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Past research found that satisfaction with lighting and ventilation, along with satisfaction with privacy and acoustics, predicts environmental satisfaction. Satisfaction with the environment then influences job satisfaction.

The current research explores details about satisfaction with lighting and views and the nature of the link between environmental satisfaction and job satisfaction. The results generally support the trends summarized from past research, except that exterior views relate to lighting quality and daylight quality more than other objective measures of daylight and lighting.

Furthermore, rather than influencing job satisfaction directly, environmental satisfaction linked to job satisfaction only through quality of compensation and quality of management/supervision. This result implies that the quality of office environments may reflect the quality of the more general aspects of an organization such as pay and leadership.

RESEARCH PAPER

Linking indoor environment conditions to job satisfaction: a field study

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Physical and questionnaire data were collected from 95 workstations at an open-plan office building in Michigan, US. 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, a significant link was demonstrated 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, lighting, occupant perception, offices, organizational productivity, view, well-being

Des données physiques et des données obtenues par questionnaire ont été recueillies auprès de 95 postes de travail dans un immeuble de bureaux décloisonnés du Michigan, aux États-Unis. Les mesures physiques comprenaient des variables thermiques, acoustiques et relatives à l'éclairage, les dimensions des meubles, ainsi qu'une évaluation de la vue extérieure potentielle. Les occupants ont répondu à un questionnaire détaillé portant sur la satisfaction à l'égard de leur environnement et de leur travail, et sur des aspects relatifs au bien-être. Ces données ont été utilisées pour tester, au moyen d'une régression médiatisée, un modèle liant l'environnement physique, par la satisfaction à l'égard de l'environnement, à la satisfaction dans le travail et aux autres mesures liées. Il a en particulier été démontré qu'il existe un lien important entre la satisfaction globale à l'égard de l'environnement et la satisfaction dans le travail, médiatisé par la satisfaction vis-à-vis de la direction et de la rémunération. L'analyse des données physiques a été limitée au domaine de l'éclairage. Les résultats ont confirmé que le fait de pouvoir accéder à une fenêtre au bureau joue un rôle important dans la satisfaction à l'égard de l'éclairage, en particulier par son effet sur la satisfaction vis-à-vis de la vue extérieure.

Mots clés: satisfaction à l'égard de l'environnement, satisfaction dans le travail, éclairage, perception par les occupants, bureaux, productivité organisationnelle, vue, bien-être

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 (Skov *et al.*, 1989; Zweers *et al.*, 1990; Ooi *et al.*, 1998; Brasche *et al.*, 2001; Chao *et al.*, 2003), 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 (Katzell *et al.*, 1992; Roznowski and Hulin, 1992; Carlopio, 1996; Lambert *et al.*, 2001; Cotton and Hart, 2003; Schneider *et al.*, 2003; Dalal, 2005).

To understand fully 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 tested was developed from the existing literature, as described below, and is shown in Figure 1.

Environmental satisfaction

The Cost-effective Open-Plan Environments (COPE) project, using survey data from 779 participants in nine buildings, generated a statistically significant overall model linking satisfaction with lighting, ventilation, and privacy and acoustics to overall environmental satisfaction. Overall environmental satisfaction in turn predicted job satisfaction in a positive relationship (Veitch *et al.*, 2007) (Figure 2). Other aspects of the COPE research elucidated relationships between the physical environment and satisfaction with lighting, ventilation, and privacy and acoustics (Veitch *et al.*, 2002, 2003, 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., Oldham and Fried, 1987; Carlopio, 1996; Wells, 2000; De Croon *et al.*, 2005). 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.

Job satisfaction

To quote Roznowski and Hulin (1992):

job satisfaction [scores] are the most useful information organizational psychologists or

