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A model of satisfaction with open-plan office conditions: COPE field findings[†]

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Abstract

This paper describes the factor structure of an office environmental satisfaction measure and develops a model linking environmental and job satisfaction. The data were collected as part of the Cost-effective Open-Plan Environments (COPE) project, in a field study that also included local physical measurements of each participant's workstation. The questionnaire was administered to 779 open-plan office occupants from nine government and private sector office buildings in five large Canadian and US cities. Exploratory and confirmatory factor analyses revealed that the 18-item environmental satisfaction measure formed a three-factor structure reflecting satisfaction with: privacy/acoustics, lighting, and ventilation/temperature. Structural equation modelling indicated that open-plan office occupants who were more satisfied with their environments were also more satisfied with their jobs, suggesting a role for the physical environment in organizational well-being and effectiveness.

1. Introduction

Despite decades of research into relations between the physical work environment, the individual workers, their interpersonal relations, and the organisation (e.g., Bauer et al., 2003; Brill, Margulis, Konar, & BOSTI, 1984; Brill, Weidemann, & BOSTI Associates, 2001; Carlopio, 1996; Oldham & Brass, 1979; Sundstrom, 1987; Sundstrom, Bell, Busby, & Asmus, 1996; Sutton & Rafaeli, 1987), the literature remains scattered and poorly linked to the engineering and design disciplines that might make use of it. Designers and facilities managers continue to ask for demonstrable proof that the physical environment influences organisational outcomes such as job satisfaction, work output, absenteeism, turnover, and, ultimately, organizational productivity. Psychologists have been unable to provide such direct evidence with sufficient scientific rigour to settle the question (Rubin, 1987; Wyon, 1996). Absent such evidence, the continued push to reduce work space size, often on the basis of containing real estate costs ("Space Planning", 2003) suggests that many business managers continue to see the physical office environment as simply a convenient space to house their employees, rather than an asset that could positively influence their staff.

One reason for the slow progress of research in this area has been the absence of commonly-used, reliable, standardised tools to measure occupants' ratings of the work environment. Stokols and Scharf (1990)set out four criteria for standardised research instruments addressing the physical work environment. First, the questionnaire should be streamlined in length and wording so participants can complete the protocols in a straightforward manner. Second, the scope of the content should be sufficiently broad so that important aspects of facility design are not neglected. Third. in addition to characteristics of the physical work environment, other variables that should be included are participants' biographic characteristics, job status or category, and ratings of job or work satisfaction. Fourth, survey items should be directly relevant to organisational problem-solving strategies. That is, the findings from research using these instruments should suggest specific organisational and environmental design strategies that can be implemented to resolve problems identified in the research.

Although there are a few questionnaires that meet these criteria, an extensive literature search did not uncover many journal articles that have used these tools to link specific physical conditions with occupants' feelings. For example, Dillon and Vischer (1987) developed a 24-item questionnaire and method for assessing occupants' feelings and judgements concerning building performance. It included 22 specific feature ratings, and two general questions. The 22 items were chosen from a larger set of 35 items on the basis that these items formed the most interpretable 7-factor solution: thermal comfort, privacy, noise control, spatial comfort, lighting comfort, building noise control, and air quality. Scores on these factors formed the basis for the beginning of a normative data set of building ratings that continues to be developed and used for building and design assessments (Vischer, 1989, 2007). However, statistical details concerning the original derivation of the factors are scant, and the questionnaire has not been taken up by the research community.

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Stokols and Scharf (1990) developed the Ratings of Environmental Features (REF) questionnaire for use in a variety of office settings. The main physical features included in the REF were acoustical privacy, air quality and lighting. The basic REF contains 27 items for which participants rate the quality of several physical features (e.g., “conversational privacy within your office” and “quality of lighting for the work you do”), on seven-point scales from “very poor” to “excellent”. Stokols and Scharf reported acceptable internal consistency values (.87 to .94) over five pilot administrations of the REF. Scharf (1995) further analyzed relationships between office design, principally enclosure around workstations, and distraction, in which REF ratings were among the outcome variables.

Another example of the development of a standardised tool is Carlopio's (1996) Physical Work Environment Satisfaction Questionnaire (PWESQ) which included the assessment of five general areas (environmental design, facilities, work organisation, equipment and tools, and health and safety). He validated the tool in a field survey involving factory and office employees in eight companies ranging from a computer assembly site to durable goods manufacturing warehouses. The PWESQ met criteria for internal consistency and discriminant validity. However, we could find no publications that used the PWESQ for further research.

To better understand the influence of the office environment on organisational well-being and effectiveness, research in this area needs to include outcomes more traditionally addressed by business and organisational researchers, such as job satisfaction, organisational commitment and absenteeism. These outcomes, among others, are building blocks that contribute to organizational productivity (e.g., Kaplan & Norton, 1992a, 1992b). A comprehensive meta-analysis of the job satisfaction-job performance relationship estimated the strength of the relationship as 0.30, and somewhat higher for high-complexity jobs (Judge, Thoresen, Bono, & Patton, 2001). Furthermore, business units with higher average job satisfaction showed lower turnover and improved profitability (Harter, Schmidt, & Hayes, 2002).

Several office environment investigations have examined direct effects of environmental features on job satisfaction (e.g., Oldham & Brass, 1979; Oldham & Fried, 1987; Sundstrom, Burt, & Kamp, 1980). More intriguing are those studies in which reactions to the physical office environment mediate the relationship between the physical conditions and relevant outcomes for organisations. Such studies offer the possibility of including both direct and indirect effects. Wells (2000), for example, found that the ability to personalise one’s work area was positively related to environmental satisfaction, which in turn positively influenced job satisfaction and employee well-being. Similarly, in his study using the PWESQ, Carlopio (1996) found that satisfaction with the physical environment and job satisfaction both related to organisational commitment (positively) and intent to turnover (negatively).

