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Psychological Benefits of Indoor Plants in Workplaces: Putting Experimental Results into Context

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Abstract. **Laboratory experiments and quasi-experimental field studies have documented beneficial effects of indoor plants on outcomes such as psychophysiological stress, task performance, and symptoms of ill health. Such studies have taken an interest in the value of indoor plants in work settings, but they typically have not considered how the effects of plants might compare with effects of other workplace characteristics. The present study makes an initial attempt to situate the potential benefits of indoor plants in a broader workplace context. With cross-sectional survey data from 385 Norwegian office workers, we used hierarchical regression analyses to estimate the associations that plants and several often-studied workplace factors have with perceived stress, sick leave, and productivity. Other variables included in our models were gender, age, physical workplace factors (e.g., noise, temperature, lighting, air quality), and psychosocial workplace factors (demands, control, social support). After controlling for these variables, the number of indoor plants proximal to a worker's desk had small but statistically reliable associations with sick leave and productivity. Although small, such associations can have substantial practical significance given aggregation over the large number of office workers over time.**

A number of studies have investigated the effects of indoor plants on outcomes relevant to the effectiveness and well-being of office workers. Those outcomes include psychophysiological stress responses, task performance, emotional states, and room assessments (Adachi et al., 2000; Chang and Chen, 2005; Coleman and Mattson, 1995; Kim and Mattson, 2002; Larsen et al., 1998; Liu et al., 2003; Lohr et al., 1996; Shibata and Suzuki, 2001, 2002, 2004). In addition, some studies have investigated attitudes toward plants in the workplace (Shoemaker et al., 1992), and the effects of indoor plants on health and discomfort symptoms related to the sick building syndrome (Fjeld, 2000; Fjeld et al., 1998, 1999).

With the exception of four field studies (Fjeld, 2000; Fjeld et al., 1998, 1999; Shoemaker et al., 1992), the previous studies on the psychological benefits of indoor plants have been experiments conducted in laboratories or simulated settings. Laboratory experiments offer important advantages for making claims about causality. These include control over the environment, control for self-selection of different people into different experimental conditions, and precise measurement of performance on standardized tasks. However, their artificiality and brief duration can elicit behavior unrepresentative of what occurs in an actual workplace (Sundstrom, 1986). The results from studies conducted in either laboratories or simulated settings might not generalize well to real workplace settings.

Part of the challenge in generalizing from laboratory experiments involves estimating the unique contribution of plants to outcomes over and above the contributions of other workplace factors. Even experiments in field settings with existing groups of employees (i.e., quasi-experiments) should consider the effects of plants in relation to other workplace factors. However, this is a complicated task because any normal physical aspect of the workplace is of "marginal utility" in enhancing worker perceptions of their job situation (Brill et al., 1984). That is, the effects of plants may be very small against a background of numerous other workplace factors known to be potent.

The outcomes that have been of interest in research on plants in the work environment can be studied against the background of two general sets of workplace factors, physical and psychosocial. For decades, psychologists have realized that physical workplace factors have an important influence on employee satisfaction and productivity (Gifford, 2002). Particular levels and characteristics of sound, lighting, temperature, and air quality can contribute to negative appraisals of demands from the environment and in turn stress (Sundstrom, 1986). In support of this notion, numerous empirical studies have found associations between factors in the physical work environment and outcomes such as task performance, health, and stress (Gifford, 2002; McCoy, 2002; Sundstrom, 1986).

However, according to Bechtel (1997), cultural values and management styles are highly intertwined with the physical form of the work environment and cannot be seen as separate. It is therefore also necessary to investigate psychosocial workplace factors. The most commonly cited approach in research on psychosocial workplace factors is the job strain model (Karasek, 1979; Karasek and Theorell, 1990). This model, commonly called the demand–control model, attributes outcomes such as stress, health, and productivity to the interaction between job demands and the worker's control over the execution of tasks and other aspects of work. A large number of studies have found that the model predicts diverse health outcomes (e.g., Karasek et al., 1981; Schnall et al., 1994; Theorell et al., 1998). A more recent version of the model includes support from coworkers, which generally improves explanation of health outcomes (Karasek and Theorell, 1990; Kristensen, 1996).

