighting (other relationships between physical conditions and satisfaction were beyond the scope of this study).

The specific hypotheses tested in this field study may be summarized as follows:

1. *The general relationships between aspects of environmental satisfaction and job satisfaction found in the COPE analysis (Figure 2) will (a) hold in this data set, and (b) extend to include satisfaction with workstation furniture and equipment, and self-reported physical symptoms.*
2. *Overall environmental satisfaction will be an important contributor to job satisfaction even when other aspects of job satisfaction are accounted for.*
3. *Job stress will predict physical symptoms and job satisfaction, and will mediate the relationship between physical conditions and physical symptoms.*
4. *Window access will be a significant predictor of satisfaction with lighting.*

2. Methods and Procedures

2.1 Setting

This dataset contained physical measurements of 95 workstations at an open-plan office building in Michigan, USA, along with survey responses from the occupants of those workstations. Data were collected by the organization's own staff, in conjunction with a third-party contractor.

The two study floors featured identical floor-plates and identical exterior shells, with the same glazing (continuous glazing along the top third of the north-facing exterior wall). However,

they did have different ambient lighting systems and somewhat different task lighting, and different workstations and furniture layouts (see Figure 3).

2.2 Participants and Survey

One hundred occupants were targeted for the study, 25 close to windows and 25 farther away from windows, on each of the two study floors. Participants received e-mails in advance of data collection describing the process. There were no direct incentives to participate, although data collection was part of a larger programming exercise to inform the development of new facilities. Approximately 5-10 of the original sample declined to participate, and some replacements in similar locations on the same floor were recruited. Data were collected over a one-week period in February/March, 2004.

Researchers approached participants at their workstations one at a time and gave them instructions on how to complete the survey. Participants then went to a nearby in-house training facility where the survey computer resided.

Participants were asked 227 questions pertaining to: demographic characteristics; job/organization characteristics; satisfaction with the physical work environment; job satisfaction; strain and emotional well-being; clothing level; health symptoms; and, the physical layout of their office and surrounding area. Participants took approximately 25-40 minutes to complete the survey. Table 1 shows basic participant characteristics, based on questionnaire responses.

2.3 Physical Measurements

While the participant answered the questionnaire, the researchers conducted a series of measurements to describe the physical conditions in the workstation. A portable device with environmental sensors was placed in the workstation (see Figure 4). This device took “snapshot” measurements of: relative humidity (%); dry bulb temp (°C); globe temp (°C); dew point (°C); air

velocity (m/s); sound pressure level (dBA); noise criterion (dB); vertical illumination level (lux).

Data collection took about 10 minutes to complete.

Additional physical descriptors were derived from the plans, photographs, and measurements done at other convenient times. These included: potential exterior view; foliage in the view; highest panel height; storage space; type of storage; work-surface area; size of workstation footprint; percent enclosure; relative daylight contribution.

The role of potential exterior view was of particular interest to the host organization, and to us, and the derivation of the related physical measure deserves further expansion. The researcher sat in the participant's chair, swivelled to face the nearest exterior window, and took a photograph of the window and surroundings using a digital camera (see Figure 5). The physical measure was the percentage of this photograph that was exterior window. The building had windows in the top third of the window wall only; therefore, views to the outside from a seated position primarily revealed only sky (e.g., see Figure 3). Some views included near-field tree branches.

3. Results

3.1 Mediated regression analysis

We used the techniques for mediated regression analysis set out by Baron and Kenny (1986) to test the linkages implied in Figure 1. This is a logical sequence of multiple regression analyses. To take one example, the chain from satisfaction with lighting → environmental satisfaction → job satisfaction. One first regresses job satisfaction on satisfaction with lighting. One next regresses environmental satisfaction (the mediator) on satisfaction with lighting. Finally, one regresses job satisfaction on satisfaction with lighting and environmental satisfaction together. All three steps must return statistically significant results. At the third step, with two predictors, one looks for the non-mediating predictor (satisfaction with lighting) to have a smaller effect size than it had at the

first step, when it was entered alone; the mediating variable (environmental satisfaction) must also have a statistically significant effect on the outcome (job satisfaction). If the effect size of the first step variable drops to zero at the third step, one has full mediation, otherwise, one has partial mediation. Longer chains are established logically, from sequential mediation analyses. This example features only one predictor/moderator variable, but multiple variables can be entered at the same time. Note that in this paper, for brevity, we do not report all overlapping three-step sequences, but tend to begin one three-step sequence with the variable that was at the end of a previous sequence.