Success in understanding how office environments influence occupants and organizations requires truly interdisciplinary research, combining rigorous measurements of physical conditions in offices (from the building sciences) with reliable, standardised tools to measure occupants’ responses to the work environment (from psychology). One example of such a study is contained in a book chapter by Hedge, Erickson, and Rubin (1992), in which physical measurements of indoor air quality and surveyed measurements of job characteristics, stress, and demographic variables (based on previously validated questionnaires) were examined as possible correlates of sick building syndrome symptoms. Overall, however, few studies have achieved a high standard of scientific rigour for both physical measurements and employee physiological and behavioural responses (Wyon, 1996). Researchers skilled in measuring the physical environment in detail are often ill-equipped to study occupants’ reactions to that environment. Similarly, psychologists and other behavioural researchers with abilities to examine occupant behaviour typically lack the expertise to quantify the physical environment with scientific rigour (Rubin, 1987; Wyon, 1996). For instance, Sutton and Rafaeli (1987) defined hotness as “the product of an employee's judgement as to how often it got too hot at a work station and the [estimated] temperature when it is at its hottest” (p. 264), rather than measuring temperature directly.

The current paper draws data from a field study that was designed to address this limitation. The field study was designed to determine the effects of open-plan office design on the indoor environment and on occupant satisfaction with that environment. The study is rare in that it combines extensive local physical measurements paired with simultaneous questionnaire data collection. The field study forms part of the Cost-effective Open-Plan Environments (COPE) project, a four-year multidisciplinary investigation of open-plan offices. The project was developed in response to the continuing pressure facing organisations and their facilities managers to reduce space allocation to individuals in open-plan offices, as a means to reduce costs. Current management philosophies also support the lowering of partitions between individual workers, in an attempt to promote communication and synergy. These trends, however, risk creating an unpleasant working environment, either directly through the creation of adverse physical conditions (e.g., more noise, added obstructions to light distribution), or indirectly through psychological processes such as privacy or stress.

Figure 1. Sample of the open-plan offices that were the focus of the COPE project.

Figure 1 shows an example of the office types studied in the COPE project. They are conventional, rectilinear cubicles created using modular systems furniture. Although there has been much talk of novel ways of working and innovative office design, contacts in the office furniture industry, including the project sponsors, informed us that a large majority of office furniture sales remain of this conventional type. Therefore, the project focused only in this area.

Figure 2 shows a conceptual model of the COPE project. The model posits that workstation characteristics (particularly workstation size and partition height, but not limited to those) (captioned 'i' in Figure 2), interacting with the performance of building services, determine the physical conditions in the workstation (ii). The physical conditions (ii) and the workstation characteristics (i) jointly determine satisfaction with features of the physical environment (iii), which in turn positively predict overall environmental satisfaction (iv) and job satisfaction (v). Different parts of the model have been tested using laboratory, computer simulation and literature review studies, in addition to the field study component.

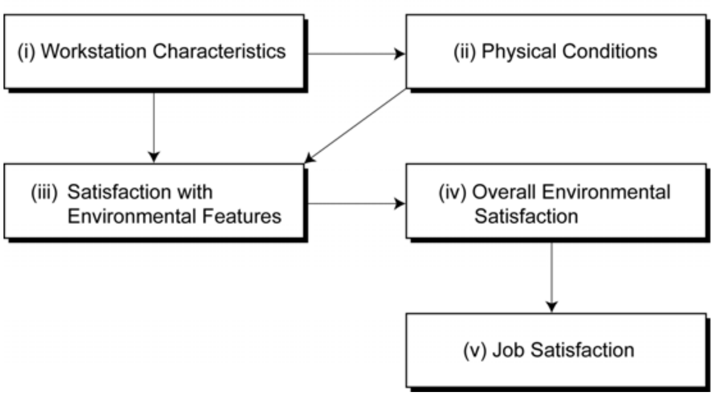

Figure 2. Conceptual model of the COPE project.

While the relationships between measured physical variables and environmental satisfaction (i, ii, & iii in Figure 2) are undoubtedly important, space considerations do not allow these analyses to be described in the current paper. These results can, however, be found in a number of publicly available COPE project reports (Newsham et al., 2003a; Newsham et al., 2003b; Veitch, Charles, Newsham, Marquardt, & Geerts, 2003) and in journal and conference papers (Charles, Veitch, Newsham, Marquardt, & Geerts, 2006; Newsham, Veitch, & Charles, 2007; Veitch, Geerts, Charles, Newsham, & Marquardt, 2005).

The current paper focuses on the relationships between environmental satisfaction and job satisfaction (iii, iv, & v in Figure 2). We report on the field validation and factor structure of the office environmental satisfaction measure developed for this field study, based on Stokols and Scharf's (1990) REF measure. The REF was selected because it was derived and validated in office settings similar to the open-plan offices that were the focus of our study and had showed good performance over several administrations. However, the REF instructions ask participants to rate the quality of environmental features; that is, to make judgements about each feature on a scale from "very poor" to "excellent". Scharf and Margulies (1992) argued that there is an important distinction to be drawn between a judgement, whose object is external to the rater, and a sentiment or feeling, and stated their opinion that judgements are more valuable in discussions of environmental quality. Our interest, however, is on the experience of the individual in the space in response to environmental conditions. Therefore, the measure we developed here asks for feelings about each feature; participants rate their degree of satisfaction on a scale from "very dissatisfied" to "very satisfied".