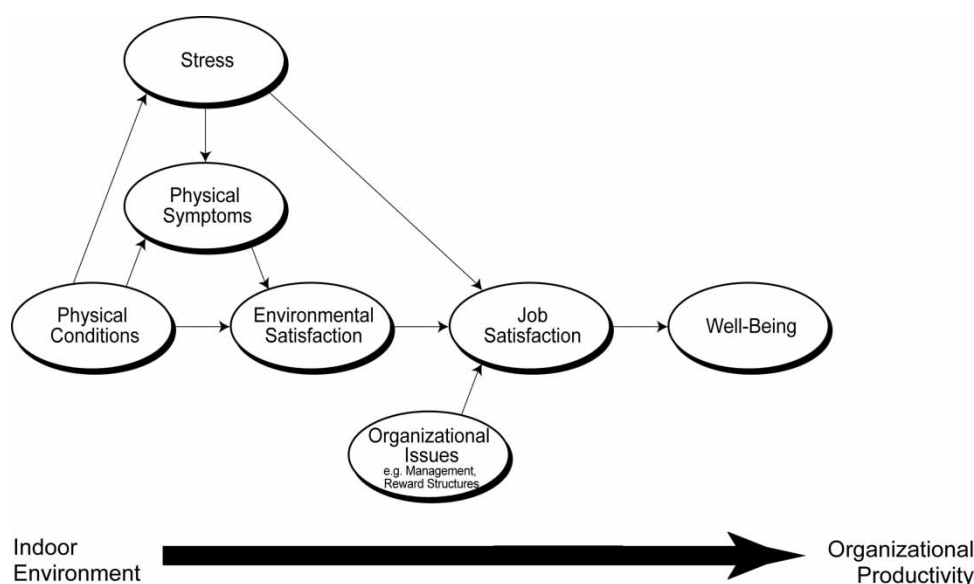


Figure 1 Conceptual model of linkages between indoor environment and outcomes important to organizational productivity

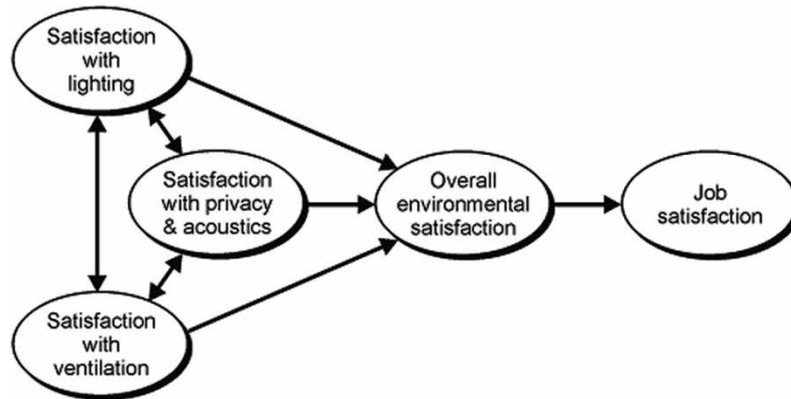


Figure 2 Relationships between environmental satisfaction and job satisfaction demonstrated through structural equation modelling on Cost-effective Open-Plan Environments (COPE) field study data

organizational managers could have ... in predicting a variety of behaviours of organizational members.

(p. 158)

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 time points. 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 ten 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 (Williams and Hazer, 1986; Mathieu and Zajac, 1990; Meyer, 1997; Gaertner, 1999; 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.

Job stress

Researchers have focused considerable interest on job stress (or, more accurately, on 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., 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 focused 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.

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 eye-strain 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., Hedge *et al.*, 1989; Broder *et al.*, 1990). There is also evidence that better physical health is correlated to higher job satisfaction and other factors such as lower job stress and better psychological well-being (e.g., Ganster and Schaubroeck, 1991; Cass *et al.*, 2003). Poor job satisfaction has been associated with a 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 a higher prevalence of physical symptoms (e.g., Stenberg *et al.*, 1994; Eriksson *et al.*, 1996; Mendelson *et al.*, 2000; Marmot *et al.*, 2006). In a review of the 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.

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).

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., Ulrich, 1984; Kaplan and Kaplan, 1989; Chang and Chen, 2005).

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.

Exploring the conceptual model

The overall conceptual model that has been drawn from the research literature is shown in Figure 1. Aspects of this conceptual model were explored 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 data set 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. The present research 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, relationships were explored 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:

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

Methods and procedures

Setting

This data set contained physical measurements of 95 workstations at an open-plan office building in Michigan, US, 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 one-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 (Figure 3).



Figure 3 Typical views of the interior of the study building (second floor on left, third floor on the right)

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 five to ten 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.

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 (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), and 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



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

view, foliage in the view, highest panel height, storage space, type of storage, work surface area, size of the workstation footprint, per cent enclosure, and relative daylight contribution.