This approach to testing a set of linked mechanisms has some drawbacks. It cannot give an estimate of the fit of the entire model, as a structural equation modelling (SEM) analysis would do. SEM was not feasible with this model because there were too many parameters to be estimated given the sample size. The sequenced regressions require many simultaneous regression analyses, with the possibility of spurious results because of the non-independence of the tests. To address this problem, we limited the tests performed to those required to explore the proposed model (rather than also testing many variations), which have empirical or theoretical justification.

3.2. Definition of variables

Composite variables were derived from the individual survey items. The allocation of individual items to composite variables was guided by several processes. For the COPE model test, we chose items similar to the items used in the COPE study (Veitch *et al.*, 2007), and supported these choices with confirmatory factor analysis. For other variables we were guided by exploratory factor analysis, and then used theoretical considerations to determine the final choice. The resulting variables used in the analyses are described in Table 2a; all questionnaire variables were scored on seven-point scales, ranging from 1 – 7, with higher values indicating better outcomes. Further information on the derivation of these variables is given in Appendix A.

Table 2b shows the variables used in the subsequent, lighting-specific analysis, which included objective physical measures as predictors. Satisfaction with lighting is a single composite variable, which includes satisfaction with glare and outside view. In addition, because satisfaction with glare and outside view tend to counteract each other in relation to window presence, we conducted analyses with a set of components of satisfaction with lighting. These were: satisfaction with glare, satisfaction with outside view, and a variable that included the same items as satisfaction with lighting, with the exceptions of satisfaction with glare and satisfaction with outside view. In this way we could examine the effect of independent variables with less chance of confounding effects. We also looked at eye irritation symptoms as a separate variable.

The physical variables were chosen as the best equivalents to those used in Veitch *et al.* (2005), which used a Hierarchical Linear Regression (HLR) approach to relating physical and personal variables to satisfaction with lighting.

3.3 Final data set

Data preparation and screening was conducted using the procedures recommended by Kline (1998). Cases with missing data were excluded from the analysis. Kurtosis was less than 8, and skewness less than 3 for all variables, which, according to Kline, provides adequate univariate normality. For univariate outliers, cases with scores greater than 3 standard deviations from the mean were excluded. For multivariate outliers, cases for which the Mahalanobis distance statistic was greater than the critical value at $p < .001$ were excluded. Note that in each phase of the analyses we excluded outliers on the variables used in that phase only. Therefore the number of cases in the analyses does differ slightly from phase-to-phase.

Initial bivariate correlations confirmed the physical differences between the two study floors, with the expected subjective responses to those differences. However, there were no significant correlations between the demographic variables (sex, age, job type) and workstation properties (area,

enclosure, potential exterior view), or measured physical variables (illuminance, sound level, humidity, temperature, air velocity). The one exception was an association between air velocity and job type ($r = -0.26$, $p = 0.02$). Further, there was no correlation between demographic variables and floor assignment. Therefore we deemed it appropriate to conduct all analyses on the data set as a whole, and did not pursue demographic variables as predictors. This approach is almost universal in the literature related to job satisfaction cited in the Introduction.

3.4 COPE model test and extension

Our initial goal was to test the general model of satisfaction relationships derived from the COPE field study, albeit with a different (although similar) set of dependent measures. In the context of mediated regression, we tested whether overall environmental satisfaction mediated the relationships between the individual satisfaction environmental measures (satisfaction with lighting, ventilation, and privacy & acoustics) and job satisfaction. The results of the regressions are shown in Table 3; the effect sizes (R^2) are medium to large. (Throughout this paper, we use Cohen's (1988) conventions in interpreting effect sizes.)