The current paper adds to research in this area by testing a model in which environmental satisfaction is positively related to job satisfaction. Specifically, we hypothesised the following:

Hypothesis 1: The Satisfaction with Environmental Features measure can be reduced to three factors, representing satisfaction with privacy, ventilation and lighting.
Hypothesis 2: The three-factor Satisfaction with Environmental Features measure can be jointly, positively related to overall environmental satisfaction, which in turn can be related to job satisfaction.

2. Method

2.1 Sites

Data were collected in nine office buildings, located in large Canadian and US cities. The first three buildings were occupied by federal government organisations and were visited in 2000 (sample A). Six further buildings were visited in 2002 (sample B) and comprised four private-sector office buildings and two provincial government office buildings. The floors visited within each building were selected because they contained open-plan offices occupied by white-collar workers, and because the occupying organizations on those floors were willing to host the visit. We were not looking for 'problem' locations or spaces with unusually superior conditions. We targeted a mix of public/private organisations and Canadian/US locations to broaden the generalizability of results. Detailed information on the buildings included in this study are provided in Charles, Veitch, Farley, and Newsham (2003).

2.2 Participants

Participants were the occupants of floors visited by the research team. Their occupations varied, but all were white-collar, knowledge workers whose work involved manipulating information and documents, on computer and on paper, most of the time. The range of occupations included engineering and architecture, accounting and finance, policy development, software development, administration, and management. All occupants present on the visit days were eligible to participate, and researchers selected as many available participants as they had time to approach during the visit day. Formal response rates were not recorded, but approximately 90% of those invited agreed to take part. There were no discernable patterns in the demographic characteristics or building locations of occupants who chose not to participate. Table 1 shows the demographic characteristics for the full sample, and for two subsets of the full sample (sample A and sample B) that were used for statistical analyses, as described below.

Table 1. *Demographic Characteristics of Participants*

Site	N	% English	% Female / % Male	Mean Age (SD)
Full sample	779	79.5	47.6 / 51.5	36.2 (10.6)
Sample A	419	87.6	48.7 / 50.4	38.6 (10.8)
Sample B	360	70.0	46.4 / 52.8	33.5 (9.5)

	Job Category (%)			
	Administration	Technical	Professional	Management
Full sample	27.1	24.9	38.4	8.6
Sample A	36.0	14.8	41.3	6.7
Sample B	16.7	36.7	35.0	10.8

	Education (%)				
	High School	Community College	University Courses	Undergraduate Degree	Graduate Degree
Full sample	11.6	15.1	14.6	34.0	22.7
Sample A	16.0	17.7	14.6	26.0	23.2
Sample B	6.4	12.2	14.7	43.3	22.2

Note. Percentages that do not sum to 100 are the result of rounding error and missing data

2.3 Procedure

2.3.1 Advance communications

The procedure was approved by our institution's Research Ethics Board, which mandated thorough communication about the research as part of the informed consent process. The project manager co-ordinated all on-site activities with local staff members in each building. Host staff led research staff on building walk-throughs, provided building plans, and co-ordinated security clearances. Where possible, the research staff met in advance with a suitable joint management-employee committee to provide information about the study. In all buildings, management sent an email to staff prior to the research team's visit, informing them of the study and indicating that it had management support. Accompanying this was a message from the research team explaining the study, emphasising confidentiality and voluntary participation, and highlighting the research team's independence from management. These e-mails were re-sent on the first day the research team made measurements.

2.3.2 Measurements

A team of two researchers conducted the measurements. The researchers introduced themselves to employees who were seated at their desks, explained the study, the measurement procedure (including an estimated time commitment, around 15 minutes), and the employee's rights should they choose to participate. If an employee agreed to participate, he or she was asked to step outside of the workstation in the company of the one of the researchers. The researcher took the participant to a nearby location, typically a vacant workstation, and gave instructions about the questionnaire. The questionnaire was presented on a hand-held computer with a touch screen, and was preceded by several practise questions to familiarise the participant with the delivery method. The researcher then left the participant to answer the questionnaire in private, and returned to help the other member of the team with the physical measurements in the workstation. The participant was instructed to return to his or her workstation for assistance from the research team if it were needed.

While the occupant was completing the questionnaire, the researchers collected physical data in the occupant's workstation. The physical measurements took approximately 13 minutes for practiced teams (Veitch, Farley, & Newsham, 2002). Once the physical measurements and occupant questionnaire were completed, the researchers moved on to invite the next available employee to participate. There was no set plan as to which employees were approached when, and some work areas were revisited several times to recruit employees who had been unavailable on previous visits to the work area.

2.4 Measures

2.4.1 Satisfaction with environmental features (SEF)

This measure comprised eighteen questions that asked participants to indicate their degree of satisfaction with various aspects of the physical environment. The wording for these items is shown in Table 2. Participants responded on a seven-point scale that ranged from 'very unsatisfactory' (1) to 'very satisfactory' (7), and were asked to respond based on the physical conditions that existed in their workstation at the time they were asked to participate. This frame of reference was chosen so that the questionnaire responses would be applicable to the physical measurements collected in each workstation by the researchers. The questions were based on Stokols and Scharf's (1990) Ratings of Environmental Features (REF) questionnaire. The item wording was modified to aid readability and to address feelings (satisfaction) rather than judgements ("rate the quality…"), and new items were constructed to address environmental features not included in the original REF, such as glare on computer screens and the degree of workstation enclosure. In addition, original items that encompassed more than one environmental feature were modified so that each new item addressed one specific feature (e.g. original item on 'air quality and circulation' was modified into two new items on 'air quality' and 'air movement').