Much of the literature on indoor plants treats their benefits as outcomes of psychological restoration. Restoration processes involve the renewal of psychological and physiological resources that normally become depleted in meeting ordinary demands (Hartig, 2004). The two restoration processes commonly cited in the literature on indoor plants concern recovery from an inability to concentrate characteristic of attentional fatigue (Kaplan, 1995) and recovery from the elevated physiological arousal and negative emotions characteristic of acute stress (Ulrich et al., 1991). In these processes, indoor plants are seen as features of the indoor environment that attract attention without effort and evoke positive emotions that can respectively promote renewal of the

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capacity to concentrate and interrupt the stress process. Note that attentional fatigue may contribute to stress; the person cannot concentrate well enough to meet demands, which the person then experiences as excessive and more stressful (Kaplan, 1995). It follows that directed attention restoration might play a role in reducing stress.

The stress process is a general one in that it mediates between an aggregate of demands from diverse workplace factors, on the one hand, and diverse immediate and longer-term outcomes on the other hand. Two of the outcomes selected for study here, sick leave and productivity, can plausibly be attributed, at least in part, to chronic stress resulting from workplace demands. Another outcome studied here, perceived stress, is thus generally seen as a mediator between environmental characteristics and health outcomes, but it is also an outcome variable that is important in its own right, reflecting as it does the worker's experience of demands.

Different research approaches will provide different kinds of information on the associations between indoor plants and important workplace outcomes (see Pearson-Mims and Lohr, 2000). To supplement the experimental studies performed to date, we present a cross-sectional survey conducted in workplaces. In this survey, the associations between indoor plants and perceived stress, sick leave, and productivity were investigated while statistically controlling for three sets of variables: physical aspects of the indoor work environment (e.g., noise, temperature, lighting, air quality); psychosocial factors (job demands, control at work, and social support from coworkers); and basic personal characteristics (age and gender) that plausibly influence levels of the workplace factors under study as well as the outcomes of interest (e.g., Karasek and Theorell, 1990). More specifically, the following question was addressed: Do indoor plants make a unique contribution to the explanation of perceived stress, sick leave, and productivity after controlling for other physical and psychosocial workplace factors that presumably feed into the same general mediating process that generates those outcomes? If our correlational evidence on this point agrees with the evidence from laboratory and field experiments, then it will strengthen the validity of claims about benefits of indoor plants (see Steptoe, 1997).

Materials and Methods

Participants and research settings

An anonymous e-mail questionnaire was sent out in Feb. 2005 to 605 office employees at three different workplaces in Norway. In one workplace, a large private company in Oslo, the questionnaire was sent to 500 employees randomly selected from departments throughout the organization. The number selected was the maximum number agreed to by the management, who allowed the employees to complete the survey during working hours. In the second workplace, a smaller private company in Oslo, the questionnaire was sent to 70 employees. At the third workplace, a governmental agency in Stavanger, the questionnaire was sent to 35 employees. At each of the latter two workplaces, all of the surveyed employees worked in one department. The given department was selected by management on the basis of the cost involved in allowing the employees to complete the survey during working hours. In each of the organizations, we sought to survey the maximum number of employees possible given the need for statistical power to test associations that previous research and theory indicated could be small.

The questionnaire was filled out by 385 persons, giving an overall response rate of 63.6%. The age of the respondents ranged from 24 to 66 years (mean, 43.1 years). The sample was disproportionately male (63%), and it consisted of predominantly long-term employees (mean, 7.1 years employed with the range extending from a few weeks up to 39 years).

The three workplaces were chosen for the present research because they all were office workplaces, were located in large cities (a criterion relevant for research objectives not addressed in this study), and had managers willing to support the participation of their employees in the research. In addition, each of the workplaces had a plant firm that installed and maintained the plants, and all of the employees were free to personalize their own workstation or office with plants or other types of decoration. In general, Norwegian office workplaces use plant firms to install plants. The workplaces investigated in the present study should therefore be representative in terms of amount and types of plants installed (Helene Gaustad, Tropisk Design, personal communication, 20 June 2006). The types of plants installed in the present workplaces included 'Dracaena fragrans', 'Dracaena concinna', 'Epipremnum aureum', 'Ficus benjamina', 'Spathiphyllum wallisii', 'Beaucarnea recurvata', and 'Schefflera arboricola'. They were placed on shelves, the tops of filing cabinets, and on the floor, and they varied in size up to 1.5 m in height on installation. Aside from the plants, the physical work environment for specific employees in the three locations varied in office type (individual and open plan), proximity to a window, and in other respects, some but not all of which were represented by the independent variables included in the present analyses.