The net result is that a mediating relationship is not indicated, because overall environmental satisfaction is not a significant predictor of job satisfaction at Step 3. The model test is not directly supported. However, the individual beta-weights are similar in size to those from the COPE field study analysis. Further, many of the bivariate correlations between individual variables were significant, and in the expected directions, as shown in Table 4.

We then attempted to broaden the model to include satisfaction with workstation furnishings and equipment at the same level as satisfaction with lighting, ventilation, and privacy & acoustics, with self-reported physical symptoms as an antecedent to these satisfaction ratings. However, Table 4 shows that there is no significant correlation between self-reported physical symptoms and overall environmental satisfaction, which is a pre-requisite for mediation. Nevertheless, many of the

bivariate correlations between individual variables were significant, and in the expected directions. In particular, self-reported physical symptoms did correlate with all of the individual environmental satisfaction measures (satisfaction with lighting, ventilation, privacy & acoustics, and workstation furnishings and equipment).

3.5 Environmental satisfaction and job satisfaction elements

It is of great interest to understand how environmental satisfaction compares to other workplace factors in the relationship to job satisfaction. The physical work environment, which is provided by management to the employee, can be considered as an expression of management's attitudes towards the employee; and conversely, we considered that environmental satisfaction would influence satisfaction with other aspects of the employment relationship. The dataset included items that allowed us to explore this issue; specifically, we examined satisfaction with employment compensation and satisfaction with management, and a model in which they mediated the relationship between overall environmental satisfaction and job satisfaction. The results of the regressions are shown in Table 5, and indicate relationships in the expected direction: Increasing environmental satisfaction was associated with increased satisfaction with compensation and with management, which were associated with increased job satisfaction; the model came close to full mediation. The effect sizes for Steps 1 and 2 are small to medium, but comparable in size to other relationships in the job satisfaction domain (e.g. Katzell *et al.*, 1992). The effect size at Step 3 is large.

3.6 Relationships to job stress

We tested a model with job satisfaction mediating the relationship between job stress and employee well-being. The results did not support a mediating relationship. However, Table 4 shows

that the bivariate correlations between these variables were significant, and in the expected directions.

We further tested a model with job stress mediating the relationship between the physical conditions described in the bottom half of Table 2b and self-reported physical symptoms. The results did not support a mediating relationship. In fact, there were no significant correlations between this limited set of physical variables and job stress. However, Table 4 shows that the bivariate correlation between job stress and self-reported physical symptoms was significant, and in the expected direction.

3.7 Extension of model to physical aspects of lighting

We extended the model to include the effect of the physical environment on symptoms and satisfaction related to lighting. We first tested the bivariate correlations between the variables of interest. Only enclosure and potential exterior view correlated with both a potential mediator and a potential final dependent variable. Further, an initial HLR analysis with these data suggested that physical variables had stronger direct relationships with satisfaction with glare and satisfaction with outside view than with satisfaction with lighting (excl. glare, view), suggesting that the former might be mediators of relationships to the latter. The model of Figure 1 also proposes that physical symptoms at least partially mediate the relationship between physical conditions and satisfaction. Two analyses consistent with these considerations satisfied the conditions for mediation. The results of the mediation tests are shown in Tables 6 and 7.

Satisfaction with outside view partially mediated the relationship between potential exterior view and satisfaction with lighting (excl. glare, view). Relationships were in the expected direction: Increasing exterior view was associated with better satisfaction with outside view, which was associated with increased lighting satisfaction. The effect size for Step 1 is small, but is large for Steps 2 and 3.

There is also a path between enclosure and satisfaction with glare, partially mediated by self-reported physical symptoms. Increasing enclosure was associated with better symptom reports, which was associated with increased satisfaction with glare. The effect sizes for Steps 1 and 2 are small to medium, the effect size at Step 3 is medium also.

3.8 Summary

The final overall set of relationships is shown in Figure 6. Solid lines in Figure 6 indicate demonstrated mediated paths, whereas dotted lines indicate significant bivariate correlations (and are therefore shown with double-headed arrows). Note that for clarity, not all significant bivariate correlations are shown in Figure 6, only those associated with tested mediation paths.