2.4.2 Overall environmental satisfaction

This scale comprised two items. The first asked participants 'What is your degree of satisfaction with the indoor environment in your workstation as a whole?', and participants responded using the same seven-point scale described above. This item was also from Stokols and Scharf's (1990) REF questionnaire. The second item asked employees to rate how the environment influenced their productivity at the time of the survey, relative to general prevailing conditions. This question was taken from a UK building use survey (Wilson & Hedge, 1987), and occupants responded on a scale ranging from '30% less productive' (1) to '30% more productive' (7) than usual.

2.4.3 Job satisfaction

The two-item job satisfaction scale was drawn from a recent Canadian federal public service survey (Treasury Board, 2000). Participants responded on a seven-point scale, ranging from 'very strongly disagree' (1) to 'very strongly agree' (7) to the following items: 'My department/agency is a good place to work', and 'I am satisfied with my job.' The latter question was modified from the original, which referred to employees' satisfaction with their career in the public service.

2.4.4 Demographic characteristics

Five questions assessed participants' demographic characteristics in terms of age, sex, education, and job type. These variables were used to compare the composition of the samples of participants in the various buildings, and as covariates in regression analyses not reported here.

2.4.5 Language

Participants had a choice of responding to the questionnaire in English or French. The French translation of the questionnaire is available in Veitch et al. (2002). The translation was produced by a professional translator from the final English version, and the adequacy of the translation was tested through back-translation by a second translator. Data from English and French participants were combined because the number of participants who chose French was small (20.5% of participants; N=160) and it seemed unlikely that questions on this particular topic would suffer from cultural biases in translation in this population. Furthermore, French-speaking and English-speaking participants occupied the same buildings, which were operated to North American standards, and there were no cultural difference in building design or operation in this sample.

2.4.6 Physical conditions

The research staff took physical measurements of the individual's workstation while the occupant completed the questionnaire. These measurements were made using a custom-designed array of physical sensors, mounted on an office chair so that it could be placed where the participant usually sat. Lighting, thermal, air quality, and acoustical conditions were all measured, and workstation characteristics were also recorded. The physical measurements are described in detail in Veitch et al. (2002). The physical data were not used in the analyses reported in this paper, but feature in other reports from the COPE project (Charles et al., 2006; Newsham et al., 2003a; Newsham et al., 2003b; Veitch et al., 2003; Veitch et al., 2005).

2.5 Statistical analyses

To test hypothesis 1, exploratory (EFA) and confirmatory factor analyses (CFA) were conducted, using subsets of the full data set. Following the collection of sample A in 2000, this sample was split into two sub-samples to conduct EFA and CFA analyses. After sample B was collected in 2002, this sample was used to conduct a second CFA analysis for comparison purposes. Hypothesis 2 was tested using structural equation modelling (SEM) on the complete dataset (samples A & B combined).

In all cases, data preparation and screening were conducted using procedures recommended by Kline (1997). Variable mean imputation was used where missing data were infrequent and randomly distributed. Cases with missing data on multiple items were excluded from analyses. Univariate outliers were identified as those with standardised scores more than three standard deviations from the mean, and were excluded from the analyses. Multivariate outliers were identified using Mahalanobis distance statistic at $p<.001$, and were also excluded from analyses. Univariate normality was assessed using skewness (absolute values above 3) and kurtosis (absolute values above 8) values. Where appropriate, the datasets were examined for multicollinearity (correlations above .80) and singularity (correlations below .30, and communality values above 1.0) prior to analyses.

Model fit for the CFA and SEM analyses was assessed using multiple statistical and fit indices including Chi-square, Goodness of Fit Index (GFI), Adjusted Goodness of Fit Index (AGFI), Comparative Fit Index (CFI), Bentler-Bonett Normed Fit Index (NFI), Bentler-Bonett Non-normed Fit Index (NNFI), Standardised Root Mean Square Residual (SRMR) and Root Mean Square Error of Approximation (RMSEA). We also looked for statistical significance of the paths, and the proportion of standardized residuals between –0.1 and 0.1. Detailed descriptions of these and other indices can be found in several sources (e.g., Byrne, 1994; Kline, 1997; Tabachnick & Fidell, 2001). In addition, the Legrange Multiplier (LM) test and the Wald W statistic were examined to determine possible misfits. The LM test provides an estimate of how much the overall chi-square statistic would decrease if a particular parameter were added. Conversely, the Wald W test estimates the amount the overall chi-square would increase if a particular free parameter were fixed, that is, dropped from the model (Kline, 1997).

3. Results

3.1 Factor structure of SEF measure

3.1.1 Data screening

Sample A was randomly divided into two independent sub-samples for exploratory and confirmatory factor analysis. Four univariate and eight multivariate outliers were identified and dropped, leaving a total of 407 cases for analysis (EFA, N=202 and CFA, N=205). The distribution of site, language, sex, education, and job category was equivalent in each group. Complete details of sample A and the two subsamples are available in Veitch et al. (Veitch et al., 2002).[1] For sample B, there were no univariate outliers, but five cases were dropped after being identified as multivariate outliers, leaving 353 cases for analysis. This sample was used for a second confirmatory

[1] A version of this analysis was presented at the Canadian Psychological Association 2002 convention (Farley & Veitch, 2002).

factor analysis. Complete details of sample B are available in Charles et al. (2003).[2]

3.1.2 Exploratory factor analysis

Examination of the correlation matrix for the EFA sub-sample (from sample A) indicated the absence of multicollinearity (the maximum correlation was .76 between the items 'overall air quality in your work space' and 'air movement in your workspace'). However, the item 'your access to a view from where you sit' had only one correlation above .30 (.30 with 'the aesthetic appearance of your office') indicating potential singularity problems. A review of the communality values indicated the same variable had a value of 1.0. Despite these concerns, access to a view has consistently been shown to positively influence occupants (Farley & Veitch, 2001). Given that this variable has strong theoretical reasons for being included in the questionnaire, it was decided to keep the variable in the data for the purposes of the EFA.