Independent variables

Personal characteristics. The participants were asked to report their gender (coded 1 = male, 2 = female) and age. Three participants did not report their gender, and four did not report their age.

Physical workplace factors. Perceptions regarding the quality of the indoor physical work environment were measured with items from the MM-questionnaire (MM 040 NA; Andersson, 1998). The participants were asked whether they had been disturbed during the last 4 weeks by 12 different workplace factors, including noise, too strong and too weak illumination, stale air, dry air, unpleasant smells, high and low temperatures, and static electricity. Responses were provided on a 5-point scale (1 = never, 5 = very often). Missing values amounted to no more than 3.4% of all responses for any item. For cases with missing responses, we calculated an indoor environment scale score (mean of the responses) with the available data (at least 10 of the 12 items). Reliability (internal consistency) for the scale is adequate (Cronbach's $\alpha = 0.82$).

Psychosocial workplace factors. The questionnaire included measures for job demands, control at work, and support from superiors and coworkers. These scales were taken from the General Nordic Questionnaire for Psychological and Social Factors at Work (QPS_{Nordic}; Dallner et al., 2000). The QPS_{Nordic} is a set of measures of fundamental psychologic and social factors at the workplace adapted to Nordic work conditions. In the original measure, the internal consistencies of the various scales ranged between 0.60 and 0.84, and test–retest reliabilities were satisfactory (r's between 0.75 and 0.83; Dallner et al., 2000). Responses to the questions concerning demands, control, and support are given on a 5-point scale that refers to the frequency with which certain experiences or events occur (1 = very seldom or never, 5 = very often or always).

Our measure of job demands covers three dimensions of demands: time pressure and amount of work (four questions), the need to make quick and complex decisions (three questions), and the perceived difficulty of work tasks and the need for more training (three questions). No more than 1.0% of the respondents did not answer one or another of the 10 questions in the scale. For cases with missing data, we calculated a scale score (mean of the responses) with the available data (nine of the 10 questions for all but one case, which was excluded). The scale has adequate internal consistency ($\alpha = 0.77$).

Our measure of control at work covers two dimensions of control: perceived influence on decisions (five questions) and perceived control over time, breaks, and the pace of work performance (four questions). No more than 0.8% of the respondents did not answer one or another of the nine questions in the scale. For cases with missing data, we calculated a scale score (mean of the responses) with the available data (eight of the nine questions for all but one case, which was excluded). The scale has adequate internal consistency ($\alpha = 0.79$).

Our measure of social support covers two dimensions: appreciation and help from one's immediate supervisor (three questions) and help from one's colleagues (two questions). One case had missing responses and was dropped from analyses. The scale score is the mean of the responses to the five items. The scale has adequate internal consistency ($\alpha = 0.83$).

Indoor plants. The presence of plants was measured with the following three questions:

1) "How many plants can you see, without turning, from your regular work station?"; 2) "How many plants are placed in your office, on your desk, or on your shelves (i.e., how is it in your own area)?"; and 3) "How many plants are placed less than 1 m from your regular work station?" The scale for each question ranged from 0 to 9 plants or more. Because the employees received the questionnaire at their computer and could fill out the questionnaire while sitting at their own work position, we assumed that their answers to these questions would not rely solely on memory. We put first emphasis on the desk because we assumed that this is where the office workers would typically spend most of their time when at work. We understood that some plants would be counted in responses to more than one of the questions, but we assumed that responses to each of the questions would provide unique information. Specifically, we assumed that the responses would differ in the degree to which they captured, respectively, 1) visual access to plants, both nearby and distant; 2) privatization of the workspace and the use of plants to demarcate the work position; and 3) the presence of nearby although not necessarily visible plants, which might influence perceptions of air quality. We also assumed that responses to the first and third questions would include plants installed both by the organization and the individual employee, whereas responses to the second question would primarily include plants brought in by the employee. Given our expectation that each of the variables provided unique information of particular interest, we did not combine them into a scale, but used them separately in our analyses. The number of respondents who did not answer one or another of these three questions ranged from two to four.