4. Discussion

Overall, the analysis provided valuable information, within the limitations of the dataset. The COPE model test, and its extension to include satisfaction with the workstation furnishings and equipment, and physical symptoms, was disappointing. Expected bivariate correlations were found, but mediated paths were not demonstrated. One possible explanation is the small sample size in the data set, because the standardized beta-weights were similar in size to those in the much larger COPE study. A further issue was the limited variability presented by data from a single organization in a single building.

Another possible explanation is that the relationship between environmental satisfaction and job satisfaction is in large part indirect, as suggested by Lee and Brand (2005). The role of satisfaction with management/compensation mediating the relationship between environmental satisfaction and job satisfaction in this study is an example of this. This link is novel and interesting, and expands upon the environmental satisfaction → job satisfaction relationship observed in the

COPE study. We know of no other study that has tested this model, but it is entirely plausible. It suggests that employees consider their physical environment as part of their compensation package. Traditional expectations have been that promotion entitles one to a larger space closer to a window (e.g., Zalesny and Farace, 1987), for example, but our results suggest a broader relationship. Our results also suggest that employees' opinion of their management is influenced by the quality of the physical environment that the management provides and maintains. Marquardt *et al.* (2002) suggested that the quality and maintenance of good indoor environments is part of the message management sends to their staff about how they are valued by the organization. Zweers *et al.* (1990) found an analogous relationship between environmental satisfaction and satisfaction with complaint handling. Leaman and Bordass, in summarizing data from 16 commercial buildings in the UK, also emphasized the importance of "... a management culture which takes staff needs seriously ..." (2001, p.141) in improving occupant satisfaction.

Skeptics have argued that environmental satisfaction as a direct actor on job satisfaction must pale into insignificance compared to factors such as pay and benefits and management practices. Indeed, our regression of satisfaction with management/compensation and environmental satisfaction as direct predictors of job satisfaction supports this view (Table 5, Step 3). However, the mediation model shows that environmental satisfaction also has an important part to play; the effect size of environmental satisfaction as a predictor of satisfaction with management/compensation was not trivial (see Steps 2a and 2b, Table 5). Overall, this finding suggests that careful attention to the design and operation of indoor environments will reap benefits in terms of how employees feel valued by the organization, and their impressions of management competence.

Our results emphasize the importance of the availability of an outside window on aspects of satisfaction with lighting. This is consistent with prior work. For example, window distance has been linked to satisfaction (Veitch *et al.*, 2005) and SBS symptoms (Fisk *et al.*, 1993), and view availability has been linked to task performance (Heschong, 2003), and health (Ulrich, 1984). The

LEED green building rating scheme (USGBC, 2006) recognizes these benefits, and offers credits for daylighting and view access. We did not find an expected negative effect of window access on glare, probably because all windows in this sample faced north and therefore never admitted direct sunlight.

Another path in the lighting analyses related the level of enclosure provided by furniture to physical symptoms and glare. We would expect that more enclosure would reduce the potential for glare, and thus reduce glare-related symptoms. The intriguing thing about this path is that it was stronger for general symptoms than for eye symptoms alone. One explanation for this comes from the work of Rea *et al.* (1985) and Heerwagen and Diamond (1992), which suggested that poor lighting can cause people to adopt non-optimal postures to avoid these conditions, which may lead to joint and muscle strains, and not just eye symptoms. Interestingly, eye symptoms loaded with back-related problems in our exploratory factor analysis.

These relationships may have been affected by the somewhat unusual window arrangement in the study building, with windows only on the top third of one north-facing wall. These windows did not provide a view of the horizon and the content that such a view angle provides, which might have tempered the positive effect of having a view. Such windows would also be less likely to cause glare than windows that extended further down the wall, which might have reduced the negative effect of window size on glare. The physical descriptor of potential exterior view also had its limitations. The photographic method clearly depends on the field of view of the particular camera; nonetheless, the relative-comparison value across workstations in this study remains. Although it does include multiple windows in the “potential exterior view” viewing direction, it does not account for whether the window was in the principal line-of-sight of the participant. Nevertheless, our results suggest value in a more systematic investigation of window access in the future.