The role of potential exterior view was of particular interest to the host organization, and to the authors, 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 (Figure 5). The physical measure was the percentage of this photograph that was exterior window. The building had windows in the top one-third of the window wall only; therefore, views to the outside from a seated position primarily revealed only sky (e.g., Figure 3). Some views included near-field tree branches.

Table 1 Descriptive statistics for participants in the study

Age (years)	Minimum = 26 years, maximum = 56, mean = 39.7, median = 40, standard deviation = 8.6
Sex	Male = 42, female = 47
Education	High school = 16, college = 48, grad school = 25
Job type	Clerical/administration = 28, technical = 42, manager = 19

Note: Values for demographic variables other than age are frequency counts. (These numbers total 89, the number of participants included in each phase of the analysis varied slightly depending on outlier removal.)

Results

Mediated regression analysis

The techniques used for mediated regression analysis to test the linkages implied in Figure 1 were those set out by Baron and Kenny (1986). 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

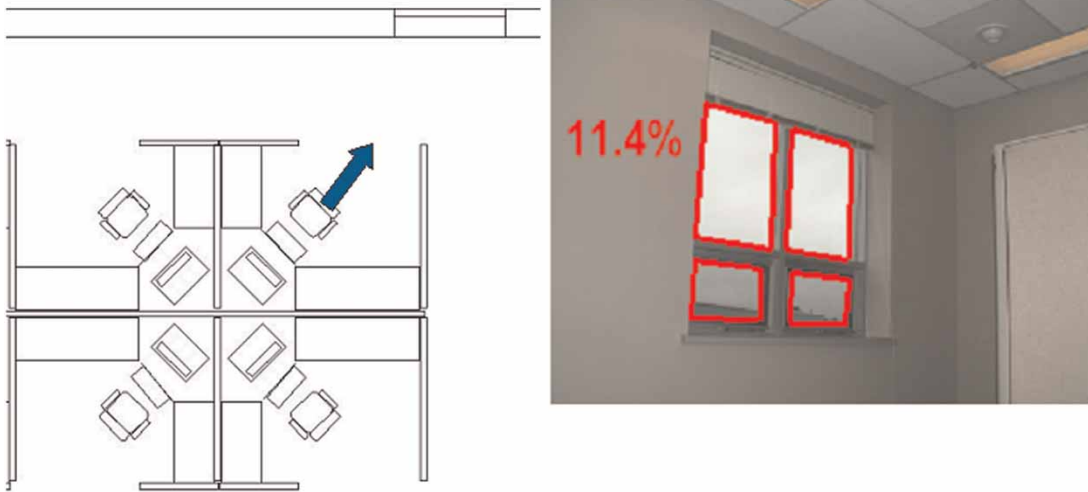


Figure 5 Steps used to calculate the potential exterior view. This is an example only and not one of the spaces from the study building

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, for brevity, not all overlapping three-step sequences are reported, but the tendency is 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 analysis would do. Structural equation modelling 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, the tests performed were limited to those required to explore the proposed model (rather than also testing many variations), which have empirical or theoretical justification.

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, items similar to the items used in the COPE study were chosen (Veitch *et al.*, 2007), and these choices were supported with confirmatory factor analysis. For other variables the authors were guided by exploratory factor analysis, and theoretical considerations then determined 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 one to seven, 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, analyses were conducted 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, one could examine the effect of independent variables with less chance of confounding effects. Eye irritation symptoms were also looked at 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.

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

Variable	<i>n</i>	Minimum	Maximum	Mean	Standard deviation
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 and 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 the 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	<i>n</i>	Minimum	Maximum	Mean	Standard deviation
Satisfaction with lighting (including glare, view)	88	1.71	6.11	3.84	0.99
Satisfaction with lighting (excluding 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 the 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 \times width) (m)	88	1.75	3.35	2.39	0.34
Enclosure: four, 2.75 m-high walls would = 100% (%)	88	10.0	80.0	44.6	15.1
Vertical illuminance measured with a portable system (lux)	88	44	394	179	76
Potential exterior view (%)	88	0.00	34.4	4.6	7.4

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 $p < 0.001$ were excluded. Note that in each phase of the analyses outliers on the variables used in that phase only were excluded. 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, it was deemed appropriate to conduct all analyses on the data set as a whole, and demographic variables as predictors were not pursued. This approach is almost universal in the literature related to job satisfaction cited in the Introduction.