Using the factor analysis procedure in EQS 5.7b (Bentler & Wu, 1995), with maximum likelihood extraction and direct oblimin (oblique) rotation, a free EFA was conducted. The cutoff for factor loadings to be included in a factor was .400. This resulted in a solution with four factors having eigenvalues greater than 1 (range = 1.038 to 7.213). Examination of the scree plot supported the four-factor solution. The four-factor solution was composed of three clear factors (labelled Satisfaction with Privacy/Acoustics, Satisfaction with Lighting, and Satisfaction with Ventilation/Temperature) with several high value loading items on each factor. A fourth factor was a stand-alone factor (View) consisting of only one variable. Although these results support a four-factor solution, the correlational problems with the 'view' item appeared to be negatively influencing this solution. According to Tabachnick and Fidell (2001) "if only one variable loads highly on a factor, the factor is poorly defined" (p. 622). Therefore, we forced a three-factor EFA solution, the results of which are shown in Table 2.

In the three-factor solution, all items appeared in the same factor as previously with the exception of the 'view' item, which loaded moderately (.54) on the Satisfaction with Lighting factor. The three factors accounted for 57.05% of the total variance observed. There were no cross loadings and all items loaded significantly on a factor, therefore all were retained. Correlations between the three factors confirmed the applicability of direct oblimin (oblique) rotation, as they exceeded 0.32 on average (Tabachnick & Fidell, 2001). Internal consistency values (Cronbach's alpha) were satisfactory for each factor (see Table 2). The factors were labelled Satisfaction with Privacy/Acoustics, Satisfaction with Lighting, and Satisfaction

Table 2. *Rotated three-factor EFA solution*

Question	Sat. with Privacy/ Acoustics	Sat. with Ventilation/ Temperature	Sat. with Lighting
SEF-7. Amount of noise from other people's conversations while you are at your workstation	.79		
SEF-17. Frequency of distractions from other people	.71		
SEF-18. Degree of enclosure of your work area by walls, screens or furniture	.72		
SEF-6. Level of visual privacy within your office	.71		
SEF-15. Distance between you and other people you work with	.68		
SEF-5. Level of privacy for conversations in your office	.79		
SEF-9. Amount of background noise (i.e. not speech) you hear at your workstation	.64		
SEF-8. Size of your personal workspace to accommodate your work, materials, and visitors	.57		
SEF-13. Your ability to alter physical conditions in your work area	.56		
SEF-4. Aesthetic appearance of your office	.51		
SEF-12. Air movement in your work area		.71	
SEF-2. Overall air quality in your work area		.71	
SEF-3. Temperature in your work area		.70	
SEF-16. Quality of lighting in your work area			.65
SEF-1 Amount of lighting on the desktop			.65
SEF-10. Amount of light for computer work			.56
SEF-11. Amount of reflected light or glare in the computer screen			.44
SEF-14. Your access to a view of outside from where you sit			.54
% of variance explained	26.1	16.6	14.4
Cronbach's alpha	.88	.82	.76
Factor correlation to Sat. with Lighting	.39	.25	
Factor correlation to Sat. with Ventilation/Temperature	.44		

Note. *N*=202. Factor loading cut-off = .400. SEF: Satisfaction with environmental features.

[2] A version of this analysis was presented at the Canadian Psychological Association 2004 convention (Charles, Veitch, Farley, & Newsham, 2004).

with Ventilation/Temperature.

3.1.3 Confirmatory factor analysis-A

A review of the correlation matrix for the CFA sub-sample (from sample A) revealed no evidence of multicollinearity. However, the item 'your access to a view from where you sit' again showed possible singularity problems with only one correlation above .30; (.42; 'the amount of lighting on the desktop'), although all communality values were less than 1.0. Given these findings it was decided to proceed with the CFA, using the three-factor EFA model as the basis for comparison.

The model submitted for analysis consisted of maximum likelihood estimations of the 18 target loadings, three factor variances, correlations between all factors and error variances for each of the 18 items.

Table 3 shows a summary of the results of the CFA, including target values for the various fit indices, based on authoritative sources (e.g., Byrne, 1994). The results of this analysis (labelled CFA-A1 in Table 3) indicated a marginal fit between the model and the data. All the factor loadings were statistically significant, but additional statistics were examined to assess the possibilities for improving model fit by adding or dropping parameters.

Table 3. *Goodness of fit indices for CFA analyses.*

	N	X^2	X^2/df	GFI	AGFI	CFI	NFI	NNFI	SRMR	RMSEA (90% CI)
Target fit			< 3	> .90	>.90	>.90	>.90	>.90	<.10	<.10
CFA-A1	205	363.4	2.75	.83	.77	.85	.78	.82	.07	.09 (.08 - .10)
CFA-A2	205	353.2	2.69	.83	.78	.86	.79	.83	.07	.09 (.08-.10)
CFA-B	353	527.6	4.00	.85	.81	.86	.82	.83	.08	.09 (.08 - .10)

Note. Detailed results for model CFA-B are shown in Figure 3. Target values are based on Byrne (1994), Kline (1997), and Tabachnick and Fidell (2001).