In addition, one should not conclude that potential window access and enclosure are the only things that govern satisfaction with lighting. The literature contains many studies demonstrating

effects of photometric descriptors and other variables including horizontal illuminance, luminance, their ratios and control (e.g. Veitch *et al.*, 2005; Newsham *et al.*, 2004). They cannot be included in the model in Figure 6 because the dataset did not contain such variables.

The physical variables used in the lighting satisfaction analysis were not correlated with stress. However, due to the initially defined scope of the study, this was a very small subset of the physical descriptors that could indicate a misfit between environmental conditions and worker needs, or a physical strain. Nevertheless, the expected correlations between stress and physical symptoms, satisfaction with management, job satisfaction, and well-being were observed.

The scope of this research placed more emphasis on lighting issues than on other aspects of the indoor environment. Nevertheless, the model in Figure 6, and previous COPE research, demonstrates that satisfaction with ventilation (including temperature and air quality), and privacy (both acoustic and visual), contribute to overall environmental satisfaction. Therefore, in taking actions to improve satisfaction with lighting, one must take care not to negatively affect other aspects of the indoor environment. For example, seating people close to windows will maximize daylight and view, but may also expose people to greater thermal extremes. In addition, privacy may also suffer, as a result of visual access or noise from the outside, or to an increase in speech propagation between adjacent workstations caused by the hard window surface and gaps between the furniture panels and the window. Exploring such relationships with this data was theoretically possible, but not within the final scope of the study.

The relationships depicted in Figure 6 is but one of many possible arrangements of these variables that could be supported by theory and prior work. We chose to focus our analysis on a model derived from our interpretation of the literature, and not to try to build models that contradicted theory but delivered statistically significant mediation tests. It is also important to recognize that there are many other variables that were not measured that could be significant predictors of variables that were in this dataset. Finally, there were many aspects of organizational

productivity that were not measured; it would be valuable to collect a more inclusive set of data to test the broader model.

5. Conclusions

With respect to the research hypotheses that we set out to test with this dataset:

1. *The general relationships between aspects of environmental satisfaction and job satisfaction found in the COPE analysis (Figure 2) will (a) hold in this data set, and (b) extend to include satisfaction with workstation furniture and equipment, and self-reported physical symptoms.*

The mediated regression analysis did not directly support the model test and extension.

However, most predicted bivariate correlations were significant and in the expected direction, and the equivalent beta-weights were similar in size to those in the COPE analysis.

2. *Overall environmental satisfaction will be an important contributor to job satisfaction even when other aspects of job satisfaction are accounted for.*

The mediation analysis supported this, showing that environmental satisfaction acted through satisfaction with management and satisfaction with compensation to affect job satisfaction.

3. *Job stress will predict physical symptoms and job satisfaction, and will mediate the relationship between physical conditions and physical symptoms.*

The expected mediation was not supported, but there were bivariate correlations as expected between job stress, physical symptoms, and job satisfaction.

4. *Window access will be a significant predictor of satisfaction with lighting.*

The mediation analysis supported this, reinforcing the important role of window access in satisfaction with lighting, particularly through its effect on satisfaction with outside view.

More enclosure by furniture panels was also associated with higher satisfaction with glare, through its effect on physical symptoms.

This analysis has demonstrated that better indoor environments play a role in elevating job satisfaction and other aspects of organizational productivity in office buildings. The results from this limited dataset, and the potential value of the outcomes to organizational decision-making, justify future studies to test the larger model of these relationships with more rigour.

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Table 1. Descriptive statistics for participants in the study. Values for Age are years, values for other demographic variables are frequency counts. (Note, these numbers total 89, the number of participants included in each phase of the analysis varied slightly depending on outlier removal)

Age	Min = 26 years, Max = 56, Mean = 39.7, Median = 40, s.d. = 8.6
Sex	Male = 42, Female = 47
Education	High School = 16, College = 48, Grad School = 25
Job Type	Clerical/Admin = 28, Technical = 42, Manager = 19

Table 2a. Descriptive statistics for the variables used in the initial analyses.