Dependent variables

Perceived stress. The 10-item version of the Perceived Stress Scale (PSS; Cohen et al., 1983; Cohen and Williamson, 1988) was designed to measure the degree to which situations in an individual's life are appraised as stressful (e.g., "How often have you during the last 4 weeks felt nervous and stressed?"). Although this is a global measure, and not specific to the work environment, we judged the scale to be appropriate because most adults spend a great proportion of their life at their workplace. The scale was translated into Norwegian from a Swedish version (Eskin and Parr, 1996). The Swedish version of the 14-item version of the PSS reported the internal consistency (Cronbach's alpha = 0.82) and split-half estimates (0.84) to be adequate. Adequate construct validity was also reported (Eskin and Parr, 1996). In the present study, the internal consistency was also found to be adequate ($\alpha = 0.78$). Responses were made with a 5-point scale (1 = never, 5 = very often). Missing values amounted to no more than 0.8% of all responses for any one of the items. For cases with missing responses, we calculated a scale score (mean of the responses) with the available data (at least eight of the 10 questions).

Sick leave. Sick leave was measured with a single question: "How many days during the last year have you been absent due to your own illness?" The response categories were from 0 d to 9 d or more. Ferrie et al. (2005) reported strong agreement between the annual number of self-reported and annual number of recorded sickness absence days for most of a large sample of white collar workers. In addition, the associations with health outcomes were similar for both measures in their study. In the present study, missing values amounted to no more than 1% of responses. Cases with missing responses were not included in the analysis for this outcome.

Productivity. Four items were used to measure productivity: 1) "Are you satisfied with the quality of the work you are doing?"; 2) "Are you satisfied with the amount of work you are doing?"; 3) "Do you show responsibility for your work?"; and 4) "Do you feel creative and problem-oriented at work?" The measure is based on the most frequently asked questions in self-reported measures of productivity (Clements-Croome and Kaluarachchi, 2000). Responses were made with a 5-point scale (1 = very seldom or never, 5 = very often or always), and the internal consistency for the scale was $\alpha = 0.67$. Missing values amounted to no more than 1.6% of all responses for any of the items. For cases with missing responses, we calculated a scale score (mean of the responses) with the available data (at least three of the four questions).

Procedures

The employees were encouraged to fill out the questionnaire in an opening letter from management that accompanied the questionnaire when delivered by e-mail. They were told that the purpose of the survey was to study both physical and psychosocial workplace factors, and they were informed that the responses to the survey would be fully anonymous. They also received permission to complete the survey during working hours. Two reminders were sent out to the nonrespondents, the first one after 1 week and the second after 2 weeks. As an incentive to participate, the employees were told that their name would be entered into a drawing for a 1000 NOK (≈$160 U.S. dollars) gift card from a large shopping chain. Because this was an electronic questionnaire and all of the questions had closed-ended questions, respondents had only two alternatives for responding; they could use one of the valid response options for any item (e.g., choosing "1" from a given 1- to 5-point scale) or they could choose to not answer the question. As indicated in the preceding descriptions of the independent and dependent variables, only a small percentage of respondents chose to not answer any given question. The responses from the questionnaires could be directly exported into an SPSS system file (SPSS 14.0, 2006) by the use of Questback, a program for the creation of electronic surveys (www.questback.com).

Statistical analyses

Given statistically equivalent means for all outcomes and most predictors under study here, together with the small number of respondents from one of the workplaces, we combined the data from the three workplaces for further analyses. Following guidelines from Tabachnick and Fidell (2006), our preliminary analyses assessed the conformance of the data with the statistical assumptions of the planned multivariate analyses. The sick leave and plant variables were all highly positively skewed and logarithmic transformations were performed for those scales. We excluded from the multivariate analysis extreme multivariate outliers identified with reference to Mahalanobis distances. Zero-order correlations among all of the independent variables and tolerance values from the regression diagnostics indicated no problems with multicollinearity (all r's <0.61; all tolerances >0.54).

We used hierarchical regression analyses to determine the unique contribution of indoor plants to each of the outcomes after controlling for gender, age, and the physical and psychosocial workplace factors. We entered each set of workplace variables sequentially and examined each in terms of its contribution to the explained variance. Gender and age were given causal priority and were entered in the first step (Cohen et al., 2003). The physical and psychosocial work environments are, as noted in the introduction, interrelated and which of them should have the casual priority is not clear-cut. However, we assigned causal priority to the physical environment because Norwegian work environment regulations would apply to the work environment of all employees in a given organization regardless of their position (which would entail the degree of demands they face and their control over work tasks). Thus, we entered the psychosocial factors in the third step. The three plant variables were entered at the fourth and final step.