The Wald W test indicated the model would not be improved by dropping any parameters. The LM test indicated the model could be improved by adding a parameter from the variable 'the aesthetic appearance of your office' to the 'satisfaction with lighting' factor. Satisfaction with the appearance of one's office or workspace might reasonably be related to the quality of lighting available. Therefore, it was decided to add the parameter and run a post hoc model.

This model, labelled CFA-A2, is summarised in Table 3. Additional statistics were further examined: The frequency distribution of the standardised residuals revealed that most residuals (91.81%) fell between -.10 and .10, which is desirable. All estimated factor loadings were significant and internal consistency values for each subscale were satisfactory (privacy, alpha = .89; lighting, alpha = .82; and ventilation, alpha = .82). However, this result was not judged to be enough of an improvement over CFA-A1 to warrant the additional complexity of a cross-loading item (a variable contributing to more than one latent variable). The cross-loading item would have complicated interpretation of further analyses using scale scores for the latent variables as dependent variables.

3.1.4 Confirmatory factor analysis-B

EQS for Windows 6.1 (Bentler & Wu, 2003) was used for CFA analysis of sample B, based on the model labelled CFA-A1. The result is shown in Table 3 (labelled CFA-B) and the complete model in Figure 4. In comparison to CFA-A1, CFA-B shows poorer fit in relation to the X^2/df fit index (4.00 as compared to 2.75). However, this statistic is very sensitive to sample size, and therefore reflects the increased size of sample B. In addition, the results show small improvements in fit for most of the remaining fit indices (GFI, AGFI, NFI, and NNFI). Only 83.7 % of the standardized residuals were between -0.1 and 0.1, which is lower than the suggested target of 90%. The LM test for the CFA-B again suggested the addition of a cross-link from 'the aesthetic appearance of your office' to 'satisfaction with lighting'. However, given the conclusions reached during CFA-A1, there was no justification to modify the model. In both CFA-A1 and CFA-B, all parameter estimates were statistically significant. Overall, sample B fit the EFA model as well as the subsample from sample A, suggesting that the model developed from the original analysis remained applicable.

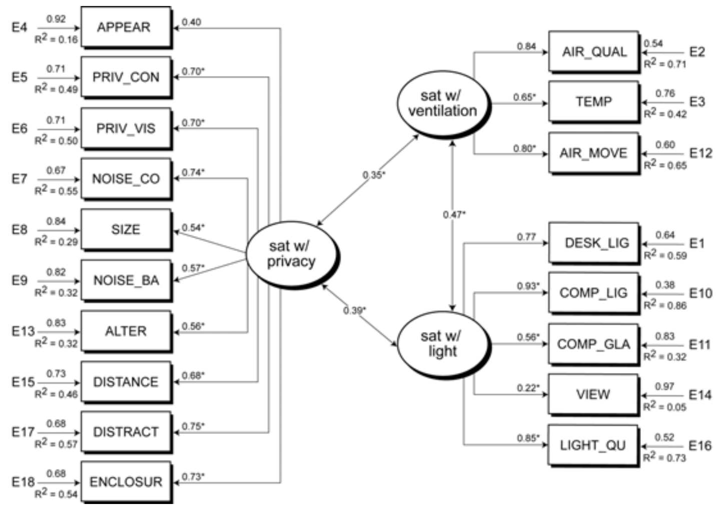

Figure 3. Complete results for the CFA (sample B).

3.2 Modelling relationships between environmental satisfaction and job satisfaction

The Satisfaction with Environmental Features measure concerns satisfaction with elements in the physical environment at work, of interest to environmental psychologists and design consultants. We used structural equation modelling to test for relationships between these facets of satisfaction and more global concepts such as overall environmental satisfaction and job satisfaction, to make the logical link to the broader literature. Complete details for this analysis are available in Charles et al. (2003).

3.2.1 Data screening

The SEM analysis was conducted on the complete dataset (A & B). The mean, standard deviation, skewness and kurtosis for all items are shown in Table 4. Three cases had missing data on all questionnaire items, and were excluded from the analysis. There were 59 cases that had missing data for one or more items. Variable mean substitution was used where appropriate (20 cases), but the remaining cases were excluded from analysis because there was missing data on multiple items or on items that loaded on the same subscale. None of the items exceeded the criteria for skewness or kurtosis. There were 18 cases that were excluded as univariate outliers, and five cases excluded as multivariate outliers. The remaining sample numbered 714 cases.

Table 4. *Descriptive Statistics for SEM Sample*

Question	*M*	*SD*	Skewness	Kurtosis
SEF-1	5.17	1.60	-0.98	0.04
SEF-2	4.37	1.63	-0.30	-1.04
SEF-3	4.34	1.62	-0.27	-1.09
SEF-4	4.51	1.66	-0.39	-0.81
SEF-5	2.63	1.57	0.83	-0.30
SEF-6	3.83	1.81	-0.05	-1.25
SEF-7	2.96	1.53	0.52	-0.62
SEF-8	4.47	1.82	-0.43	-1.08
SEF-9	4.17	1.59	-0.28	-0.89
SEF-10	4.97	1.48	-0.87	-0.16
SEF-11	4.46	1.68	-0.43	-0.93
SEF-12	4.09	1.62	-0.13	-1.02
SEF-13	3.54	1.57	0.16	-0.84
SEF-14	4.38	2.23	-0.27	-1.43
SEF-15	4.62	1.59	-0.62	-0.59
SEF-16	4.75	1.57	-0.65	-0.65
SEF-17	3.76	1.54	0.04	-0.99
SEF-18	4.34	1.65	-0.34	-0.96
OES-1	3.85	1.48	0.23	-0.57
OES-2	4.26	1.54	-0.25	-1.03
JS-1	5.05	1.19	-0.97	1.54
JS-2	5.10	1.24	-0.78	0.71

Note. N=714. SEF: Satisfaction with environmental features. OES: Overall Environmental Satisfaction. JS: Job Satisfaction

Examination of the correlation matrix for the full dataset indicated no multicollinearity problems (largest correlation 0.73 between 'quality of lighting in your work area' and 'amount of light for computer work'). The item 'access to a view from where you sit' was again only weakly correlated with other items, indicating potential singularity problems. However, given that there are strong theoretical reasons for including this item in the questionnaire, the item was retained.