Variable	N	Min.	Max.	Mean	s.d.
Satisfaction with lighting	89	1.71	6.11	3.94	0.98
Satisfaction with ventilation	89	1.75	7.00	4.19	1.23
Satisfaction with privacy & acoustics	89	1.17	5.92	3.69	1.02
Satisfaction with workstation furnishings and equipment	86	2.60	6.20	4.60	0.83
Overall environmental satisfaction	89	1.50	6.50	4.20	1.07
Job satisfaction	89	3.75	7.00	5.59	0.72
Satisfaction with employment compensation	86	1.67	7.00	4.47	1.09
Satisfaction with management	86	1.61	7.00	4.56	1.02
Self-reported stress associated with job	86	1.00	5.89	3.51	1.03
Employee well-being	86	1.67	7.00	4.94	1.32
Self-reported physical symptoms	86	2.17	6.80	4.82	1.01

Table 2b. Descriptive statistics for the variables used in the analyses extended to physical aspects related to lighting.

Description	N	Min.	Max.	Mean	s.d.
Satisfaction with lighting (incl. glare, view)	88	1.71	6.11	3.84	0.99
Satisfaction with lighting (excl. glare, view)	88	1.40	5.95	3.84	1.06
Satisfaction with glare	88	1.00	7.00	4.85	1.47
Satisfaction with view to the outside	88	1.00	7.00	2.86	1.80
Self-reported eye irritation	87	1.00	7.00	3.92	1.73
Self-reported physical symptoms	88	0.44	6.80	4.66	1.13
Square root of workstation area (length x width) [m]	88	1.75	3.35	2.39	0.34
Enclosure: four, 2.75m-high walls would =100% [%]	88	10.0	80.0	44.6	15.1
Vertical illuminance measured with portable system [lux]	88	44	394	179	76
Potential exterior view [%]	88	0.00	34.4	4.6	7.4

Table 3. Results of mediated regression for COPE model test. B are unstandardized regression coefficients.

Step 1	DV= Job satisfaction	Step 2	DV= Overall		Step 3	DV= Job satisfaction
			environmental satisfaction			
IV ↓	B	IV ↓	B		IV ↓	B
Satisfaction	0.11	Satisfaction	0.39***		Satisfaction	0.09
with lighting		with lighting			with lighting	
Satisfaction		Satisfaction			Satisfaction	
with	0.10	with	0.02		with	0.10
ventilation		ventilation			ventilation	
Satisfaction		Satisfaction			Satisfaction	
with privacy &	0.21**	with privacy &	0.36***		with privacy &	0.19*
acoustics		acoustics			acoustics	
					Overall	
					environmental	0.06
					satisfaction	
F(3,85)	6.35***	F(3,85)	10.74***		F(4,84)	4.86***
R ²	0.18	R ²	0.28		R ²	0.19
R _{adj} ²	0.15	R _{adj} ²	0.25		R _{adj} ²	0.15

N=89 * $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$

Table 4. Bivariate correlations for COPE model test and extension analysis (N=86).

	Job Stress	... physical symptoms	Satis. with lighting	Satis. with privacy & acoustics	Satis. with ventilation	Satis. with workstation ...	Overall environmental satis.	Satis. with ... compensation	Satis. with management	Job satisfaction	Employee well-being
Job Stress	1										
Self-reported physical symptoms	0.22 *	1									
Satisfaction with lighting	0.03	0.29 **	1								
Satisfaction with privacy & acoustics	0.29 **	0.33 **	0.07	1							
Satisfaction with ventilation	0.07	0.46 ***	0.37 ***	0.10	1						
Satisfaction with workstation furnishings and equipment	0.03	0.38 ***	0.10	0.19	0.20	1					
Overall environmental satisfaction	0.09	0.12	0.39 ***	0.39 ***	0.20	0.31 **	1				
Satisfaction with employment compensation	-0.14	0.22 *	0.17	0.16	0.14	0.41 ***	0.30 **	1			
Satisfaction with management	0.32 **	0.25 *	-0.00	0.40 ***	0.11	0.27 *	0.33 **	0.36 **	1		
Job satisfaction	0.30 **	0.25 *	0.20	0.31 **	0.21	0.27 **	0.26 **	0.39 ***	0.61 ***	1	
Employee well-being	0.68 ***	0.26 *	0.11	0.26 *	0.17	0.07	0.07	-0.06	0.27 *	0.26 *	1