The job strain model proposes that control and social support at work moderate the effect of job demands on outcomes such as strain (Karasek and Theorell, 1990). To test this proposition, the respective variables were first mean-centered to minimize multicollinearity (Aiken and West, 1991), and then interaction terms were created from them. In an initial round of analyses, the interaction terms were included. However, because they did not contribute to explanation in any of the initial analyses, we dropped them from the analyses for which we report results here. All analyses were performed using SPSS 14.0 for Windows software (SPSS, Chicago).

Results

The descriptive statistics for the measured variables and their interrelations are presented in Table 1. As shown, the three plant

Table 1. Zero-order correlations, means, ranges, and standard deviations for the variables included in hierarchical regression analyses of relationships between the presence of indoor plants in office workplaces and the self-reported stress, sick leave, and productivity of employees.

	Variables											
	1	2	3	4	5	6	7	8	9	10	11	12
1. Perceived stress												
2. Sick leave	0.19**											
3. Productivity	–0.34**	–0.08										
4. Gender	0.23**	0.18**	0.01									
5. Age	–0.12	–0.15**	0.08	–0.09								
6. Indoor environment	0.19**	0.07	–0.02	0.18**	–0.05							
7. Demand	0.12*	–0.06	0.00	–0.05	–0.03	0.13*						
8. Control	–0.26**	–0.11*	0.27**	–0.11*	–0.02	–0.22**	–0.07					
9. Support	–0.26**	–0.03	0.24**	0.06	–0.11*	–0.16**	–0.12*	0.33**				
10. Plants in view	–0.01	–0.09	0.09	0.13*	–0.05	–0.00	0.06	0.03	0.06			
11. Own plants	0.04	–0.07	0.01	0.22**	0.06	–0.06	–0.04	–0.07	0.04	0.41**		
12. Plants nearby	0.10*	0.03	–0.04	0.22**	–0.00	0.03	–0.01	–0.08	0.02	0.49**	0.61**	
Mean	2.43	3.85	4.15	__	43.12	2.24	3.19	3.63	3.97	2.99	1.94	1.64
Range	1.2–4.5	0–9+	2.8–5.0	__	24–66	1.0–4.2	1.8–4.5	1.3–5.0	1.2–5.0	0–9+	0–9+	0–8
Standard deviation	0.53	3.14	0.48	__	10.83	0.59	0.51	0.59	0.74	2.27	1.62	1.05

Note: Means and standard deviations are given for the untransformed sick leave and plant variables.
*,**Significant at $P < 0.05$ or < 0.01, respectively.

variables correlate weakly, at most, with the outcomes. Only one of the correlations involving plants is statistically significant; the greater the number of plants placed within 1 m from the respondent's desk (plants nearby), the higher the level of perceived stress. All of the plant variables correlate with gender; women tended to report greater exposure with regard to indoor plants at their desk (own plants) and in view (plants in view). Otherwise, the correlations between indoor plants and the independent variables are weak and not statistically reliable.

As indicated by the mean values for the outcomes, as shown in Table 1, our sample was fairly healthy, because they had a moderate level of perceived stress, rather few days taken for sick leave in the past year, and rather high self-reported productivity. As for the independent variables, the participants reported that they were modestly disturbed by noise and problems in the indoor environment such as temperature, lighting, and air quality. Similarly, the respondents reported moderately high levels of demands and somewhat higher levels of control and support. They also reported quite low numbers for each of the three indoor plant variables.

The results of the regression analysis of perceived stress are given in Table 2. At step 1, gender has a reliable positive association with perceived stress, whereas age has a reliable negative association; higher age is attended by lower perceived stress. At step 2, with the entry of the physical work environment variable, the association with age is rendered statistically nonsignificant, but physical work environment has a significant positive association; the more frequently respondents were disturbed by workplace factors, the greater their perceived stress. However, this association is greatly diminished in step 3, when the psychosocial factors were added. As already suggested by the zero-order correlations in Table 1, the perceived quality of the indoor environment is apparently confounded with psychosocial workplace factors. Of the psychosocial factors, only control and support have reliable

Table 2. Hierarchical regression analysis examining associations between indoor plants in office workplaces and perceived stress of employees controlling for personal, physical, and psychosocial workplace factors (N = 367).