3.2.2 Structural equation modelling

Prior to the collection of sample B, preliminary SEM analyses were conducted on sample A, to explore possible models relating satisfaction with environmental features, overall environmental satisfaction and job satisfaction (Veitch et al., 2002). These preliminary analyses indicated that the best-fitting model consisted of the three, intercorrelated, factors (identical to the CFA model, Figure 3), plus unidirectional paths from each factor to overall environmental satisfaction, and a unidirectional path from overall environmental satisfaction to job satisfaction. Other models were explored, but this model had the best fit, was the most parsimonious, and was consistent with the literature (Veitch et al., 2002). Therefore, we used this model as the basis for analyzing the structural relations in the full data set.

The goodness of fit statistics are summarized in Table 5 and the complete model is shown in Figure 4. Overall, the fit is modest, but acceptable. All parameter estimates were statistically significant (see Figure 4), and 91.7% of the standardized residuals lay between -0.1 and 0.1. The Wald W statistic indicated that the model would not be improved by dropping any parameters. The LM test indicated that the model could be improved by adding a parameter from the variable ‘the aesthetic appearance of your office’ to ‘overall environmental satisfaction’. However, the addition of this parameter would add a cross-loading item to the model, thereby increasing complexity of interpretation. This added complexity was unlikely to be justified by a significant increase in model fit, and so we decided not to include this extra parameter in the model. The model described in Figure 4 adequately fits the full dataset, and is clear and easily interpretable.

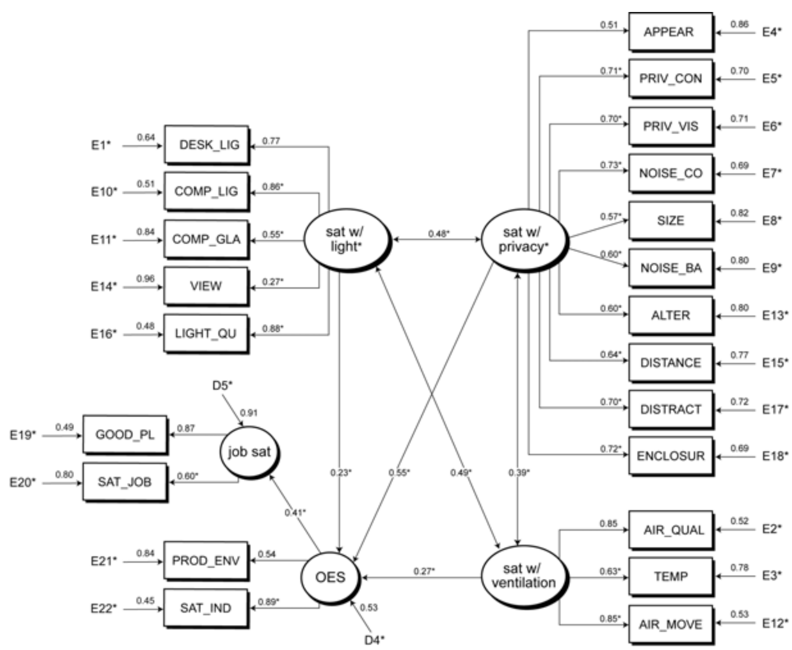

Figure 4. Complete results for the SEM of environmental satisfaction and job satisfaction (full data set).

Table 5. *Goodness of fit indices for SEM analysis*

	N	*X*^{2}	*X*^{2}*/df*	GFI	AGFI	CFI	NFI	NNFI	SRMR	RMSEA (90% CI)
Target fit			< 3	> .90	>.90	>.90	>.90	>.90	<.10	<.10
Full sample	714	1042.2	5.16	.88	.84	.88	.85	.86	.06	.08 (.07 - .08)

Note. Full results with parameter estimates are shown in Figure 4. Target values are based on Byrne (1994), Kline (1997), and Tabachnick and Fidell (2001).

4. Discussion

The 18-item Satisfaction with Environmental Features measure was designed to be a useful, brief tool for the study of satisfaction with elements of the physical environment in relation to measured physical conditions. We hypothesised that the 18 items could be meaningfully reduced to a smaller number of underlying latent variables. In addition, we sought to relate environmental satisfaction to job satisfaction in order to establish the logical link to the broader organizational psychology literature.

Exploratory and confirmatory factor analysis (with two independent confirmatory samples) determined that a three-factor structure, reflecting satisfaction with privacy/acoustics; satisfaction with lighting; and, satisfaction with ventilation/temperature, best fit the data. Thus, Hypothesis 1 was supported. The fit was modest according to most goodness-of-fit indices, but all the paths were statistically significant and over 90% of the standardized residuals lay between -0.1 and 0.1. We believe that the fit was reduced by the generally high satisfaction with lighting (items SEF-1. SEF-10, SEF-11, SEF-14, and SEF-16 in Table 4), because of restricted range and a degree of non-normality in the distributions of these variables. Despite this, the results were consistent across two independent confirmatory samples, and are also broadly consistent with other researchers, who typically find three to five factors, including those for lighting, ventilation and noise/privacy (e.g., González, Fernández, & Cameselle, 1997; Veitch & Newsham, 1998).