* $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$

Table 5. Results of mediated regression on job satisfaction. B are unstandardized regression coefficients.

Step 1	DV= Job satisfaction	Step 2a	DV=		DV=		DV= Job satisfaction
			Satisfaction with compensation	Step 2b	Satisfaction with management	Step 3	
IV ↓	B	IV ↓	B	IV ↓	B	IV ↓	B
Overall		Overall		Overall		Overall	
environmental satisfaction	0.16*	environmental satisfaction	0.30**	environmental satisfaction	0.31**	environmental satisfaction	0.02
						Satisfaction with compensation	0.12*
						Satisfaction with management	0.36***
F(1,84)	5.94*	F(1,84)	8.30**	F(1,84)	10.04**	F(3,82)	18.32***
R ²	0.07	R ²	0.09	R ²	0.11	R ²	0.40
R _{adj} ²	0.06	R _{adj} ²	0.08	R _{adj} ²	0.10	R _{adj} ²	0.38

N=86 * $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$

Table 6. Results of mediated regression on SATLIGHTMOD. B are unstandardized regression coefficients.

DV= Satisfaction		DV= Satisfaction		DV= Satisfaction	
Step 1	with lighting (excl. glare, view)	Step 2	with outside view	Step 3	with lighting (excl. glare, view)
IV ↓	B	IV ↓	B	IV ↓	B
Potential exterior view	0.04*	Potential exterior view	0.16***	Potential exterior view	-0.03
				Satisfaction with outside view	0.39***
F(1,86)	5.21*	F(1,86)	66.42***	F(2,85)	18.26***
R ²	0.06	R ²	0.44	R ²	0.30
R _{adj} ²	0.05	R _{adj} ²	0.43	R _{adj} ²	0.28

N=88 * $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$

Table 7. Results of mediated regression on GLARE. B are unstandardized regression coefficients.

Step 1		Step 2		Step 3	
DV= Satisfaction with glare		DV= Self-reported physical symptoms		DV= Satisfaction with glare	
IV ↓	B	IV ↓	B	IV ↓	B
Enclosure	0.02*	Enclosure	0.02**	Enclosure	0.01
				Self-reported physical symptoms	0.48***
F(1,86)	5.23*	F(1,86)	9.09**	F(2,85)	9.32***
R ²	0.06	R ²	0.10	R ²	0.18
R _{adj} ²	0.05	R _{adj} ²	0.09	R _{adj} ²	0.16
N=88 * <i>p</i> ≤0.05, ** <i>p</i> ≤0.01, *** <i>p</i> ≤0.001					

Figure Labels

Fig. 1. Conceptual model of linkages between indoor environment and outcomes important to organizational productivity.

Fig. 2. Relationships between environmental satisfaction and job satisfaction demonstrated through structural equation modeling on COPE field study data.

Fig. 3. Typical views of the interior of the study building (2nd floor on left, 3rd floor on right).

Fig. 4. Collection of instruments used to acquire indoor environment data in each workstation.

Fig. 5. Illustration of the steps to calculate the potential exterior view. Note, this is an example only, and not one of the spaces from the study building.

Fig. 6. Relationships demonstrated by analysis of field data. Dotted lines indicate bivariate correlations, and solid lines indicate mediated paths.

Figure 1.

Figure 2.

Figure 3.

Figure 4.

Figure 5.

Figure 6.