COPE model test and extension

The 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, tests addressed whether overall environmental satisfaction mediated the relationships between the individual satisfaction environmental measures (satisfaction with lighting, ventilation, and privacy and 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 uses Cohen's (1988) conventions in interpreting effect sizes.)

The net result is that a mediating relationship is not indicated because overall environmental satisfaction

Table 3 Results of mediated regression for the Cost-effective Open-Plan Environments (COPE) model test

Step 1 IV ↓	DV = job satisfaction B	Step 2 IV ↓	DV = overall environmental satisfaction B	Step 3 IV ↓	DV = job satisfaction B
Satisfaction with lighting	0.11	Satisfaction with lighting	0.39***	Satisfaction with lighting	0.09
Satisfaction with ventilation	0.10	Satisfaction with ventilation	0.02	Satisfaction with ventilation	0.10
Satisfaction with privacy and acoustics	0.21**	Satisfaction with privacy and acoustics	0.36***	Satisfaction with privacy and acoustics	0.19*
				Overall environmental satisfaction	0.06
$F(3, 85)$	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

Notes: B, unstandardized regression coefficients; DV, dependent variable; IV, independent variable.
 $n = 89$; * $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$.

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.

An attempt was made to broaden the model to include satisfaction with workstation furnishings and equipment at the same level as satisfaction with lighting, ventilation, and privacy and 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 prerequisite 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 the individual environmental satisfaction measures (satisfaction with lighting, ventilation, privacy and acoustics, and workstation furnishings and equipment).

Environmental satisfaction and job satisfaction elements

It is of great interest to understand how environmental satisfaction compares with 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, it was considered that environmental satisfaction would influence satisfaction with other aspects of the employment relationship. The data set included

items that allowed one to explore this issue; specifically, satisfaction with employment compensation and satisfaction with management were examined, 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 they 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; and the model came close to full mediation. The effect sizes for Steps 1 and 2 are small to medium, but comparable in size with other relationships in the job satisfaction domain (e.g., Katzell *et al.*, 1992). The effect size at Step 3 is large.

Relationships to job stress

A model with job satisfaction was tested 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.

Further, a model was tested 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.

Table 4 Bivariate correlations for the Cost-effective Open-Plan Environments (COPE) model test and extension analysis ($n = 86$)

	Job stress	Self-reported physical symptoms	Satisfaction with lighting	Satisfaction with privacy and acoustics	Satisfaction with ventilation	Satisfaction with workstation furnishings and equipment	Overall environmental satisfaction	Satisfaction with employment compensation	Satisfaction 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 and 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

Notes: * $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$.

Table 5 Results of mediated regression on job satisfaction

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

Notes: *B*, unstandardized regression coefficients.
n = 86, **p* ≤ 0.05, ***p* ≤ 0.01, ****p* ≤ 0.001.

Extension of model to physical aspects of lighting

The model was extended to include the effect of the physical environment on symptoms and satisfaction related to lighting. The bivariate correlations between the variables of interest were first tested. Only enclosure and potential exterior view correlated with both a potential mediator and a potential final dependent variable. Further, an initial hierarchical linear regression (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 (excluding glare, view), suggesting that the former might be mediators of relationships to the latter. The model shown in 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 (excluding 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 also medium.

Summary

The final overall set of relationships is shown in Figure 6. Solid lines 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, only those associated with tested mediation paths.

Table 6 Results of mediated regression on SATLIGHTMOD

Step 1 IV ↓	DV = satisfaction with lighting (excluding glare, view) B	Step 2 IV ↓	DV = satisfaction with the outside view B	Step 3 IV ↓	DV = satisfaction with lighting (excluding glare, view) B
Potential exterior view	0.04*	Potential exterior view	0.16***	Potential exterior view Satisfaction with the outside view	-0.03 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

Notes: B, unstandardized regression coefficients.
 $n = 88$, * $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$.

Table 7 Results of mediated regression on GLARE

Step 1 IV ↓	DV = satisfaction with glare B	Step 2 IV ↓	DV = self-reported physical symptoms B	Step 3 IV ↓	DV = satisfaction with glare B
Enclosure	0.02*	Enclosure	0.02**	Enclosure Self-reported physical symptoms	0.01 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

Notes: B, unstandardized regression coefficients.
 $n = 88$, * $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$.