Comparisons between such studies are tricky because of differing sets of items included and different analytic choices, and because some investigators have used multivariate techniques despite small sample sizes. For instance, González, et al. (1997) found five latent variables underlying environmental evaluations, which they named Evaluation (aesthetics), Temperature, Noise, Air, and Space; their analysis of a 13-item scale had only 83 participants (subjects: items = 6.4). Veitch and Newsham (1998) used a variation of the Stokols and Scharf (1990) Ratings of Environmental Features and reported a five-factor solution (Noise, Ventilation, Furniture, Washrooms, and Lighting), based on 294 participants and 23 items, a more acceptable subjects: items ratio (12.8). However, they used principal components analysis with varimax rotation, a technique that does not permit correlations between components, as was the case here. Some authors would argue that intercorrelated components are logically expected with ratings of environments, which are experienced as an integrated whole.

Two items, related to view and aesthetics, proved problematic in our analyses. The aesthetics item was suggested, on the basis of LM tests, as a possible cross-linkage between two of the satisfaction factors. We chose not to add this cross-linkage because of the added complexity it would bring to the model. In addition, adding this cross-linkage would cause problems for the creation of subscale scores to be used in future regression analyses with physical conditions as predictors. Additional CFA analysis indicated that the addition of this cross-linkage did not improve model fit sufficiently to offset the additional complexity created (see Table 3, model CFA-A2).

The second item, related to view, exhibited potential singularity problems. We suspect that part of the reason is that the question might have been difficult to answer for those people without a close access to a window. As access to a view has consistently been reported in the literature as beneficial to occupants (Farley & Veitch, 2001), we chose to retain this item in the model. Future analyses will closely examine the role of having a window as a determinant of environmental satisfaction.

The three-factor model appears to be broadly generalizable across public- and private- sector samples and both Canadian and U.S. organizations. The data in sample A was exclusively from employees in Canadian federal government departments; sample B was split between employees of Canadian provincial government departments (29%) and Canadian and U.S.-based private sector workers (71%). The model fit was unchanged from one sample to the other, suggesting that for these variables, the type of organization from which participants are drawn does not change the structural relations between the variables.

The development and field validation of the Satisfaction with Environmental Features measure provides the basis for explorations of the relationship between physical office conditions and environmental satisfaction. The aim of the COPE project was to use this measure to better understand how workstation characteristics (e.g. presence of a window) and physical conditions (e.g. lighting level) influenced the relevant environmental satisfaction factor(s) (e.g. satisfaction with lighting). The statistical examination of such relationships (denoted i, ii, and iii in Figure 2) is needed in order to make practical recommendations to designers about open-plan office design choices to promote employee satisfaction. The COPE project analyses on these relationships are available elsewhere (Charles & Veitch, 2002; Newsham et al., 2003a; Newsham et al., 2003b; Veitch et al., 2003) and form the basis for existing and future empirical articles on this topic (e.g., Charles et al., 2006; Newsham et al., 2007; Veitch et al., 2005). Other possible directions for future analyses include examination of the effects of job category on environmental and job satisfaction.

Hypothesis 2 was supported: The overall model of relations between the three environmental satisfaction factors, overall environmental satisfaction, and job satisfaction (Figure 3) revealed good consistency with the conceptual model for the COPE project (see elements iii, iv, and v in Figure 2), moderately good fit indices, and parsimony. Here too, restricted range and somewhat non-normal distributions probably limited the model fit; the items for satisfaction with lighting and those for job satisfaction both had high means (over 5 out of 7 for the job satisfaction items). The model is consistent with those of other researchers, suggesting that occupants who are more satisfied with their physical environment also report greater job satisfaction (e.g., Dillon & Vischer, 1987; Donald & Siu, 2001; Wells, 2000).

This finding is important both as a validation of the Satisfaction with Environmental Features measure, and because of the link it establishes between the physical work environment and the organisational psychology literature. Several researchers have demonstrated that job satisfaction is related to organisational outcomes such as commitment, intent to turnover, customer satisfaction, and absenteeism (e.g., Carlopio, 1996; Hardy, Woods, &

Wall, 2003; Hellman, 1997; Koys, 2001; Shaw, 1999). Carlopio (1996) found that satisfaction with the physical work environment including environmental design (e.g., light quality, light direction, air quality, cleanliness) and job satisfaction together predicted organisational commitment and intent to turnover, with more satisfied employees reporting greater organizational commitment and lower intent to turnover. Hallman (1997) conducted a meta-analysis of over 50 studies, confirming that the relationship between job satisfaction and intent to leave was significantly different from zero and consistently negative.

These effects appear to extend to the organizational level. Harter et al. (2002) conducted a meta-analysis on 198,514 employees from 7,939 business-units in 36 companies, to examine the relationships between employee satisfaction and organisational outcomes. Their findings indicated that the average job satisfaction for each business-unit was consistently related to business-unit customer satisfaction, turnover, accidents, productivity and profitability.

Our results, therefore, suggest that satisfaction with the physical environment may indirectly contribute to wider organisational outcomes; a hypothesis that warrants further attention in future work. Although industrial/organizational psychology has paid scant attention to workplace design in the 50 years since Herzberg (1966) dismissed it as a dissatisfier, these findings and others reveal that a satisfactory physical environment is one component of a satisfied workforce and an effective organisation.

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