Appendix A. Scale Development

In Table A1 we show the individual scale items used in each principal composite measure, and the Cronbach alpha reliability measure. The final composite measure was the mean of the individual items. However, note that items followed by a number in parentheses were themselves intermediate scales of multiple related items, combined in one or more steps. The number indicates how many items formed this intermediate scale, and text in parentheses indicates the concepts addressed by this intermediate scale.

The individual items in the composite variables were all scored by the participants on seven-point scales. In all cases only the end points of the scales were labelled, however, the labels differed between the scales. For example, depending on the format of the question, labels included: “Low Quality – High Quality”; “Strongly Agree – Strongly Disagree”, “Ugly – Appealing”, “Often Bothered – Never Bothered”, “Most Important – Least Important”, etc. In creating composite variables, all labelling schemes were considered equivalent in providing a numerical scale, and reverse coding was used, if necessary, to ensure that the direction of all scales was the same. Therefore, all variables ranged from 1 (bad) – 7 (good).

A detailed example for one composite scale, satisfaction with lighting, is shown in Table A2. More detail on the scale development may be obtained by contacting the authors.

Table A1. Composite scales, with a summary of their individual items, and overall reliability measure.

Variable	Cronbach α
Satisfaction with lighting	
Task Visibility, Flicker, Overall Lighting, Daylighting, Outside View From Your Office, Glare Problems (2), Aesthetics (4 – Visual Appearance, Colour Scheme)	0.73
Satisfaction with ventilation	
Heating/Cooling, Air Quality (4 – Smell, Stuffiness, Air Quality)	0.73
Satisfaction with privacy & acoustics	
Privacy, Speech Communication on Phone, Noise from Co-workers, General Noise (3), Space (2 – Storage, Room to Move), Interruptions (2)	0.80
Satisfaction with workstation furnishings and equipment	
Mouse Comfort, Mouse Adjustability, Chair, Armrests, Phone System Quality, Phone System Attributes, Keyboard Ease of Use, Keyboard Adjustability, Computer Monitor Adjustability, Computer Monitor Arrangement	0.74
Overall environmental satisfaction	
Work Environment, Workstation	0.71
Job satisfaction	
Good Company (2 – Quality of being an Employee, Organization), Job Features	0.71
Satisfaction with employment compensation	
Compensation Quality, Salary (2), Benefits (2)	
Satisfaction with management	
Organizational Leadership (3), Employee-Management Relations (2), Employee Morale, Organizational Difficulty	0.80
Self-reported stress associated with job	
Stress (3 – Stressful Job, Relaxing Job), Job Fatigue, Not Enough Time	0.74
Employee well-being	

Sleep Problems, Family/Social Life Impact, Emotional Impact	0.78
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Self-reported physical symptoms	
Neck/Shoulders/Back (5), Chest (3 – Air Passages, Breathing), Hands (3), Feet, Arms, Eyes	0.75
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Satisfaction with lighting (excl. glare, view)	
Task Visibility, Flicker, Overall Lighting, Daylighting, Aesthetics (4 – Visual Appearance, Colour Scheme)	0.70
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Satisfaction with glare	
Glare Problems (2)	0.83
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Satisfaction with outside view, single item	
Outside View From Your Office	N/a
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Self-reported eye irritation, single item	
Eyes Irritated because of Work	N/a
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Table A2. Detailed derivation of the satisfaction with lighting scale, showing individual questionnaire items, intermediate composite variables, and reliability scores.

Bothered by lights flickering (often-never)

Overall lighting quality (low-high)

Overall daylight quality (low-high)

Overall quality of outside view from your office (low-high)

Glare often is a problem in my work area (strongly agree-
strongly disagree)

Glare problems (serious-no)

glare
Cronbach Alpha = .83

General quality of visual appearance of your office (low-high)

Work area (ugly-visually appealing)

appearance
Cronbach Alpha = .80
aesthetic
Cronbach Alpha = .85

Overall quality of color scheme of your office (low-high)

Color scheme (awful-perfect)

colour
Cronbach Alpha = .82

Satisfaction with
lighting
Cronbach Alpha = .73