	Step 1: personal	Step 2: + physical	Step 3: + psychosocial	Step 4: + plants
Gender	0.21***	0.19***	0.20***	0.19***
Age	–0.10*	–0.10	–0.12**	–0.13**
Indoor environment		0.15**	0.07	0.07
Demands			0.08	0.08
Control			–0.14**	–0.13**
Support			–0.25***	–0.25***
Plants in view				–0.06
Own plants				–0.02
Plants nearby				0.08
$R^2_{adjusted}$ (R^2)	0.05 (0.06)	0.07 (0.08)	0.18 (0.19)	0.18 (0.20)
F_{change}	11.68***	9.01**	16.33***	0.71

Note. Cell values are standardized regression coefficients (β), except for the last two rows as indicated.
*,**,***Significant at $P < 0.05$, 0.01, or 0.001, respectively.

associations with perceived stress; as one should expect, lower perceived stress attended higher levels of perceived control and support. Gender and age also contributed to explained variance at step 3. Finally, at step 4, after controlling for the other variables in the model, none of the log-transformed plant variables has a reliable association with perceived stress. The set of plant variables as a whole does not significantly contribute to the explanation of variance in perceived stress (i.e., ≈1%, the change in R^2 from step 3 to step 4).

The results of the regression analysis of sick leave are given in Table 3. At step 1, gender has a positive association with the log-transformed sick leave variable, indicating that women reported more days of absence from work as a result of sickness than men. Age has a negative association with sick leave, which indicates that older employees took fewer days of sick leave. Adding the physical workplace factors in step 2 did not contribute to explained variance. In step 3, only control has an association with sick leave such that less control is associated with more sick leave. The inclusion of the plant variables, in step 4, led to a statistically reliable increase in explained variance. All three of the log-transformed plant variables are associated with sick leave but, unexpectedly, in different directions; plants in view and own plants are negatively associated with sick leave, indicating that more plants in these positions are associated with less sick leave, whereas plants nearby is positively associated with sick leave, indicating that the greater the number of plants nearby, the more sick leave taken. The contribution of the set of plant variables to the explanation of variance in sick leave is small but statistically reliable (≈1% change in R^2 from step 3 to step 4).

Note that although none of the plant variables has a reliable zero-order correlation with sick leave, all of them have reliable associations in the multivariate analysis. This suggests that one or more of the plant variables has worked as a suppressor. When included in a multivariate analysis, a suppressor variable removes irrelevant variance in other independent variables and thus enhances the relationship that the other independent variables have with the dependent variable (Tabachnick and Fidell, 2006).

Table 4 includes the results of the regression analysis for productivity. In step 1, neither gender nor age has an association with productivity. The same holds for the physical work environment variable added in step 2. However, with the inclusion of the psychosocial workplace factors in step 3, the

Table 3. Hierarchical regression analysis examining associations between indoor plants in office workplaces and employee sick leave controlling for personal, physical, and psychosocial workplace factors (N = 364).

	Step 1: personal	Step 2: + physical	Step 3: + psychosocial	Step 4: + plants
Gender	0.18***	0.18***	0.16**	0.17**
Age	–0.14**	–0.14**	–0.15**	–0.14**
Indoor environment		0.04	0.02	0.01
Demands			–0.07	–0.07
Control			–0.11*	–0.11*
Support			–0.02	–0.02
Plants in view				–0.12*
Plants own				–0.14*
Plants nearby				0.15**
$R^2_{adjusted}$ (R^2)	0.06 (0.06)	0.05 (0.06)	0.07 (0.08)	0.08 (0.09)
F_{change}	11.21***	0.62	2.15	3.56*

Note. Cell values are standardized regression coefficients (β), except for the last two rows as indicated.
*,**,***Significant at $P < 0.05$, 0.01, or 0.001, respectively.

Table 4. Hierarchical regression analysis examining associations between indoor plants in office workplaces and employee productivity controlling for personal, physical, and psychosocial workplace factors (N = 367).