Overall, the analysis provided valuable information, within the limitations of the data set. 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.

observed in the COPE study. The authors 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 the results suggest a broader relationship. The 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 (2001), in summarizing data from 16 commercial buildings in the UK, also emphasized the importance of 'a management culture which takes staff needs seriously ...' (p. 141) in improving occupant satisfaction.

Sceptics have argued that environmental satisfaction as a direct actor on job satisfaction must pale into insignificance compared with factors such as pay and benefits and management practices. Indeed, the 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 (Table 5, Steps 2a and 2b). 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.

The 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 Leadership in Energy and Environmental Design (LEED) green building rating scheme (US Green Building Council (USGBC), 2006) recognizes these benefits and offers credits for daylighting and view access. The expected negative effect of window access on glare was not found, 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. It would be expected 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 the 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 one-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, the results suggest value in a more systematic investigation of window access in the future.

In addition, it should not be concluded 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., Newsham *et al.*, 2004; Veitch *et al.*, 2005). They cannot be included in the model in Figure 6 because the data set 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 affect other aspects of the indoor environment negatively. For example, seating people close to windows will maximize daylight and view, but may also expose them 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 these 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. A choice was made to focus the analysis on a model derived from the 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 data set. 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.

Conclusions

With respect to the research hypotheses that the authors set out to test with this data set:

- *The general relationships between aspects of environmental satisfaction and job satisfaction found in the Cost-effective Open-Plan Environments (COPE) analysis (Figure 2) will (1) hold in this data set and (2) 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.
- *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.
- *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.
- *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 data set, 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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Appendix A. Scale development

Table A1 shows the individual scale items used in each principal composite measure, and the Cronbach's alpha (α) 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 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) to 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's α
<i>Satisfaction with lighting</i>	
Task visibility, flicker, overall lighting, daylighting, outside view from your office, glare problems (2), aesthetics (4 – visual appearance, colour scheme)	0.73
<i>Satisfaction with ventilation</i>	
Heating/cooling, air quality (4 – smell, stuffiness, air quality)	0.73
<i>Satisfaction with privacy and acoustics</i>	
Privacy, speech communication on phone, noise from co-workers, general noise (3), space (2 – storage, room to move), interruptions (2)	0.80
<i>Satisfaction with workstation furnishings and equipment</i>	
Mouse comfort, mouse adjustability, chair, armrests, telephone system quality, telephone system attributes, keyboard ease of use, keyboard adjustability, computer monitor adjustability, computer monitor arrangement	0.74
<i>Overall environmental satisfaction</i>	
Work environment, workstation	0.71
<i>Job satisfaction</i>	
Good company (2 – quality of being an employee, organization), job features	0.71
<i>Satisfaction with employment compensation</i>	
Compensation quality, salary (2), benefits (2)	
<i>Satisfaction with management</i>	
Organizational leadership (3), employee–management relations (2), employee morale, organizational difficulty	0.80
<i>Self-reported stress associated with job</i>	
Stress (3 – stressful job, relaxing job), job fatigue, not enough time	0.74
<i>Employee well-being</i>	
Sleep problems, family/social life impact, emotional impact	0.78
<i>Self-reported physical symptoms</i>	
Neck/shoulders/back (5), chest (3 – air passages, breathing), hands (3), feet, arms, eyes	0.75
<i>Satisfaction with lighting (excluding glare, view)</i>	
Task visibility, flicker, overall lighting, daylighting, aesthetics (4 – visual appearance, colour scheme)	0.70
<i>Satisfaction with glare</i>	
Glare problems (2)	0.83
<i>Satisfaction with the outside view, single item</i>	
Outside view from your office	n.a.
<i>Self-reported eye irritation, single item</i>	
Eyes irritated because of work	n.a.

Note: n.a., Not applicable.

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			Satisfaction with lighting Cronbach's $\alpha = 0.73$
Glare problems (serious–no)		Cronbach's $\alpha = 0.83$		
General quality of visual appearance of your office (low–high)	Appearance		Aesthetic Cronbach's $\alpha = 0.85$	
Work area (ugly–visually appealing)		Cronbach's $\alpha = 0.80$		
Overall quality of colour scheme of your office (low–high)	Colour			
Colour scheme (awful–perfect)		Cronbach's $\alpha = 0.82$		