	Step 1: personal	Step 2: + physical	Step 3: + psychosocial	Step 4: + plants
Gender	0.01	0.02	0.02	0.03
Age	0.07	0.07	0.10*	0.10*
Indoor environment		–0.02	0.06	0.06
Demands			0.04	0.03
Control			0.22***	0.22***
Support			0.22***	0.22***
Plants in view				0.12*
Plants own				0.03
Plants nearby				–0.11
$R^2_{adjusted}$ (R^2)	0.01 (0.01)	0.01 (0.01)	0.11 (0.12)	0.13 (0.14)
F_{change}	0.95	0.17	16.19***	2.70

Note. Cell values are standardized regression coefficients (β), except for the last two rows as indicated.
*,***Significant at $P < 0.05$ or 0.001, respectively.

association between age and productivity becomes reliable. Also, both control and support have reliable positive associations with productivity; the more control and support, the more productivity. With the addition of the three log-transformed plants variables in step 4, however, there is not a significant increase in explained variance in productivity. However, plants in view is reliably associated with productivity such that more plants in view are associated with greater productivity.

Discussion

With the present cross-sectional survey study, we addressed the following question: Do indoor plants contribute to the explanation of perceived stress, sick leave, and productivity after controlling for other often-studied physical and psychosocial workplace factors? In addressing this question, we sought to put previous experimental research findings into a broader context. We found that after controlling for gender, age, and physical and psychosocial workplace factors, the number of indoor plants proximal to the worker had small but statistically reliable associations with sick leave and productivity. However, the change in explained variance that followed the addition of the set of indoor plant variables was statistically reliable only for sick leave.

We thus provide correlational evidence of associations between indoor plants and employee self-reports of sick leave and productivity. The associations are small, but to the extent that our results agree with the results of the laboratory and field experiments reported to date, they strengthen the validity of causal claims about benefits of indoor plants. One could also go beyond this quite general statement and ask how the associations that we have measured compare in magnitude and direction with the effects measured in experimental studies. This question is difficult to answer in a precise way given the variations across the experimental studies in outcome measures and plant exposure characteristics (Bringslimark et al., 2007). Nonetheless, we can make a few observations in this regard. For one, in the present study, the indoor plant variables were not significantly associated with perceived stress. Our global measure of stress was not specific to work-related circumstances, so it also captured the experience of stressful situations outside of the work environment. This may have worked to weaken the association between workplace plants and perceived stress, although we cannot say to what degree. However, we can mention that in experimental studies using psychophysiological stress measures in a controlled setting, plants also had rather weak and not always statistically significant effects (Chang and Chen, 2005; Coleman and Mattson, 1995; Kim and Mattson, 2002; Liu et al., 2003; Lohr et al., 1996). Such results challenge efforts to interpret the effects of indoor plants in terms of psychological restoration.

That said, it is important to bear in mind that our participants had, on average, rather low scores on perceived stress, rather few problems with the indoor environment, and only moderately high levels of job demands. To the degree that workplace plants are psychologically beneficial because they promote restoration, they will be less potent if the workers in question generally have modest restoration needs (see Shoemaker et al., 1992). Previous experimental studies suggest that the effects of plants are greater for those who have relatively high levels of stress (e.g., Kim and Mattson, 2002).

Another observation with regard to the comparison between our results and those of the previous experimental research concerns health and sick leave. Previous experimental studies have not investigated the effect of workplace plants on sick leave, but Fjeld et al. (1998) conducted a quasi-experiment in which self-reported health symptoms were investigated. In their study, the addition of plants to the work environment was followed by a 21% mean reduction in health symptoms. Fjeld et al. (1998) introduced quite a large amount of plants; altogether, 18 plants were introduced into single offices in their intervention. In the present study, the reported amount of plants was small for all three plant variables; thus, the relatively small association between plants and sick leave in this study may reflect on a relatively low presence of plants for the workers under study. Still, the species of plants installed by plant firms in the organizations under study were moderate to large in size and leafy, so they presumably were a readily visible part of the work environment.

With regard to productivity, we can make a number of observations when comparing our results with the extant experimental findings. One observation again concerns the number of plants. Having many plants present may promote health, but it might also decrease productivity. In a study conducted in a simulated workplace setting, Larsen et al. (1998) found that the inclusion of many plants had a negative effect on task performance. In contrast to their findings, we found a positive association between number of plants in view and productivity. However, the number of plants in their experiment exceeded the number of plants reported by our respondents.

Other observations regarding our productivity results concern the character of the tasks and the visibility of plants. The small associations between plants and productivity in the present study might in part be attributable to the characteristics of the tasks in the work setting. Shibata and Suzuki (2002) found that a single plant had a significant positive effect on performance of a creative task but not on performance of a concentration task. In the present study, however, the

measure of productivity did not distinguish between creativity and concentration demands of work tasks. Shibata and Suzuki (2002) also investigated the visibility of the plants, placing it either in front or to the side of the participants. The plant in front of the participant's position had the greatest effect. This can be compared with the results of the present study in which only plants in view were associated with productivity.

Three final observations concern the associations between plants and outcomes generally. First, plants in and around workstations, where people focus on work, may have weaker effects than plants in break rooms made for restoration. This hypothesis was tested by Shibata and Suzuki (2001), who found that plants had a greater stress-reducing effect during a break than while performing a task. Second, when plants are introduced in a laboratory or a field setting in an intervention study, the effect may initially be substantial but then diminish as the research participants habituate to the presence of plants. The present results reflect on a longstanding exposure to plants in workplaces, and the small associations may reflect on the fact of habituation. Yet, the effect of plants might not diminish to zero with habituation. Rather, the introduction of plants might engender persistent effects for all employees. This brings us to our final observation. If all employees were affected by the plants placed in workspaces, break rooms, and other areas throughout a workplace, it could become difficult to discern an association between plants in a particular location and some outcome. In the present study, all of the employees were exposed to plants throughout the building, so it is possible that any effects of the plants in and around their individual workstations might have been overshadowed by the general effects of the plants. Arguably, a more accurate way to determine the effects of plants would be to compare people who have no exposure to plants at work with people who are exposed to plants at work; however, such a comparison might involve a variety of confounding factors such as differences in the kind of work performed.

Although small, the associations for each plant variable have the same direction for each of the outcomes. Having more plants in view and more own plants were attended by lower stress (although not significantly so), less sick leave, and more productivity when controlling for gender, age, and other workplace factors. Conversely, the number of plants nearby had positive associations with all three outcomes, although only that for sick leave was statistically reliable. The consistency in the signs of the associations suggests that plants feed into a general process common to all three outcomes such as stress.

Of course, the finding that plants nearby has a positive association with sick leave seems contradictory to the hypothesis that plants placed close to workers will promote well-being, for example, by purifying the air (e.g., Wolverton et al., 1989; Wood et al., 2002). We can only speculate that the variable is a proxy for some other aspect of the work environment. We note that having plants nearby does not necessarily mean that the participants have visual access to the plants, and when plants are placed close to a person without them being aware of it, they may be in a work situation that predisposes to sick leave.

It must be noted that employee–environment relations are complex. They involve a host of factors inside and outside of the workplace as well as characteristics of the individual worker, his or her family, and so on. Thus, in the present study, like in most research on occupational health, we make no claim to have controlled for all factors that might influence the outcomes under study. Rather, we investigated the relative contribution of indoor plants compared with a selected set of often-studied workplace factors previously shown to be associated with the health and effectiveness outcomes. Further research can consider not only the relative contributions of indoor plants compared with still other workplace factors, but also the way in which indoor plants may interact with those factors in affecting outcomes. In this regard, the possibility that the presence of indoor plants interacts with the type of office (individual versus open plan) and the availability of a window view seems particularly important.

Indoor plants in workplaces are themselves complex subjects for study. With the measures we have reported on here, we have represented some, but by no means all, of the aspects of indoor plants with potential relevance for perceived stress, productivity, and sick leave. Aspects such as size, shape, species, and color might play important roles in how plants are perceived and evaluated by employees and so in relations between plants and outcomes like those studied here. That said, some such aspects of plants in workplaces do not lend themselves to reliable measurement within the context of a survey. Further research, with observations collected by researchers on-site, can assess the extent to which aspects of plants beyond their mere presence contribute to outcomes such as those studied here.

The fact of small associations between workplace plants and worker stress, sick leave, and productivity should not discourage further experimentation or correlational studies such as this one. Most people spend a large proportion of their life at work. Even small effects can have great practical significance when aggregated over a large number of people over time.

It is thus important not only to investigate the work demands that give rise to stress, which has been one of the main foci in previous work-related research, but also to investigate the factors that enhance coping, restoration, and performance in the work environment (see Heerwagen et al., 1995; Kaplan, 1993; Pearson-Mims and Lohr, 2000; Ulrich and Parsons, 1992).

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